

INTRODUCTION
TO
WORK
STUDY

Edited by George Kanawaty
Fourth (revised) edition

International Labour Office Geneva

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Preface

to the fourth (revised) edition

During the 12 years that have passed since the third (revised) edition of this book was published, many developments have taken place. Technology has brought about profound changes in methods of operation, whether at the factory or in the office. Innovations in production management have brought to the fore a whole array of new and promising approaches to methods of work. There has been a continued growth in the services sector, mostly at the expense of the industrial and agricultural sectors. Simultaneously, new and different arrangements of working time were introduced in a multitude of enterprises.

Work study could not remain indifferent or aloof to such changes. If one of its aims is to improve methods of work, it cannot achieve that goal in isolation from current thinking and future trends that relate to operations technology. Furthermore, advances in technology, particularly in the field of information systems, can be harnessed to become a powerful tool of work study.

With this in mind, the present edition was prepared. Six new chapters dealing with production management approaches and their relation to work study were added (Part Three), as well as a new chapter on method study at the office. The part dealing with work measurement (Part Four) was revised so as to encompass the whole spectrum of techniques ranging from macroscopic systems such as structured estimations to micro approaches such as predetermined time standards. Sections on the use of information systems and computerization in work study were incorporated in the text alongside more traditional approaches. The chapters on working conditions and new forms of work organization were also revised in line with current thinking in these areas.

We hope that with this new orientation the book will continue to enjoy the wide popularity and success with which it met in developing and industrialized countries alike. In fact, to date and since it was first published in 1957 over 300,000 copies have been sold, so that *Introduction to work study* easily heads the list of best-selling books published by the ILO. The previous editions were also translated into many languages.

The original 1957 edition was intended mainly as a training manual for use by people attending courses in work study at management development and productivity centres in the numerous countries to which ILO technical cooperation missions were attached. It also aimed at providing basic teaching material for members of the staff of these centres. This original edition was prepared by the late C. R. Wynne-Roberts, at the time Chief of the

Management Development Branch of the ILO, in collaboration with E. J. Riches, former Treasurer and Comptroller to the ILO. Several members of ILO management development teams working in the field helped to prepare detailed and valuable comments, among them Hans Fahlström, L. P. Ferney, Hy Fish, C. L. M. Kerkhoven, J. B. Shearer and Seymour Tilles. Several others such as F. de P. Hanika, Winston Rogers and the late T. U. Matthew contributed valuable criticism and commentaries.

The second revised edition was published ten years later. Certain aspects of the book, particularly the part on work measurement, were strengthened while the original intention of keeping the book as an introductory text to be used mainly for educational purposes was adhered to. This edition was prepared by R. L. Mitchell, then an official of the ILO Management Development Branch. This revision benefited from the advice and collaboration of J. B. Shearer.

The third revised edition, published in 1979, was intended to reorient the publication so as to make it equally useful to the work study practitioner, teacher and student. Several new chapters were introduced, and other chapters modified substantially to accommodate developments in work study and also to illustrate how work study can contribute both to productivity improvement and to a safe and satisfying working environment. The editor of this edition was George Kanawaty, then Chief of the ILO Management Development Branch, who also wrote several parts of the new material. Useful and valuable contributions were made by J. Burbidge, F. Evans, R. Lindholm, L. Parmaggianni and P. Steele.

The current edition was again conceived and edited by George Kanawaty, Consultant and former Director of the ILO Training Department, who wrote many chapters of the new material while updating others. Particular acknowledgement is due to John Heap, of Leeds Polytechnic in the United Kingdom, for his valuable contribution to the present text and his earlier review of the previous edition. Several colleagues of the ILO Working Conditions and Environment Department contributed the revised chapter on working conditions. They include K. Kogi, J. Thurman, D. Gold, J. C. Hiba, S. Machida, G. Trah, S. Li and N. V. Krishnan. Thanks are also due to Rolf Lindholm for updating the chapter on work organization. Klaus North of the ILO Entrepreneurship and Management Development Branch reviewed the previous edition and coordinated the preparation of the present one.

Last but not least, a work of this nature requires considerable technical, administrative and secretarial back-up. Acknowledgements are in order to the staff of the ILO Editorial and Document Services Department, particularly R. Beattie and L. Neil, and to D. Klingler, F. Kaufmann and C. Pett for their helpful and valued administrative and secretarial assistance. The index was compiled by P. Nash.

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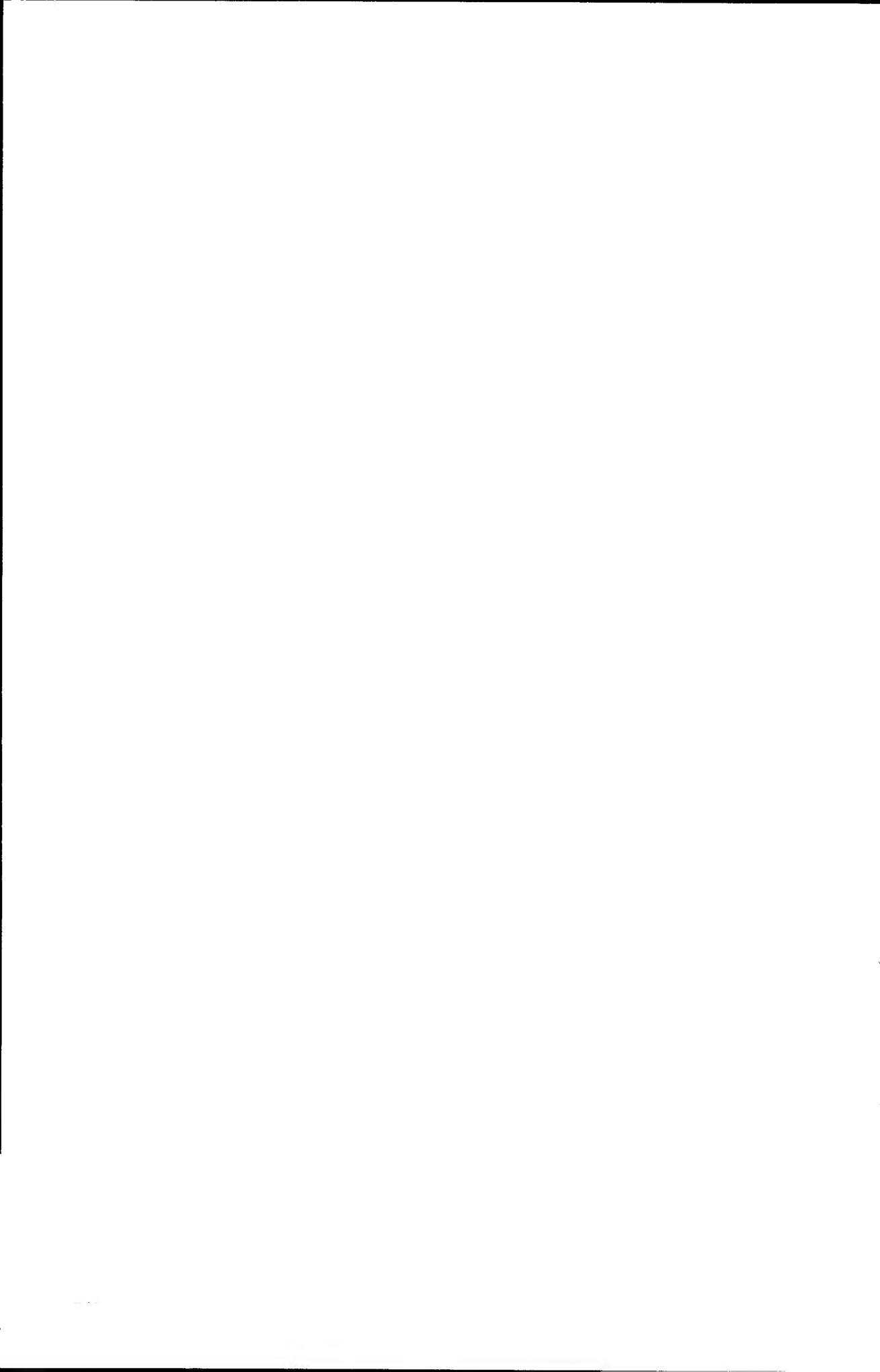
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PART ONE

**Productivity, work study
and the human factor**



Productivity and the quality of life

1. Basic needs, quality of life and productivity

In 1950 the world population stood at 2.5 billion. By the year 2000 it will reach 6.2 billion, an increase of 250 per cent in just 50 years. Over 90 per cent of that increase has occurred in developing countries. By the year 2000 close to 1 billion people will be living below the poverty line and struggling to meet their basic needs. These basic needs are:

- Food**
Enough food every day to generate the energy needed for living and working.
- Clothing**
Enough clothing to afford protection from adverse weather conditions and to permit bodily cleanliness.
- Shelter**
A shelter that provides protection under healthy conditions and that is equipped with certain household equipment and furniture.
- Security**
Security against violence and against unemployment, and that provides for one's personal needs in sickness or old age.
- Health and essential services**
Safe drinking-water, sanitation, access to energy use, medical care, education and a means of transport.

For better-off segments of the population, the aspiration is to raise their standard of living further and improve their quality of life. This is foreseen as an improvement in the quality of these basic needs, and in the range and quantity available so that a person exerts the option of choice among various alternatives, for example in housing, clothing or food. Human aspirations also extend to a desire for a healthier and cleaner environment, cultural activities, the ability to have and make use of leisure time in an enjoyable manner, and an income that would allow a person to support these various endeavours.

For a society or a nation to raise the standard of living of its population, it must strive to maximize the return from its resources or improve **productivity** so that the economy can grow and sustain a better quality of life.

2. What is productivity?

Productivity may be defined as follows:

$$\text{PRODUCTIVITY} = \frac{\text{OUTPUT}}{\text{INPUT}}$$

This definition applies in an enterprise, a sector of economic activity or the economy as a whole. The term “productivity” can be used to assess or measure the extent to which a certain output can be extracted from a given input. While this appears simple enough in cases where both the output and the input are tangible and can be easily measured, productivity can be more difficult to estimate once intangibles are introduced. Let us take an example.

A potter working eight hours a day produces 400 pots a month using a wood-fired kiln.

- Let us assume that as a result of a change in the method of work he was able to produce 500 pots a month instead of 400 with the same equipment and hours of work. His productivity calculated in terms of number of pots produced will then have increased by 25 per cent.
- Let us now assume that as a result he was unable to sell all 500 pots and had to lower his price from \$2 a pot to \$1.80 a pot. If he wants to assess his productivity gain, the potter may be more interested in using monetary terms rather than simply the number of pots produced. He could then argue that the value of his output used to be $400 \times 2 = \$800$ a month and is now $500 \times 1.80 = \$900$ a month. His input has not changed. Hence his productivity gain is $\frac{\$(900-800)}{\$800} = 12.5$ per cent.

From this deliberately simple example, one can make two observations. First, productivity was used to measure increase in output expressed in numbers of pots produced, in the first case, and in monetary terms in the second, giving different values in each case. In other words, depending on what one is interested in measuring, the nature of the output and input will vary accordingly. Second, while actual **production** increased in this example from 400 to 500 pots, **productivity** in monetary terms did not show the same corresponding increase. This means that we have to distinguish between increased production and increased productivity, which in this example was measured in terms of monetary gains.

- Let us continue with our example and assume that the potter decided to replace his wood-fired kiln by an oil-fired kiln. This cost him an investment of \$6,000, which he reckons should be amortized over ten years. In other words, the cost of this investment will be \$600 a year for ten years, or \$50 a month. He also would need oil that would cost him \$50 a month more than what he would have paid for the wood. Let us also assume that his production remained constant at 500 pots a month. Measured in monetary terms, the value of his output is $500 \times 1.80 = \$900$ per month, from which will be deducted \$50 for capital investment and \$50 for fuel, or \$100. Thus his monetary gain is $\$900 - \$100 = \$800$.

In this case his productivity expressed in monetary gain has not improved since, while originally he was producing only 400 pots, he sold them for \$2 each — arriving at the same financial figure.

- However, our potter may wish to argue that as a result of the new kiln his quality has improved, that he will have fewer rejects returned and that the users' satisfaction will increase over time so that he may be able to increase his price again. Furthermore, his own sense of satisfaction at work has improved, as it has become much easier to operate the new kiln. Here, the definition of the output has been enlarged to encompass quality and a relatively intangible factor, that of consumer satisfaction. Similarly, the input now encompasses another intangible factor, that of satisfaction at work. Thus productivity gains become more difficult to measure accurately because of these intangible factors and because of the time lag that needs to be estimated until users' satisfaction will permit an increase in prices of the pots produced in the new kiln.

This simple example helps to show that the factors affecting productivity in an organization are many, and often interrelated. Many people have been misled into thinking of productivity exclusively as the productivity of labour, mainly because labour productivity usually forms the basis for published statistics on the subject. It also becomes evident how, in a community or a country, improving productivity or extracting the best possible yield from available resources does not mean exploitation of labour but the harnessing of all available resources to stimulate a higher rate of growth that can be used for social betterment, a higher standard of living and an improved quality of life. In this book, however, we will be restricting ourselves to productivity issues and more specifically to work study as it applies to the individual enterprise.

3. Productivity in the individual enterprise

Productivity in the individual enterprise may be affected by a series of external factors, as well as by a number of deficiencies in its operations or internal factors. Examples of external factors include the availability of raw materials and skilled labour, government policies towards taxation and tariffs, existing infrastructure, capital availability and interest rates, and adjustment measures applied to the economy or to certain sectors by the government. These external factors are beyond the control of any one employer. Other factors, however, are within the control of managers in an enterprise and these are the ones that will be discussed.

The output and input factors in an enterprise

In a typical enterprise the output is normally defined in terms of products or services rendered. In a manufacturing concern, products are expressed in numbers, by value and by conformity to predetermined quality standards. In a service enterprise such as a public transport company or a travel agency, the output is expressed in terms of the services rendered. In a transport company

this may be the number of customers or tons of cargo per kilometer carried. In a travel agency it could be value of tickets sold or average value of tickets per customer, and so on. Both manufacturing and service enterprises should equally be interested in consumers' or users' satisfaction, such as number of complaints or rejects.

On the other hand, the enterprise disposes of certain resources or inputs with which it produces the desired output. These are:

Land and buildings

Land and buildings in a convenient location.

Materials

Materials that can be converted into products to be sold, both as raw materials or auxiliary materials such as solvents or other chemicals and paints needed in the process of manufacturing and packaging material.

Energy

Energy in its various forms such as electricity, gas, oil, or solar power.

Machines and equipment

Machines and equipment necessary for the operational activities of the enterprise, including those intended for transport and handling, heating or air conditioning, office equipment, computer terminals and the like.

Human resources

Men and women trained to perform the operational activity, to plan and control, to buy and sell, to keep track of accounts and to perform other operations such as maintenance or administrative and secretarial jobs.

Another factor of production or input is that of **capital** which, while not explicitly defined here, is implicitly included since it is used to finance the purchase of land, machinery, equipment, materials and labour, and to pay for the services rendered by human resources.

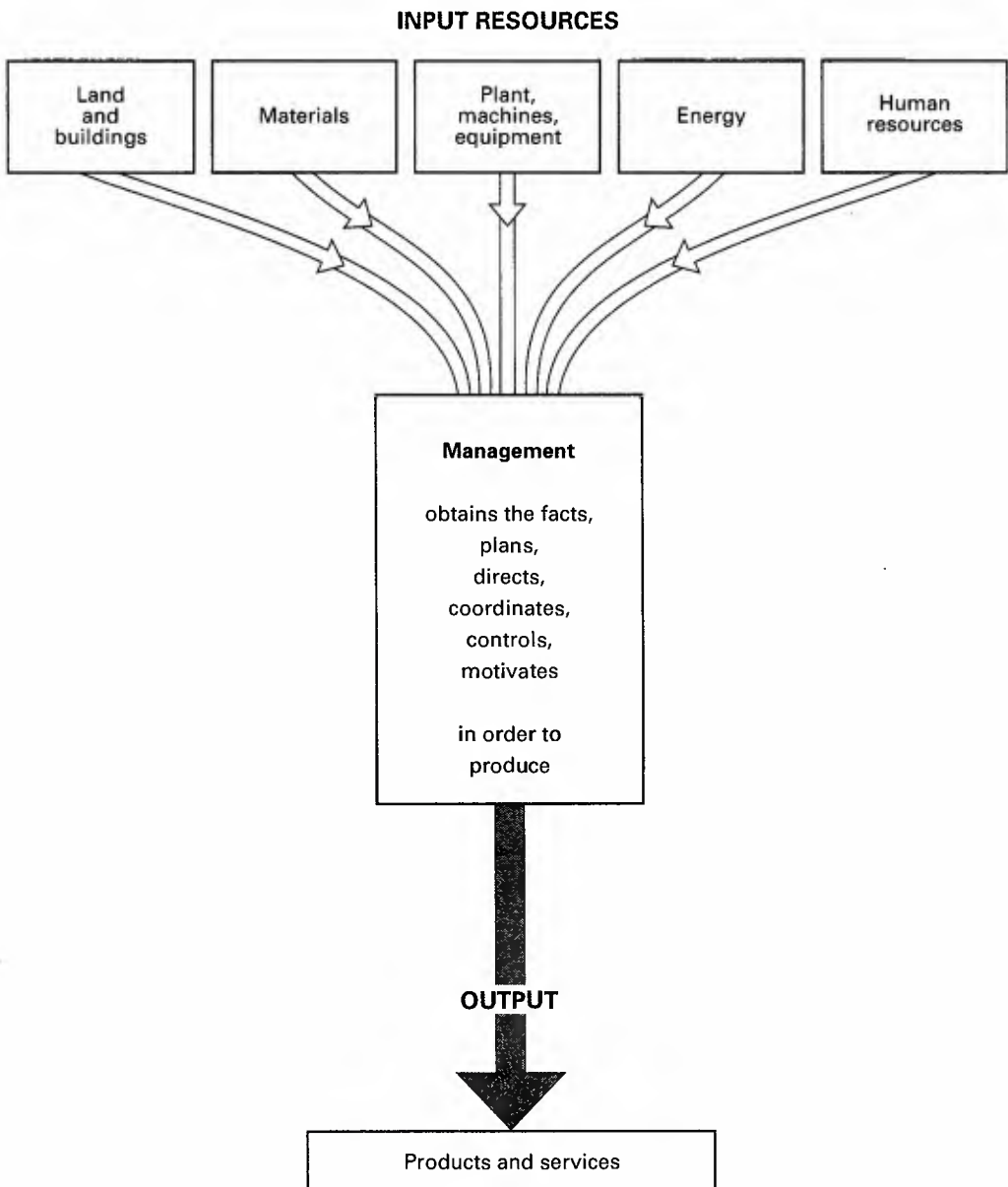
The use which is made of all these resources combined determines the **productivity** of the enterprise.

4. The task of management

The management of an enterprise is responsible for seeing that the enterprise resources mentioned above are combined in the best possible way to achieve the highest productivity.

In any concern larger than a one-person business (and to some extent even in a one-person business), harnessing and coordinating these resources and balancing one resource against another is the task of management. If management fails to do what is necessary, the enterprise will fail in the end. In such a case, the five resources become uncoordinated — like the efforts of five horses without a driver. The enterprise — like a driverless coach — moves forward jerkily, now held up for lack of material, now for lack of equipment, because machines or equipment are badly chosen and even more badly maintained, or because energy sources are inadequate or employees unwilling to contribute their best. Figure 1 illustrates this management function.

Figure 1. Role of management in coordinating the resources of an enterprise



In its quest for higher productivity, an efficiency-minded management acts to influence either one or both of the two factors, the output (i.e. products and services) or the input (i.e. the five resources at its disposal). Thus management may be able to produce a larger quantity of, and/or better-quality or higher-value, products or services with the same input, or it may achieve a better result by changing the nature of the input such as investing in advanced

technology, information systems and computers or by using an alternative source of raw material or energy.

It is rare, however, that one manager or a small team of top managers can by themselves attend to the normal running of an enterprise and at the same time devote enough thinking and energy to the various issues involved in improving productivity. More frequently they will rely on specialists to assist them in this task, and among them is the work study practitioner. In the next chapter, we shall see how work study and productivity are related.

Work study and productivity

In the previous chapter, we mentioned that management frequently calls on specialists to assist it in improving productivity. One of the most powerful tools they can use is that of work study.

Work study is the systematic examination of the methods of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out.¹

Work study then aims at examining the way an activity is being carried out, simplifying or modifying the method of operation to reduce unnecessary or excess work, or the wasteful use of resources, and setting up a time standard for performing that activity. The relation between productivity and work study is thus obvious. If work study results in cutting down the time of performing a certain activity by 20 per cent, merely as a result of rearranging the sequence or simplifying the method of operation and without additional expenditure, then productivity will go up by a corresponding value, that is by 20 per cent. To appreciate how work study acts to cut down costs and reduce the time of a certain activity, it is necessary to examine more closely what that time consists of.

1. How the total time of a job is made up

The time taken by a worker or a machine to carry out an operation or to produce a given quantity of a certain product may be considered as made up in the following manner, which is illustrated in figure 2.

There is first:

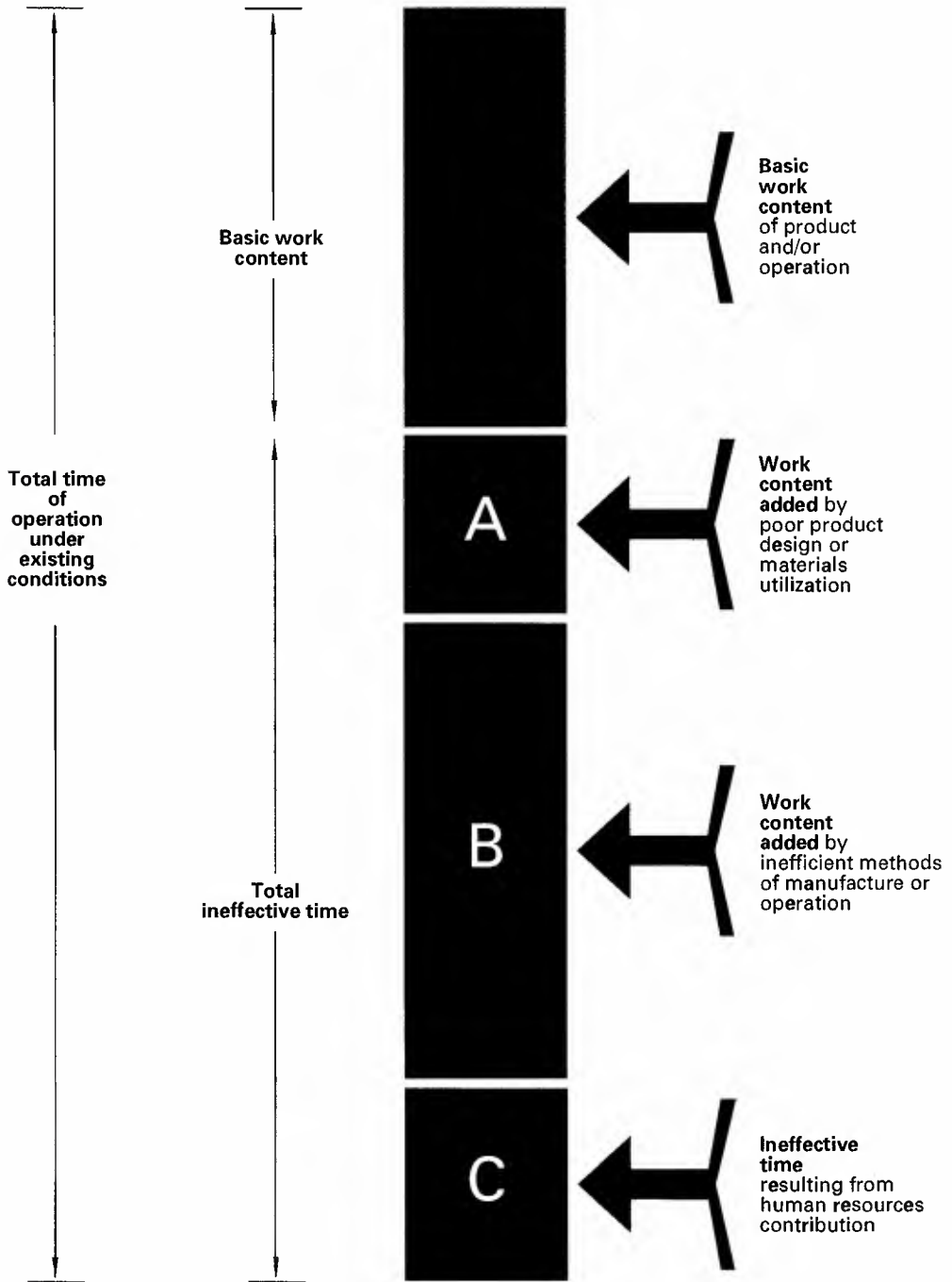
The basic work content of the product or operation²

Work content means, of course, the amount of work “contained in” a given product or a process measured in “work-hours” or “machine hours”.

¹ This definition differs somewhat from that given in the British Standards Glossary. See British Standards Institution (BSI): *Glossary of terms used in management services*, BS 3138 (London, 1991).

² The word “operation”, whenever used, applies also to non-manufacturing activities such as transport services or office operations.

Figure 2. How operational time is made up



- A **work-hour** is the labour of one person for one hour.
- A **machine-hour** is the running of a machine or piece of plant for one hour.

The basic work content is the time taken to manufacture the product or to perform the operation if the design or specification of the product or service provided were perfect, if the process or method of operation were perfectly carried out, and if there were no loss of working time from any cause whatsoever during the period of the operation (other than legitimate rest pauses permitted to the operative). **The basic work content is the irreducible minimum time theoretically required to produce one unit of output.**

This is obviously a perfect condition which never occurs in practice, although it may sometimes be approached, especially in line manufacturing or process industries. In general, however, actual operation times are far in excess of it on account of:

excess work content

The work content is increased by the following:

A. Work content added by poor design or specification of product or its parts, or improper utilization of materials

There are several ways in which unnecessary time and waste (resulting in higher cost of the product) can be attributed to poor design of the product or its parts, or to incorrect quality control.

A.1. Poor design and frequent design changes

The product may be designed in such a way that it may require a large number of non-standard parts causing a lengthy time of assembly. Excessive variety of products and lack of standardization of products or their parts may mean that work has to be produced in small batches, with time lost as the operator adjusts and shifts from one batch to the next.

A.2. Waste of materials

The components of a product may be so designed that an excessive amount of material has to be removed to bring them to their final shape. This increases the work content of the job and wastes material as well. Operations requiring cutting in particular need careful examination to see if the resulting waste can be reduced to a minimum or reused.

A.3. Incorrect quality standards

Quality standards that are too high or too low can increase work content. In engineering industries, insisting on sometimes unnecessarily tight tolerances requires extra machining and a corresponding waste of material. On the other hand, setting tolerances too loose may result in a large number of rejects. Deciding on the appropriate quality standard and the method of quality control is an important efficiency consideration.

B. Work content added by inefficient methods of manufacture or operation

Ineffective time and higher cost can result from a poor method of carrying out the operations, resulting in unnecessary movements of persons or materials.

Similarly, such ineffective time can be due to inappropriate handling methods, poor maintenance of machinery or equipment resulting in frequent breakdowns, or poor inventory control causing delays because of an absence of products or parts or higher costs as a result of overstocking.

B.1. Poor layout and utilization of space

The space used for any operation represents an investment. Proper utilization of space is an important source of cost reduction, particularly when an enterprise is expanding and needs an increased working area. Furthermore, a proper layout reduces wasted movement, time and effort.

B.2. Inadequate materials handling

Raw materials, parts and finished products are invariably being moved from one place to another throughout a production operation. The use of the most appropriate handling equipment for the purpose can save time and effort.

B.3. Frequent stoppages as production changes from one product to another

The proper planning and control of production operations can ensure that one production batch or order follows immediately on another so that idle time of machinery, equipment or labour is eliminated or minimized.

B.4. Ineffective method of work

A sequence of operations may be well planned but each or some of them done in a cumbersome manner. By examining the way a certain operation is carried out and devising a better method, ineffective time can be reduced.

B.5. Poor planning of inventory

In every operation, raw material is usually ordered and stocked ahead of time and at every stage of the operation an inventory of so-called "materials-in-progress" or semi-finished products and various parts are temporarily stocked waiting to be processed. These various inventories represent a tied-up investment. A proper inventory control system when installed can minimize such an idle investment while ensuring that the operators do not run out of the material needed.

B.6. Frequent breakdown of machines and equipment

Poor maintenance results in machinery and equipment that are often out of action, and idle time ensues while waiting for repairs. Installing a preventive maintenance system and mounting maintenance campaigns would ensure the smooth functioning of machinery and equipment.

C. Work content resulting mainly from the contribution of human resources

Workers in an enterprise can influence the time of operations voluntarily or involuntarily as follows:

C.1. Absenteeism and lateness

If management fails to provide a safe and satisfying work climate, workers could respond by absenteeism, lateness or deliberately working slowly.

C.2. Poor workmanship

If workers are improperly trained, the resulting poor workmanship can mean that the job has to be done again. Losses may also occur because of wasted material.

C.3. Accidents and occupational hazards

If management fails to provide a safe and healthy place to work, accidents or occupational illnesses can occur, with resulting effects on morale and increased absenteeism.

The impact of all the factors mentioned above under headings A to C is shown in figure 3. If these factors can be eliminated (an ideal situation which, of course, never occurs in real life), as shown in figure 4, the minimum time and cost for the production of a given output and hence the maximum productivity is achieved. It can therefore be seen that the work study specialist has to keep all these in mind when examining an operation and trying to develop an improved method. In Part Three we expand on these methods and techniques that can be used to reduce costs, cut ineffective time and develop a better method of work.

2. Interrelationship of the various methods used to reduce ineffective time

None of the methods discussed above can be properly applied in isolation. Each one has an effect and is affected by others. It is impossible to plan programmes of work without standards provided by measuring the times of operations. At the same time production planning will be made easier if a sound personnel policy and a well-applied incentive scheme encourage workers to perform reliably. Standardization of products or parts will make the job of inventory control easier by demanding less variety of materials to be bought and held in stock.

* * *

It will be seen that in our discussion in this chapter we have gradually moved from a study of productivity of the enterprise as a whole to the productivity of a certain part of it, namely the productivity of certain operations and of labour. We have looked briefly at some of the methods and techniques that can be used to provide information on how productivity may be improved. Work study uses this type of information, whether manual or computerized, to develop new methods of work and to measure workloads and duration of tasks. In Part Three of this book these various techniques will be discussed in more detail.

Figure 3. Basic and added work content

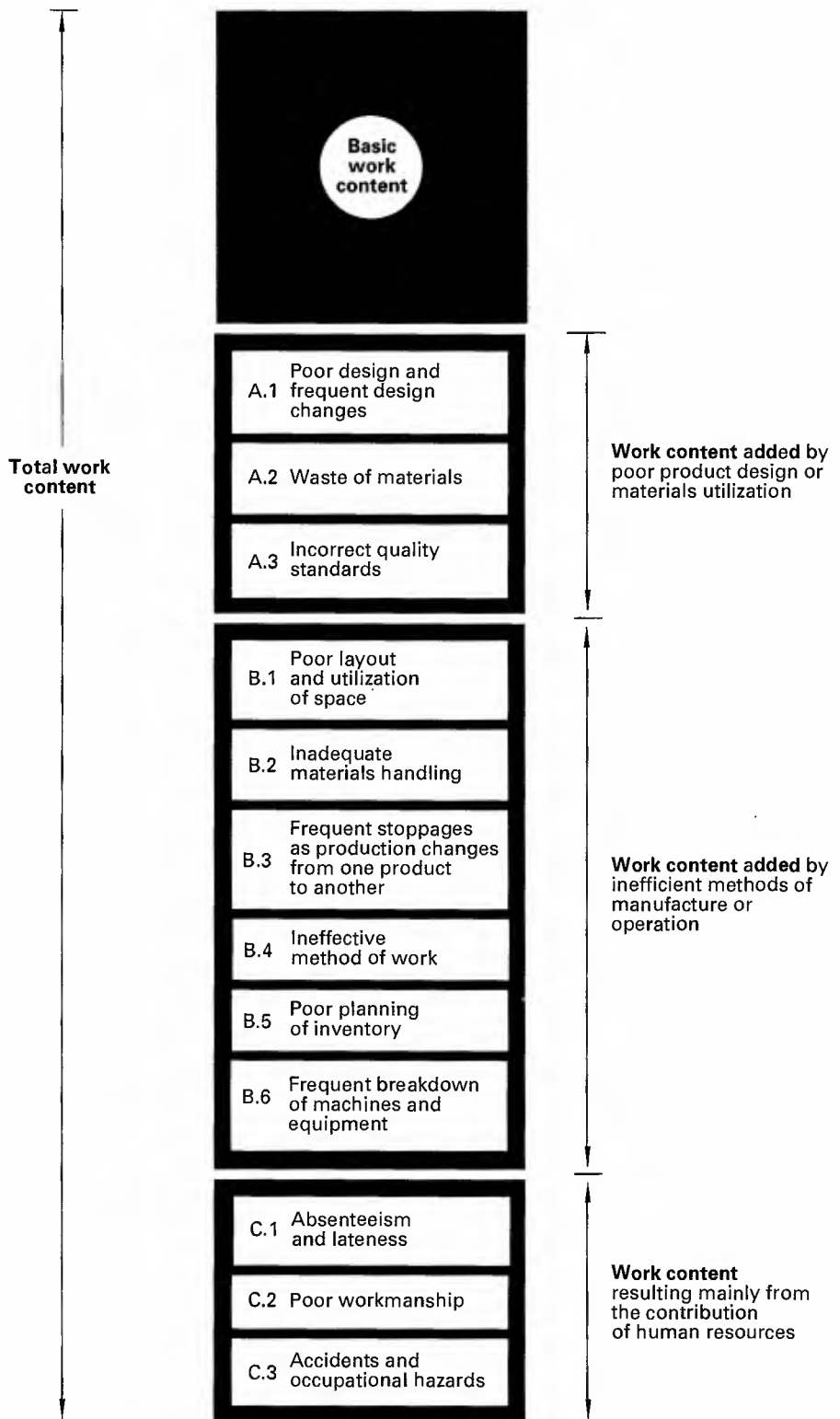
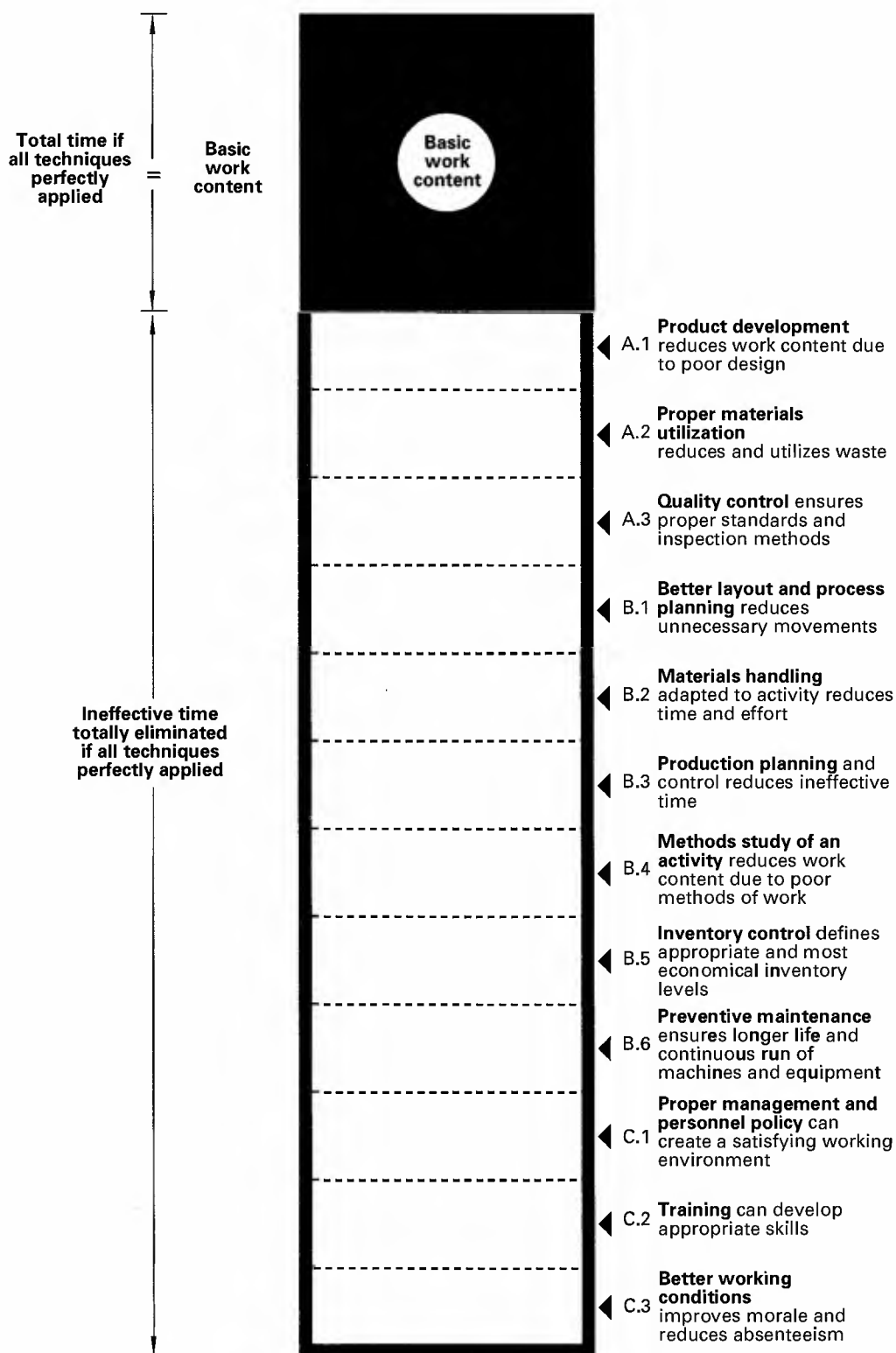


Figure 4. How management techniques can reduce ineffective time





CHAPTER 3

Work study, the approach

1. Why is work study valuable?

There is nothing new about the investigation and improvement of operations at the workplace; good managers have been investigating and improving ever since human effort was first organized on a large scale. Managers of outstanding ability — geniuses — have always been able to make notable advances. Unfortunately, no country seems to have an adequate supply of competent managers. The prime value of work study lies in the fact that, by carrying out its systematic procedures, a manager can achieve results as good as or better than the less systematic genius was able to achieve in the past.

Work study succeeds because it is systematic both in the investigation of the problem being considered and in the development of its solution. Systematic investigation takes time. It is therefore necessary, in all but the smallest firms, to separate the job of making work studies from the task of management. Factory managers or supervisors, in their day-to-day work, with its many human and material problems, are never free from interruption for long. However capable they may be, managers can rarely afford to devote a long time, without interruption, to the study of a single activity on the factory floor or in a working area. This means that it is almost always impossible for them to obtain all the facts about what is happening in the course of that activity. Unless all the facts are known, it is impossible to be sure that any alterations in procedure which are made are based on accurate information and will be fully effective. It is only by continuous observation and study at the workplace or in the area where the activity is taking place that the facts can be obtained. This means that work study must always be the responsibility of someone who is able to undertake it full time, without direct management duties: someone in a staff and not a line position.¹ Work study is a service to management and supervision.

We have now discussed, very briefly, some aspects of the nature of work study and why it is such a valuable “tool” of management. There are other reasons to be added to the above. These may be summarized as follows:

- (1) It is a means of raising the productivity of a plant or operating unit by the reorganization of work, a method which normally involves little or no capital expenditure on facilities and equipment.

¹ People in “line” positions exercise direct supervisory authority over the ranks below them. “Staff” appointees, on the other hand, are strictly advisers with no power or authority to put their recommendations into operation. Their function is to provide expert information.

- (2) It is systematic. This ensures that no factor affecting the efficiency of an operation is overlooked, whether in analysing the original practices or in developing the new, and that **all** the facts about that operation are available.
- (3) It is the most accurate means yet evolved of setting standards of performance, on which the effective planning and control of production depends.
- (4) It can contribute to the improvement of safety and working conditions at work by exposing hazardous operations and developing safer methods of performing operations.
- (5) The savings resulting from properly applied work study start at once and continue as long as the operation continues in the improved form.
- (6) It is a “tool” which can be applied everywhere. It can be used with success wherever work is done or plant is operated, not only in manufacturing shops but also in offices, stores, laboratories and service industries such as wholesale and retail distribution and restaurants, and on farms.
- (7) It is relatively cheap and easy to apply.
- (8) It is **one of the most penetrating tools of investigation available to management**. This makes it an excellent weapon for starting an attack on inefficiency in any organization since, in investigating one set of problems, the weaknesses of all the other functions affecting them will gradually be laid bare.

This last point is worth further discussion. Because work study is systematic, and because it involves investigation by direct observation of all the factors affecting the efficiency of a given operation, it will show up any shortcomings in all activities affecting that operation. For example, observation may show that the time of an operative on a production job is being wasted through having to wait for supplies of material or to remain idle through the breakdown of the machine. This points at once to a failure of material control or a failure on the part of the maintenance engineer to carry out proper maintenance procedures. Similarly, time may be wasted through short batches of work, necessitating the constant resetting of machines, on a scale which may only become apparent after prolonged study. This points to poor production planning or a marketing policy which requires looking into.

Work study acts like a surgeon's knife, laying bare the activities of a company and their functioning, good or bad, for all to see. It can therefore “show up” people. For this reason it must be handled, like the surgeon's knife, with skill and care. Nobody likes being shown up, and unless the work study specialist displays great tact in handling people he or she may arouse the animosity of management and workers alike, which will make it impossible to do the job properly.

Managers and supervisors have generally failed to achieve the savings and improvements which can be effected by work study because they have been unable to apply themselves continuously to such things, even when they

have been trained. It is not enough for work study to be systematic. To achieve really important results it must be applied **continuously**, and throughout the organization. It is no use work study practitioners doing a good job and then sitting back and congratulating themselves, or being transferred shortly afterwards by management to something else. The savings achieved on individual jobs, although sometimes large in themselves, are generally small when compared with the activity of the company as a whole. The full effect is felt in an organization only when work study is applied everywhere, and when everyone becomes imbued with the attitude of mind which is the basis of successful work study: **intolerance of waste in any form, whether of material, time, effort or human ability**; and the refusal to accept without question that things must be done in a certain way "because that is the way they have always been done".

2. Techniques of work study and their relationship

The term "work study" embraces several techniques, but in particular method study and work measurement. What are these two techniques and what is their relationship to one another?

Method study is the systematic recording and critical examination of ways of doing things in order to make improvements.²

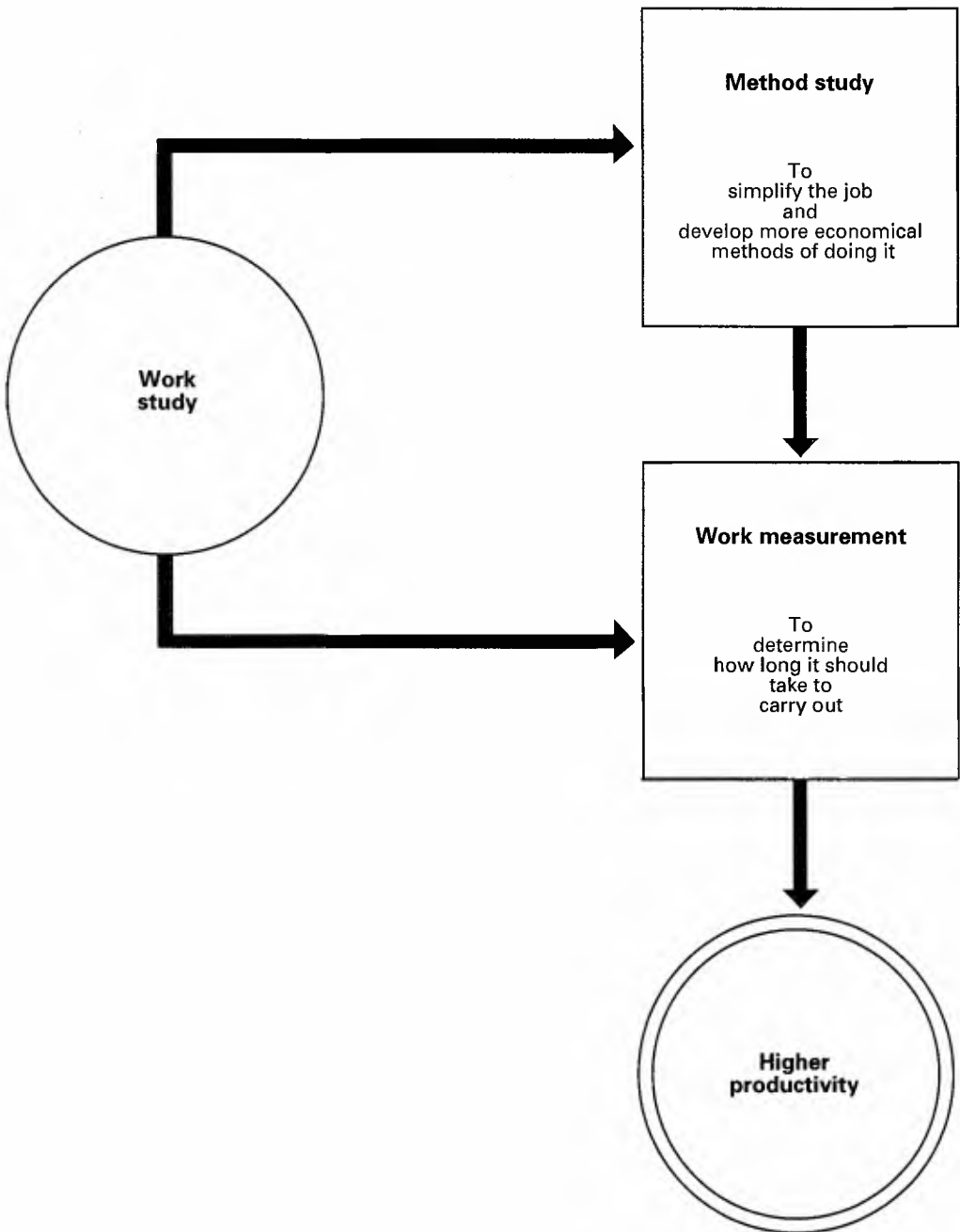
Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out a task at a defined rate of working.²

Method study and work measurement are, therefore, closely linked. Method study is concerned with the reduction of the work content of a job or operation, while work measurement is mostly concerned with the investigation and of any ineffective time associated with it; and with the subsequent establishment of time standards for the operation when carried out in the improved fashion, as determined by method study. The relationship of method study to work measurement is shown simply in figure 5.

As will be seen from later chapters of this book, both method study and work measurement are themselves made up of a number of different techniques. Although method study should precede the use of work measurement when time standards for output are being set, it is often necessary

² These definitions are those adopted in the BSI: *Glossary of terms used in management services*, BSI 3138 (London, 1991).

Figure 5. Work study



to use one of the techniques of work measurement, such as work sampling (see Chapter 19), in order to determine why ineffective time is occurring and what is its extent, so that management can take action to reduce it before method study is begun. Again, time study may be used to compare the effectiveness of alternative methods of work before deciding on the best method to install.

These techniques will be dealt with in detail in the chapters devoted to them. For the present we must consider the basic procedure of work study which applies to **every** study, whatever the operation or process being examined whether in industry, in a service enterprise or in the office. This procedure is fundamental to the whole of work study. **There is no short cut.**

3. Basic procedure of work study

There are eight steps in performing a complete work study. They are:

- (1) **Select** the job or process to be studied.
- (2) **Record** or collect all relevant data about the job or process, using the most suitable data collection techniques (explained in Part Two), so that the data will be in the most convenient form to be analysed.
- (3) **Examine** the recorded facts critically and challenge everything that is done, considering in turn: the purpose of the activity; the place where it is performed; the sequence in which it is done; the person who is doing it; the means by which it is done.
- (4) **Develop** the most economic method, taking into account all the circumstances and drawing as appropriate on various production management techniques (explained in Part Three), as well as on the contributions of managers, supervisors, workers and other specialists with whom new approaches should be explored and discussed.
- (5) **Evaluate** the results attained by the improved method compared with the quantity of work involved and calculate a standard time for it.
- (6) **Define** the new method and the related time and present it to all those concerned, either verbally or in writing, using demonstrations.
- (7) **Install** the new method, training those involved, as an agreed practice with the allotted time of operation.
- (8) **Maintain** the new standard practice by monitoring the results and comparing them with the original targets.

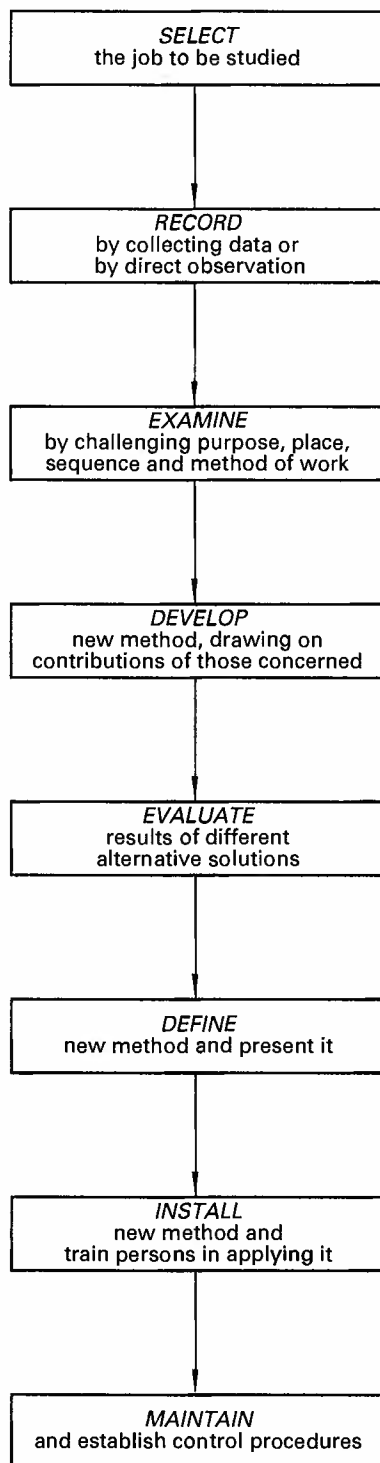
Steps 1, 2 and 3 occur in every study, whether the technique being used is method study or work measurement. Step 4 is part of method study practice, while step 5 calls for the use of work measurement. It is possible that after a certain time the new method may prove to be in need of modification, in which case it would be re-examined again using the above sequence.

These eight steps (figure 6) will be discussed in detail in the chapters devoted to method study and work measurement. Before doing so, however, we shall discuss the role of the work study practitioner and the human factor in the application of work study.

4. Work study and production management

When work study emerged in the early part of this century as a technique aimed at rationalizing and measuring work, the emphasis was on economy of

Figure 6. The approach to work study



motion and movement. Because of that it was called time and motion study. Later on, it began to encompass other aspects of observing and analysing work, and the earlier term was abandoned in favour of "work study". Simultaneously, in the late 1940s and later on in the 1960s, other disciplines were developed, namely industrial engineering and production management respectively. These disciplines differed from work study in the sense that they were devoted to increasing the efficiency of a production operation as a whole, not just the methods of work. Thus modern production management looks at various aspects of production such as product design, quality control, layout and materials handling, production planning and control, maintenance management and invariably work study. These techniques may be applied, singly or in combination, in the enterprise. Furthermore, with time many of them began to rely increasingly on sophisticated quantitative methods such as operations research to solve ever more complicated operational problems. Advances in the fields of computers and information systems helped to boost production management techniques to the level attained at present.

While work study has continued to be a relatively simple and cheap method of rationalizing methods of work, it has also continued to develop. Thus, many work study trained specialists realize that several of the existing production management techniques can also be used advantageously by them to help develop improved methods of work. In a sense they provide an array of techniques that cannot and need not be ignored. For this reason, Part Three of this fourth (revised) edition of *Introduction to work study* explains in a simple manner the various new techniques that are now at the disposal of work study specialists to assist them with their analysis and development of improved methods of work. It can also be seen that the career of a work study practitioner can now evolve in two directions: first, a more professional path where he or she can continue to develop knowledge and skills in these new operational fields to become a production management specialist or, second, a managerial path where he or she can acquire a high-level position by virtue of specialized training.



The human factor in the application of work study

1. The human factor in enterprise operations

The human factor is one of the most crucial elements in enterprise operations, for it is through people that management can control the utilization of its resources and the sale of its products or services. To give the best of their ability, employees must be motivated to do so. Managers must be able to provide a motive or a reason for doing something, or make people want to do it. It is of little use for management to prepare elaborate plans or give instructions for carrying out various activities if the people who are supposed to carry out the plans do not wish to do so — even though they may have to. The result would be half-hearted effort and sloppy workmanship. Coercion is no substitute for action that is taken voluntarily and willingly. Thus, employees at all levels must feel a sense of belonging to the enterprise; they should develop a sense of security, and the feeling that they are working in a safe, healthy and enriching working environment. When this happens they will contribute not only their labour but also many useful suggestions that can lead to productivity improvement, and assist willingly the work study person in developing improved methods of work.

One of the greatest difficulties in obtaining the active cooperation of workers is the fear that raising productivity will lead to unemployment. Workers are afraid that they will work themselves out of their jobs. This anxiety is greatest when unemployment is already high and a worker who loses his or her job will find it hard to find another. Even in industrialized countries where the levels of unemployment are relatively lower than developing countries, this fear is very real to those who have already experienced unemployment.

Since this is so, unless workers are assured of adequate assistance in facing their problems, they may resist any steps which they fear, rightly or wrongly, will make them redundant, even temporarily.

Even with written guarantees, steps taken to raise productivity can meet with resistance. This resistance can generally be reduced to a minimum if everybody concerned understands the nature of, and the reason for, each step taken and is involved in its implementation. Workers' representatives should be trained in the techniques of increasing productivity so that they will be able both to explain them to their fellow workers and to use their knowledge to ensure that no steps are taken which are harmful to them. Many of these

safeguards can best be implemented through joint productivity committees and works councils.

If work study is to contribute seriously to the improvement of productivity, relations between management and workers must be reasonably good before any attempt is made to introduce it, and the workers must have confidence in the sincerity of management towards them; otherwise they will regard it as a way of getting more work out of them without any benefit to themselves. If management is able to create a satisfying working environment at the enterprise and a culture that welcomes and encourages productivity improvement, then a work study development programme may be seen as "owned" jointly by managers, supervisors and the workforce.

2. Work study and management

It was said above that one of the principal reasons for choosing work study as the subject of this book is that it is a most penetrating tool of investigation. Because a well-conducted work study analysis is ruthlessly systematic, the places where effort and time are being wasted are laid bare one by one. In order to eliminate this waste, the causes of it must be looked for. The latter are usually found to be bad planning, bad organization, insufficient control or the lack of proper training. Since members of the management and supervisory staffs are employed to perform these functions, it will look as if they have failed in their duties. Not only this, but the increase in productivity which the proper use of work study usually brings about may appear to emphasize this failure further. Applying work study in one working area can start a chain-reaction of investigation and improvement which will spread in all directions throughout the organization: to the plant engineer's department, the accounts department, the design office or the sales force. Skilled workers may be made to feel like novices when they find that their methods, long practised, are wasteful of time and effort, and that new workers trained in the new methods soon surpass them in output and quality.

Any technique which has such far-reaching effects must obviously be handled with great care and tact. People do not like to be made to feel that they have failed, especially in the eyes of their superiors. They lose their self-confidence and begin to ask themselves whether they may not be replaced. Their feeling of security is threatened.

At first sight, this result of a work study investigation may seem unfair. Managers, supervisors and workers, generally speaking, are honest, hard-working people who do their jobs as well as they can. They are certainly not less clever than work study specialists. Often they have years of experience and great practical knowledge. If they have failed to obtain the most from the resources at their disposal, it is generally because they have not been trained in, and often do not know the value of, the systematic approach which work study brings to problems of organization and performance of work.

This must be made clear to everybody from the very beginning. If it is not made clear, and if the work study person is at all tactless in handling people, he

or she will find that they will combine to put obstacles in the way, possibly to the point where the task is made impossible.

If the application of work study in an enterprise is to succeed, it must have the understanding and the backing of management at all levels, starting at the top. If top management, the managing director, the managing agent or the president of the company do not understand what the work study person is trying to do and are not giving him or her their full support, it cannot be expected that managers lower down will lend their support either. If the work study person then comes into conflict with them, as he or she may do in such circumstances, he or she may well lose the case, however good it may be, if an appeal is made to the top. Do not forget that in any organization **people lower down tend to take their attitudes from the person at the top.**

The first group of people to whom the purpose and techniques of work study must be explained is therefore the management group, the managing director or managing agent and, in large companies or organizations, the departmental heads and assistant heads. It is the usual practice in most countries to run short "appreciation" courses for top management before starting to apply work study. Most work study schools, management development institutes, technical colleges and work study organizations also run short courses for the managers of companies who are sending staff to be trained as specialists.

Here it is necessary to give a word of warning. Running even the simplest and shortest course in work study is not easy, and newly trained work study specialists are strongly advised not to try to do so by themselves. They should seek advice and assistance. It is important that an enterprise's work study staff take an active part in the course, **but they must know their subject and be able to teach it.**

If a course for management is to be run, however, the work study specialist must try as hard as possible to persuade the person at the top to attend and, if possible, to open the proceedings. Not only will this show everyone that he or she has the support of top management, but departmental and other managers will make efforts to attend if they think their "boss" is going to be there.

3. Work study and the supervisor

The work study specialist's most difficult problem may often be the attitude of supervisors. They must be won over if he or she is to obtain good results from work study; indeed, their hostility may prevent him or her from doing any effective work at all. Supervisors represent management to the worker on the shop floor, and just as departmental managers will take their attitudes from the top manager, so the workers will take theirs from their supervisors. If it is evident that the supervisor thinks that "this work study stuff is nonsense", the workers will not respect the specialist and will make no efforts to carry out his or her suggestions, which, in any case, have to come to them through their supervisor.

Before the work study practitioner starts work, the whole purpose of work study and the procedures involved must be very carefully explained to the supervisor, so that he or she understands exactly what is being done and why. Unless this is done, the supervisor is likely to be difficult, if not actually obstructive, for many reasons. Among them are the following:

- (1) Supervisors are the people most deeply affected by work study. The work for which they may have been responsible for years is being challenged; if, through the application of work study methods, the efficiency of the operations for which they are responsible is greatly improved, they may feel that their prestige in the eyes of their superiors and of the workers will be lessened.
- (2) In most firms where specialists have not been used, the whole running of a certain operation — planning programmes of work, developing job methods, making up time sheets, setting piece rates, hiring and firing workers — may have been done by the supervisor. The mere fact that some of these responsibilities have been taken away is likely to make him or her experience a loss of status. No one likes to think that he or she has “lost face” or “lost ground”.
- (3) If disputes arise or the workers are upset, supervisors are the first people who will be called upon to clear matters up, and it is difficult for them to do so fairly if they do not understand the problem.

The sources from which supervisors are recruited differ widely in different parts of the world. In some countries supervisors are frequently selected on a basis of seniority from among the best-skilled persons in the enterprise. This means that they are often middle-aged and may be set in their ways. Because most supervisors have practised their occupation or skills for many years, they find it difficult to believe that they have anything to learn from someone who has not spent a very long time in the same occupation.

Supervisors may therefore resent the introduction of work study specialists into their departments unless they have had some training to prepare them for it. Since supervisors are nearer to the practical side of the job than management, and so are more intimately connected with work study, the work study course that they take should be longer and more detailed than that given to management. Supervisors should know enough to be able to help in the selection of jobs to be studied and to understand the factors involved, should disputes arise over methods or time standards. This means that they should be acquainted with the principal techniques of method study and work measurement, and the particular problems and situations in which they should be applied. Generally speaking, courses for supervisors should be full time and of not less than one week's duration. The trainees should be given opportunities of making one or two simple method studies and of measuring the time of an operation. **The value to the work study person of a supervisor who understands and is enthusiastic about what he or she is trying to do cannot be overemphasized.** He or she is a powerful ally.

The work study practitioner will only retain the supervisors' friendship and respect by showing from the beginning that he or she is not trying to usurp their place. The following rules **must** be observed:

- (1) The work study person must **never** give a direct order to a worker. All instructions must be given through the supervisor. The only exception to this is in matters connected with methods improvements where the worker has been asked by the supervisor to carry out the instructions of the work study person.
- (2) Workers asking questions calling for decisions outside the technical field of work study should **always** be referred to their supervisor.
- (3) The work study person should take care **never** to express opinions to a worker which may be interpreted as critical of the supervisor (however much he or she may feel like it!). If the worker later says to the supervisor: ". . . but Mr/Ms . . . said . . .", there will be trouble!
- (4) The work study person must **not** allow the workers to "play him or her off" against the supervisor or to use him or her to get decisions altered which they consider harsh.
- (5) The work study person should seek the supervisor's advice in the selection of jobs to be studied and in all technical matters connected with the process (even if he or she knows a great deal about it). The work study person should never try to start alone.

This list of "Do's" and "Don't's" may look frightening but is mainly common sense and good manners. The workers in any working area can only have **one** boss — their supervisor — and everything must be done to uphold his or her authority. Of course, once the work study person and the supervisor have worked together and understand one another, there can be some relaxation; but that is a matter of judgement, and any suggestion for relaxation should come from the supervisor.

A great deal of space has been given to the relationship between the work study practitioner and the supervisor because it is the most difficult of all the relationships, and it must be good. One of the best methods of ensuring that this is so is to provide both parties with the proper training.

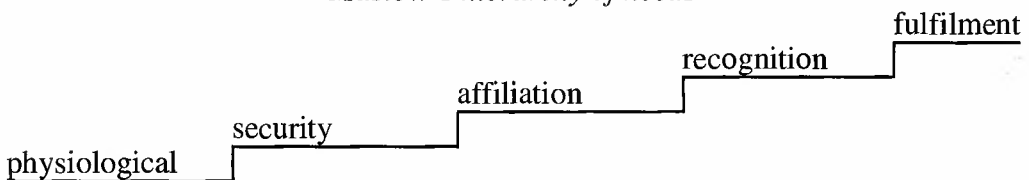
4. Work study and the worker

When the first conscious attempts at work study were made at the turn of the century, little was known about the way people behaved at work. As a result, workers often resisted or were hostile to work study. During the past 40 years, however, a great deal of research has been carried out to discover more about the way people behave — the aim being not only to explain that behaviour but, if possible, also to predict how people will react to a new situation. For a work study specialist this is an important consideration, since through his or her interventions he or she is invariably and continuously creating new situations.

Behavioural scientists believe that individuals are motivated to act in a certain way by a desire to satisfy certain needs. One of the widely accepted notions about needs was developed by Abraham Maslow, who postulated that there are certain essential needs for every individual and that these needs arrange themselves in a hierarchical pattern. Maslow argues that it is only when one need becomes largely satisfied that the next need in the hierarchy will start to exert its motivating influence.

At the bottom of the hierarchy are **physiological needs**. These are the basic needs that must be met to sustain life itself. Satisfying one's physiological needs will be the primary concern of any person, and until one has done so one will not be concerned with any other issues. However, once workers feel reasonably sure of fulfilling their physiological needs, they will seek to satisfy the next need in the hierarchy, that of **security**. Security is taken to mean a feeling of protection against physical and psychological harm, as well as security of employment. For workers who have already satisfied both their physiological and their security needs, the next motivating factor is that of **affiliation**, that is wanting to belong to a group or an organization and to associate with others. Next on the hierarchical scale is the **need to be recognized**, and this is followed by the need for **fulfilment** (sometimes called "self-actualization"). This last need expresses the desire of people or workers to be given an opportunity to show their particular talents.

Maslow's hierarchy of needs



In practice, most people satisfy some of these needs in part and are left with some that are unsatisfied. In developing countries people are probably preoccupied more with their basic needs. In developed countries, on the other hand, where physiological and security needs are normally met in large part, people would seem to be motivated more by needs at the upper end of the hierarchy.

One of the interesting results of the research carried out in this area, and which should be of concern to us here, is the discovery that, in order to satisfy affiliation needs, workers associate with each other to form various types of informal group. Thus a worker is usually a member of a task group, that is a group composed of workers performing a common task. He or she may also be a member of various other groups, such as a friendship group composed of fellow workers with whom he or she has something in common or with whom he or she would like to associate.

This means that every organization has a formal and an informal structure. The formal structure is defined by management in terms of authority relationships. Similarly, there also exists an informal organization composed of a great number of informal groups which have their own goals and activities

and which bear the sentiments of their members. Each group, it was found, expects its members to conform to a certain standard of behaviour, since otherwise the group cannot achieve its goal, whether this be accomplishing a task or providing a means for friendly interaction. It was found, for example, that a task group tends to establish among its members a certain quota for production which may or may not be in line with what a supervisor or a manager wants. In a typical situation, a worker will produce more or less according to this informally accepted quota. Those who are very high or very low producers, and who thus deviate substantially from that norm, will be subjected to pressure from the group to conform to the norm.

Disregarding or ignoring such basic and elementary notions of behaviour has often created resentment and outright hostility. It is now easy to understand that a work study person who makes a unilateral decision to eliminate an operation, resulting in the loss of a job for a worker or a number of workers, is in fact undermining the basic need for security; a negative reaction can therefore be expected. Similarly, the imposition of an output quota on a worker or a group of workers without prior consultation or winning their cooperation can yield resentment and breed resistance.

How, then, should a work study person act? The following are some useful hints:

- (1) The problem of raising productivity should be approached in a balanced way, without too great an emphasis being placed on productivity of labour. In most enterprises in developing countries, and even in industrialized countries, great increases in productivity can generally be effected through the application of work study to improve plant utilization and operation, to make more effective use of space and to secure greater economy of materials before the question of increasing the productivity of the labour force need be raised. The importance of studying the productivity of all the resources of the enterprise and of not confining the application of work study to the productivity of labour alone cannot be overemphasized. It is only natural that workers should resent efforts being made to improve their efficiency while they can see glaring inefficiency on the part of management. What is the use of halving the time workers take to do a certain job or of imposing a production output on them by well-applied work study if they are held back by a lack of materials or by frequent machine breakdowns resulting from bad planning by their superiors?
- (2) It is important that the work study person be open and frank as to the purpose of the study. Nothing breeds suspicion like attempts to hide what is being done; nothing dispels it like frankness, whether in answering questions or in showing information obtained from studies. Work study, honestly applied, has nothing to hide.
- (3) Workers' representatives should be kept fully informed of what is being studied, and why. They should receive induction training in work study so that they can understand properly what is being attempted. Similarly, involving the workers in the development of an improved method of

operation can win them over to the new method and can sometimes produce unexpected results. Thus, by asking workers the right questions and by inviting them to come forward with explanations or proposals several work study specialists have been rewarded by clues or ideas that had never occurred to them. After all, a worker has an intimate knowledge of his or her own job and of details that can escape a work study person. One tried and tested practice is to invite the workers in a section to be studied to nominate one of their number to join the work study specialist and, together with the supervisor, to form a team that can review the work to be done, discuss the results achieved and agree on steps for implementation.

- (4) Although asking for a worker's suggestions and ideas implicitly serves to satisfy his or her need for recognition, this can be achieved in a more direct way by giving proper credit where it is due. In many instances a supervisor, a worker or a staff specialist contributes useful ideas that assist the work study person to develop an improved method of work. This should be acknowledged readily, and the work study person should resist the temptation of accumulating all the glory.
- (5) The work study person must make it clear that it is the work, and not the worker, that is being studied. This becomes much easier if the workers have had a proper introductory course explaining the principles and outlining the techniques of work study.
- (6) In some circumstances it may be possible to involve the workforce in work study investigations even more directly (for example, by training them in some of the basic techniques and allowing them to contribute to discussions through the establishment of a "productivity circle", set up for the duration of a project or on a longer-term basis). Through such a process the workers can see more clearly that the techniques are used to study the work and not the workers themselves.
- (7) It is important that the work study person should remember that the objective is not merely to increase productivity but also to improve job satisfaction, and that he or she should devote enough attention to this latter issue by looking for ways to minimize fatigue and to make the job more interesting and more satisfying. In recent years several enterprises have developed new concepts and ideas to organize work to this end and to attempt to meet the workers' need for fulfilment. These are treated briefly in the last chapter of this book.

5. The work study practitioner

We have talked a great deal in the preceding sections about what is required from the work study practitioner, suggesting by our requirements a human being who is almost too good to be true. The ideal person for the job is likely to be found very rarely, and if he or she is a successful work study specialist, can easily be promoted to higher posts. Nevertheless, there are certain qualifications and qualities which are essential for success.

Education

The very minimum standard of education for anyone who is to take charge of work study application in an enterprise is a good secondary education with matriculation or the equivalent school-leaving examination, or better still a university education, preferably in the engineering or business fields.

Practical experience

It is desirable that candidates for posts as work study specialists should have had practical experience in the industries in which they will be working. This experience should include a period of actual work at one or more of the processes of the industry. This will enable them to understand what it means to do a day's work under the conditions in which the ordinary workers with whom they will be dealing have to work. Practical experience will also command respect from supervisors and workers, and an engineering background enables one to adapt oneself to most other industries.

Personal qualities

Anyone who is going to undertake improvements in methods should have an inventive turn of mind, be capable of devising simple mechanisms and devices which can often save a great deal of time and effort, and be able to gain the cooperation of the engineers and technicians in developing them. The type of person who is good at this is not always so good at human relations, and in some large companies the methods section is separated from the work measurement section, although both could be under the same chief.

The following are essential qualities:

- Sincerity and honesty**
The work study person must be sincere and honest; only if this is the case will he or she gain the confidence and respect of those with whom he or she will work.
- Enthusiasm**
He or she must be really keen on the job, believe in the importance of what he or she is doing and be able to transmit enthusiasm to the people round about.
- Interest in and sympathy with people**
The person must be able to get along with people at all levels. It is necessary to be interested in them, to be able to see their points of view and to understand the motives behind their behaviour.
- Tact**
Tact in dealing with people comes from understanding them and not wishing to hurt their feelings by unkind or thoughtless words, even when these may be justified. Without tact no work study person is going to get very far.
- Good appearance**
The person must be neat and tidy and look efficient. This will inspire confidence among the people with whom he or she has to work.

□ **Self-confidence**

This can only come with good training and experience of applying work study successfully. The work study practitioner must be able to stand up to top management, supervisors, trade union officials or workers in defence of his or her opinions and findings, and to do so in such a way that will win respect and not give offence.

These personal qualities, particularly the ability to deal with people, can all be further developed with the right training. Far too often this aspect of the training of work study specialists is neglected, the assumption being that, if the right person is selected in the first place, that is all that needs to be done. In most work study courses more time should be given to the human side of applying work study.

It will be seen from these requirements that the results of work study, however "scientifically" arrived at, must be applied with "art", just like any other management technique. In fact, the qualities which go to make a good work study person are the same qualities as go to make a good manager. Work study is an excellent training for young men and women destined for higher management. People with these qualities are not easy to find, but the careful selection of persons for training as work study specialists will repay itself in the results obtained, in terms both of increased productivity and of improved human relations in the workplace.

Having described the background against which work study is to be applied, we can now turn to the question of applying it, starting with method study. Before we do so, however, attention must be given to some general factors which have considerable bearing on its effect, namely the conditions under which the work is done in the area, factory, workshop or office concerned.

Working conditions and the working environment

1. General considerations

The interdependence between working conditions and productivity is increasingly recognized. The first move in this direction came when people began to realize that occupational accidents had economic as well as physical consequences, although at first only their direct costs (medical care, compensation) were perceived. Subsequently, attention was paid to occupational diseases as well. As a final step it was realized that the indirect costs of occupational accidents (working time lost by the injured person, the witnesses and the accident investigators, production stoppages, material damage, work delays, possible legal and other costs, reduced output when the injured person is replaced and subsequently when he or she returns to work, and so on) are usually far higher — as much as several times higher in some cases — than the direct costs.

The reduction in productivity and the increase in production rejects and manufacturing waste that result from fatigue due to excessively long working hours and bad working conditions — in particular, lighting and ventilation — have shown that the human body, in spite of its immense capacity for adaptation, is far more productive when working under optimal conditions. Indeed, in certain developing countries it has been found that productivity can be improved merely by improving the conditions under which people work.

Generally speaking, occupational safety and health and ergonomics have not been given sufficient consideration in modern management techniques, in spite of the modern tendency to consider an industrial enterprise as a total system or a combination of subsystems.

These problems have been seen in a different light since public opinion and, in particular, the trade unions became aware of them. It has been possible to detect in the stresses imposed by modern industrial technology the source of those forms of dissatisfaction which occur, in particular, among workers employed on the most elementary type of repetitive and monotonous jobs that are lacking in any interest whatsoever.

Thus, not only may a hazardous working environment be a direct cause of occupational accidents and diseases, but workers' dissatisfaction with working conditions which are not in line with their current cultural and social level may also be at the root of a decline in production quality and quantity, excessive labour turnover and increased absenteeism. Obviously, the consequences of

such a situation will vary according to the socio-cultural environment. Nevertheless, wherever there is a demand for labour, it would be senseless to believe that firms whose working conditions have not developed in line with technical progress and economic growth can count on a stable workforce and achieve profitable levels of productivity.

2. Occupational safety and health organization

The most effective method of obtaining good results in the prevention of occupational hazards includes the following:

- to recognize the importance of the employer's responsibilities for ensuring that the workplace is safe and without risk to workers' health;
- to adopt an occupational safety and health policy that provides for the establishment of a good occupational safety and health organization within the enterprise; and
- to encourage strong participation of workers in safety and health activities at the workplace; including safety committees, inspection and accident investigation, and the appointment of specialists.

It is equally important that workers are adequately informed of the nature of the occupational hazards they may be exposed to; this should be considered as a fundamental right. Furthermore, workers should always have the right to remove themselves from a work situation which they have reasonable justification to believe presents an imminent and serious danger to their life or health.

The structure of safety services needs to be formalized. Its essential features should be a precise allocation of responsibilities within a structure which can ensure sustained action and a joint effort by employers and workers to maintain a safe and healthy working environment. This may be accomplished through joint safety committees. Responsibility for safety and health in an enterprise cannot be isolated from day-to-day functions such as management, production, maintenance and other related service activities. This responsibility should be an integral aspect of the workplace and follow the management structure from the senior executive to line supervisors.

Education and training on safety and health matters should always be an integral part of training activities at any enterprise regardless of size. These should be carried out in such a way that the safety and health needs of the enterprise are constantly addressed at all levels, leading to positive action that will tend to emphasize solutions rather than merely the recognition of hazards. The activities are most effective when their goals are in line with other management goals of the enterprise.

Sufficient time and effort must be invested in implementing these training activities. New workers should receive an orientation to their tasks so that they will learn to perform their jobs in a safe manner. This should be followed by regular refresher training. Safety committee members and safety representatives should receive specialized training to support and facilitate the improvement of the work environment. The training of managers and

supervisors is particularly important and due emphasis should be placed on action for improvement.

3. Safety criteria

Studies of occupational hazards in modern industry have revealed the extremely complex nature of the possible causes of occupational accidents or diseases.

Occupational accidents

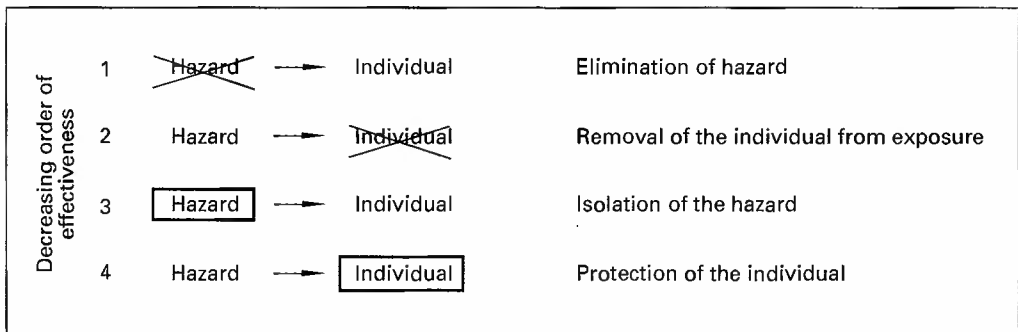
The causes of occupational accidents are never simple, even in an apparently commonplace accident; consequently, the number and variety of classifications are great. Statistics show that the most common causes of accidents are not the most dangerous machines (circular saws, spindle moulding machines, power presses, for example) nor the most dangerous substances (explosives, volatile flammable liquids, chemicals), but rather quite ordinary actions like stumbling, falling, the faulty handling of goods or use of hand tools, or being struck by a falling object.¹ Similarly, those who have accidents most frequently are not the disabled but, on the contrary, those who are the best equipped from the physical and psycho-sensorial point of view, i.e. young workers.

It should be kept in mind that in modern industry there are a variety of both visible and invisible hazards at the workplace. Visible hazards include unfenced scaffolds, openings in the floor, dripping or leaking chemicals or the unlocked working zone of a robot. Invisible hazards are now becoming more and more common and dangerous. They include inert gases, welding fumes, noise, vibration or unforeseen effects of a mixture of chemicals.

Technical progress has created new health hazards while at the same time making the prevention of occupational accidents achievable in practice. It greatly reduces the severity of conventional hazards and significantly improves safety standards. In addition, since in many countries commuting accidents have now been brought under the heading of occupational accidents, the demarcation line between occupational and non-occupational hazards has become less distinct and the role of the human factor and the importance of the circumstances attending an accident have become increasingly clear. An accident is often the result of a combination of technical, physiological and psychological factors: it depends on both the machine and the environment (lighting, noise, vibration, vaporizing substances, oxygen deficiency), as well as the worker's posture and work-induced fatigue; but it is also conditioned by commuting circumstances and other activities outside the plant and by ill-temper, feelings of frustration, youthful exuberance and other specific physical or mental states. In the developing countries, in addition, malnutrition, endemic diseases, lack of adaptation to industrial work and the immense changes that industry has brought to the worker's individual and family life and customs also play a part. It is therefore not surprising that, nowadays, increasing

¹ ILO: *Accident prevention*, A workers' education manual (Geneva, second ed., 1983).

Figure 7. The four basic methods of controlling occupational hazards classified by decreasing order of effectiveness



Source: Adapted from E. Gniza: "Zur Theorie der Wege der Unfallverhütung", in *Arbeitsökonomik und Arbeitsschutz* (Berlin), Vol. 1, 1957, No. 1.

attention is being paid to the accident hazards inherent in human behaviour, be it in the factory or elsewhere, and that the problems of safeguarding the worker's health and welfare are now being examined using an integrated approach.

The first precaution to take, in order to avoid accidents, is the elimination of potential causes, both technical and human. The ways of doing this are too numerous and varied to be listed extensively here. However, to mention but a few, there are the observance of technical rules and standards, careful supervision and maintenance, safety training for all workers, and the establishment of good working relationships.

The main technical safety criteria are listed in decreasing order of effectiveness in figure 7.

Some 30 per cent of all accidents occur in manual handling; work study can contribute to reducing the incidence of these accidents quite simply by reducing the number of handling operations and the distance involved in transporting goods. A significant percentage of other accidents could be prevented by eliminating dangerous operations through prior work study, process analysis and flow process charts (as explained in Part II) and, in general, by a critical examination of work organization with a view to accident prevention.

Work-related diseases

The situation relating to the causes of occupational diseases and ways of preventing them is equally complex. Technical progress has been so rapid that it has often created new and totally unrecognized hazards which have resulted in occupational diseases even before the disease was recognized as such. Yet this same technical progress has provided extremely effective tools for the early detection of signs or symptoms of occupationally induced morbidity, and even methods for assessing exposure levels before they have any biological effect. The study and monitoring of the working environment have, in this way, assumed a fundamental importance in the prevention of occupational diseases.

Industrial hygiene measures are similar to those that have already been mentioned for accident prevention. One important point needs to be made, however. Industrial hygiene has been a subject of study for a much shorter period than occupational safety. It is a discipline which involves both medical and technical knowledge. It is therefore essential that the management of an enterprise comes to grips with the problem and adopts the most suitable approaches for its solution; such approaches are not, however, of universal application since they have to be matched to the individual circumstances of the enterprise and its workers.

A number of basic general criteria in industrial hygiene can nevertheless be put forward. First of all, as has been found in the field of mechanical safety, in industrial hygiene too the most effective means of prevention is that which occurs at the design stage — be it of a building, plant or work process — since any subsequent improvement or modification may perhaps be too late to protect workers' health and will certainly be more expensive. Dangerous operations (for example, those resulting in environmental pollution or producing noise or vibration) and harmful substances which may contaminate the atmosphere at the workplace should be replaced by harmless or less harmful operations or substances.

Priority should be given to technical preventive measures with an emphasis on the effective use of control technologies. Where it is impossible to provide group safety equipment, use should be made of supplementary work organization measures which, in certain cases, may include a reduction of the duration of exposure to risk. Where group technical measures and administrative measures do not reduce exposure to acceptable levels, workers must be provided with suitable personal protective equipment. However, other than in exceptional cases or for special types of work, reliance should not be placed on personal protective equipment as the basic means of safety. This is not only for physiological reasons but also a matter of principle, since the worker may, for a wide range of reasons, fail to make use of this equipment.

4. The prevention of industrial accidents

Fire prevention and protection

The prevention of fire and, in certain cases, explosion and the appropriate protective measures should receive particular attention, especially in hot and dry countries and above all in certain industries where a fire may lead to widespread material damage and, should it occur during working hours, to injury and even death. Measures to prevent fires (fire prevention) and measures to reduce the threat of injury and death and to limit the extent of damage (fire protection) should receive special attention.

The first principle of fire prevention is to design buildings, processes and storage facilities in such a way as to limit the possible combination of oxygen, fuel and an increase in temperature. In this regard, the construction of facilities and process engineering should always strive to reduce the possibility of a fire developing and spreading. Fire risks exist in all workplaces. The highest priority should be given to locating the fire as soon as possible

and, with the facilities and measures available, reducing the possibility of the fire growing and spreading to other parts of the workplace. It is therefore important that the choice of materials used in the process or in support of the process should be those with the lowest risk of contributing to a possible fire or explosion. Good housekeeping also considerably reduces the risk.

The second principle is to eliminate or reduce sources of heat or ignition, thus limiting the rise in temperature. Measures such as restricting open flames, for example welding torches, and banning the smoking of cigarettes should be taken. The process heat should also be carefully controlled so as not to pose a risk.

Preparedness for fire emergencies should always be organized by management along the following lines:

- every workplace should have an **emergency plan** with information detailing the role of every worker in case of a fire or other emergency;
- there should be at least two **clear, properly marked, unobstructed exits** leading to areas of safety;
- there must be a way of **notifying personnel of a need to evacuate**, such as an alarm system. This should produce a sufficiently loud signal for all workers to hear the alarm. In some applications, for example where there is a high level of noise, visual signals such as flashing or revolving lights are also frequently used;
- the right type of fire extinguisher** should always be provided in adequate numbers for the given risk, and placed accordingly. Different types of fire extinguisher exist for different fire risks and there are national codes for the different types of risk. Each extinguisher should be labelled with easy-to-read instructions and an indication of which fire extinguisher to use for which risk;
- every worker should have **hands-on training** concerning the proper use of the extinguisher, including both when and when not to use it. The training should also cover safety considerations in using an extinguisher;
- the provision of **automatic fire protection** such as sprinklers has proved to be very effective in protecting escape routes for workers, as well as in rapidly controlling fire. This is especially true in certain high-risk industries such as chemicals and textiles.

Fire can strike a workplace on any day at any time. Adequate preparation can greatly reduce the extent of injury or damage to property. The six essential features for preparedness are as follows:

- (1) A way to notify all workers to evacuate to a safe area.
- (2) An emergency plan detailing what should be done by whom during a fire or other emergency.
- (3) A trained firefighting team which carries out regular firefighting and evacuation drills.
- (4) Periodic inspection of evacuation routes, including emergency exits, firefighting equipment, alarm systems, automatic fire protection systems and fire hazards.

- (5) A method of rapidly notifying the fire brigade and assuring its familiarity with the facilities, processes, and fire protection schemes and equipment.
- (6) Periodic fire alarm and evacuation exercises.

Major hazard control

The potential for major industrial accidents has become more significant as the production, storage and use of hazardous substances has increased. Major fires, explosions or the dispersion of toxic chemicals can cause deaths and injuries to workers and the public, result in the evacuation of communities and adversely affect the environment as a whole. In addition to the steps outlined above under "Fire prevention and protection", special measures are necessary to prevent such industrial disasters. Because of the complexity of the industrial activities concerned, the control of major accidents needs to be based on a systematic approach.

The basic components of major hazard control systems² are:

- Identifying major hazard installations.** Government authorities and management should set up, on a priority basis, a system to identify plants where major hazards exist. This may be done by means of a list of hazardous chemicals or categories of chemicals and associated threshold quantities.
- Information about the plant.** Once the plants concerned have been identified, additional information needs to be collected about their design and operation. This information, which is often presented in the form of a safety report, should be gathered and arranged systematically, and should be accessible to everyone concerned within the industry, such as management and workers, and outside the industry, such as the government bodies which may require it for licensing and inspection purposes. In order to achieve a complete description of the hazards, it may be necessary to carry out safety studies and hazard assessments.
- Action inside the plant.** Management has the primary responsibility for operating and maintaining a safe plant. A sound safety policy is therefore required. Technical inspection, maintenance, plant modification, and training and selection of suitable personnel must be carried out according to sound procedures. In addition to the preparation of the safety report, accidents should be investigated and reports submitted to the authorities. Lessons should be learnt from accidents and near misses.
- Emergency planning.** All previous elements focus on the prevention of the occurrence of major accidents. Emergency planning aims at mitigating the consequences of major accidents, and assumes that absolute safety cannot be guaranteed. In addition to the measures mentioned above, management may need to:

² For further details, see ILO: *Prevention of major industrial accidents*, An ILO code of practice (Geneva, 1991), and idem: *Major hazard control*, A practical manual (Geneva, 1988).

- set up and train a fire brigade;
- provide alarm systems with a direct line to the fire brigade or public emergency forces;
- draw up an emergency plan, including information about hazardous substances and their antidotes, guidelines for fighting the emergency, and alarm and communication routes;
- coordinate with the authorities regarding their contingency plan.

In setting up emergency planning, a distinction is made between on-site and off-site planning. A well-structured and clear plan is one which is based on a well-prepared safety report and which can be quickly and effectively employed when a major accident occurs.

5. Working premises

It would be inappropriate to deal here with the technical details of plant location and construction, but certain basic principles need to be appreciated and applied if management is subsequently to obtain viable results. This point should be borne in mind by the work study specialist, especially when plant installation is being studied.

In developing a layout, emphasis should be placed on the principle of isolating any operation which is hazardous or constitutes a nuisance. Wherever possible, work premises should be above ground level and equipped with windows having a surface area of not less than 17 per cent of the floor area. Minimum ceiling height should not be less than 3 metres and each worker should have at least 10 cubic metres of air (or more where temperatures or the level of atmospheric pollution are high). For the purposes of accident prevention, it is important to ensure that each worker has an adequate minimum free-floor area which should not be less than 2 square metres per person.

Walls and ceilings should have a finish which prevents the accumulation of dirt, avoids moisture absorption and, where necessary, reduces noise transmission; floor coverings (table 1) should be of the non-slip, non-dust-forming and easy-to-clean type and should, where necessary, have good electrical and thermal insulation properties.

Finally, the principles of good housekeeping should be applied.

6. Good housekeeping

Building work premises in accordance with safety and hygiene regulations is not enough, however, if the plant or workshop is not kept clean and tidy. Good housekeeping, which when used with reference to a factory or workplace is a general term embracing tidiness and general state of repair, not only contributes to accident prevention but is also a factor in productivity. In fact, it is by looking at such things as how material and equipment are stored, whether aisles and gangways are kept free of obstructions and the cleanliness of working areas that a person can even form an idea of the whole attitude of management to productivity and to safety.

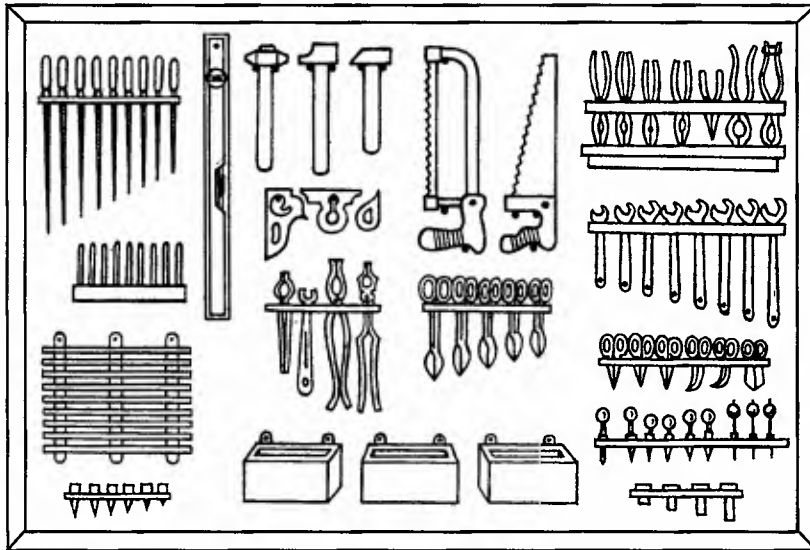
Table 1. Properties of various industrial floor surfaces¹

Properties	Type of surface								
	Concrete	Ceramic tiles	Plastics (2-component compounds)	Plastics (sheet or strip)	Xylo-lite	Wood blocks	Parquet	Poured asphalt	Rolled bituminous surfaces
Abrasion resistance	Very good	Very good	Very good ³	Medium to good	Poor	Good	Medium to good	Good	Good
Compression resistance	Very good	Very good	Very good ³	Medium	Medium	Good	Medium to good	Medium	Good
Impact resistance	Medium	Medium	Dependent on type	Good	Good	Very good	Good to very good	Good	Good to very good
Thermal insulation (contact)	Bad	Bad	Bad ³	Bad to medium	Medium	Very good	Very good	Medium	Medium
Shrinkage, stretching	Dependent on type	None	Poor	Poor	Dependent on moisture content	Dependent on moisture content	Dependent on moisture content	None	None
Acid resistance	Bad	Very good	Good	Usually good	Bad	Good	Good	Poor ⁴	Medium to bad
Alkali resistance	Good	Very good	Poor to very good depending on type	Usually good	Bad	Medium to good	Medium to good	Good	Good
Water resistance	Good	Very good	Good	Good	Bad	Bad	Bad	Very good	Good
Oil and fuel resistance	Unsuitable unless specially treated	Very good ²	Good	Medium to good	Unsuitable	Good	Good	Unsuitable	Good
Solvent resistance	Good	Very good	Certain types resistant	Good	Unsuitable	Good	Good	Bad	Medium
Dust formation	Yes	No	No	No	Yes	Yes	No	No	No
Ease of cleaning	Satisfactory	Good	Very good	Good	Satisfactory	Relatively bad	Satisfactory to good	Good	Medium to good
Fire resistance	Very good	Very good	Bad	Medium	Good	Bad	Bad	Medium	Quite good
Dielectric properties	Bad	Good	Good	Good	Depends on atmospheric humidity	Good (if dry)	Good (if dry)	Good	Quite good
Friction sparking	Yes	Yes	No	No	No	No	No	No	Yes

¹ Determined by the Swiss Federal Materials Testing Laboratory and Research Institute (Laboratoire fédéral d'essai des matériaux et Institut de recherches), Dübendorf, August 1969. ² Except perhaps the joints. ³ In these cases in particular, the characteristics depend on the filler employed. ⁴ The "acid-resistant" type is unaffected by non-oxidizing inorganic acids.

Source: Office fédéral de l'industrie, des arts et métiers et du travail (Suisse): *Hygiène et prévention des accidents dans les entreprises industrielles*, ordonnance 3 relative à la loi sur le travail (Berne, 1975).

Figure 8. Arrangement and storage of tools



Source: J. E. Thurman et al.: *Higher productivity and a better place to work, Action manual* (Geneva, ILO, 1988), figure 8.

Good housekeeping involves certain basic elements:

- Unnecessary items should be disposed of: those that will not be used should be thrown away and other rarely used items collected and stored in a suitable manner.
- Tools and equipment should be arranged in a way that allows easy access and return to their designated place. Boards on which hand-tools may be displayed are useful in this context (figure 8).
- Gangways and passages should be kept clear and the floor painted with lines at least 5 centimetres wide that distinguish them as such. Depots and storage areas should be similarly marked. Toxic matter should be painted in a different colour to identify it as such.
- The work area should be kept clean. Dust may be harmful to certain operations, oil and grease can cause accidents, and deposits of toxic material or chemicals left unattended are a source of occupational diseases. Continuous cleaning of floors, workbenches, machinery and equipment can prolong their working life and show when repairs or maintenance are required.
- Working clothes should also be kept clean in order to reduce the skin-absorption hazard of certain toxic substances (aniline and its derivatives, benzene, its homologues and derivatives, organo-phosphorus compounds, tetraethyl lead and other organic metal compounds, carbon tetrachloride and other solvents, nicotine, and so on) and the problem of skin sensitization and chronic or acute irritation. Prolonged contact of the skin with certain substances (especially mineral oils and aromatic hydrocarbons) may produce chronic dermatitis, sometimes followed by

the development of cancer. Workers exposed to toxic substances should have twin-compartment clothing lockers to keep their working clothes separate from their other clothes. Similarly, it is advisable to provide a centralized laundry service for working clothes in plants using highly toxic substances.³

- Workers employed on dirty jobs or exposed to dangerous or toxic substances should have wash-rooms with a tap for every three or four workers and a shower for every three workers (and never less than one for every eight workers) to ensure that workers do not give up taking a shower because they have to wait too long. Adequate toilet facilities should be provided no farther than 75 metres from work areas.

7. Lighting

It is estimated that 80 per cent of the information required in doing a job is perceived visually. Good visibility of the equipment, the product and the data involved in the work process is an essential factor in accelerating production, reducing the number of defective products, cutting down waste and preventing visual fatigue and headaches among the workers. It may also be added that both inadequate visibility and glare are frequently causes of accidents.

Visibility depends on a number of factors. These are the size and colour of the workpiece, its distance from the eyes, the persistence of the image, the lighting intensity, and contrasts of colour and lighting levels with the background. All these factors should be studied, especially in the case of precision work, work in a dangerous environment or where there are other reasons for dissatisfaction or complaint. Lighting is probably one of the more important physical factors and the one which is easiest to correct.⁴

In principle, lighting should be adapted to the type of work. However, the level of illumination, measured in lux, should be increased not only in relation to the degree of precision or miniaturization of the work (table 2), but also in relation to the worker's age, since older people require a higher level of illumination than young ones, especially if they are to recognize details and to maintain a sufficiently rapid visual reaction. Moreover, older people are highly susceptible to glare since their recovery time is longer. The accumulation of dust and the wear of the light sources cut down the level of illumination by 10-50 per cent of the original level. This gradual drop in the level should therefore be compensated for when designing the lighting system. Regular cleaning of lighting fixtures is obviously essential.

In general, the light should be uniformly diffused (figures 9, 10 and 11); slight shadows help to distinguish objects, but shadows that are too pronounced should be avoided. Excessive contrasts in lighting levels between the worker's

³ For further details, see Abu Bakar Che Man and David Gold: *Safety in the use of chemicals at work* (Geneva, ILO, forthcoming).

⁴ For further information on visual ergonomics and the parameters that influence visual performance, see International Organization for Standardization: *Principles of visual ergonomics: The lighting of indoor work systems*, ISO 8995 (Geneva, 1989).

Table 2. Recommended minimum values of illumination for various classes of visual task

Class of visual task	Minimum illumination of task (lux) ¹	Typical examples
Casual seeing	100	Boilerhouse (coal and ash handling); dead storage of rough, bulky materials; locker rooms
Ordinary rough tasks	150	Rough, intermittent bench and machine work; rough inspection and counting of stock parts; assembly of heavy machinery
Moderately critical tasks	300	Medium bench and machine work, assembly and inspection; ordinary office work such as reading, writing, filing
Critical tasks	700	Fine bench and machine work, assembly and inspection; extra-fine painting, spraying; sewing dark-coloured goods
Very critical tasks	1 500	Assembly and inspection of delicate mechanisms; tool- and die-making; gauge inspection; fine grinding work
Exceptionally difficult or important tasks	3 000 or more	Fine watchmaking and repairing

¹ These figures refer to the mean value of illumination obtained during the life of the installation and averaged over the work plane or specific task area (i.e. the so-called "service value of illumination").

Source: ILO, International Occupational Safety and Health Information Centre (CIS): *Artificial lighting in factory and office*, CIS Information Sheet No. 11 (Geneva, 1965), table 1.

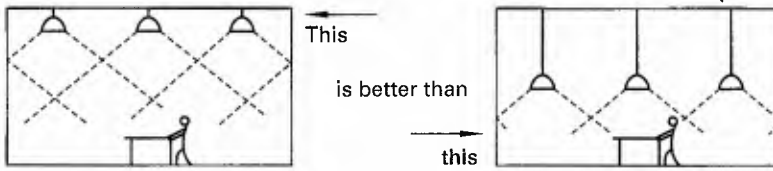
Table 3. Recommended maximum lighting intensity ratios

Points involved	Ratio
Between the work and the immediate environment	5 to 1
Between the work and distant surfaces	20 to 1
Between the light source or the sky and adjacent surfaces	40 to 1
All points in the worker's immediate vicinity	80 to 1

task and the general surroundings should also be avoided. Table 3 shows the maximum intensity ratios that should be observed in order to prevent the development of visual fatigue and health disorders such as conjunctivitis and headaches.

The use of natural light should be encouraged. This can be achieved by installing windows that open, which are recommended to have an area equal to at least one-sixth of the floor area. However, daylight varies with the season, the time of day, the distance of workstations from the windows and the presence or absence of blinds. For this reason it is essential to have artificial lighting available all the time should the need to use it arise. The use of artificial lighting will enable people to maintain proper vision and will ensure that the lighting intensity ratios between the task, the surrounding objects and the general environment are maintained.

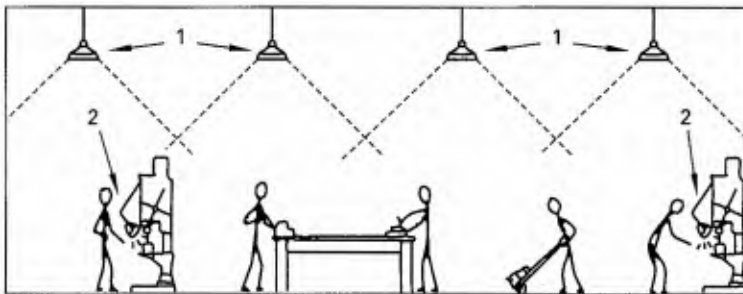
Figure 9. Mounting of general lighting units



General lighting units should preferably be mounted as high as possible.

Source: ILO, CIS: *Artificial lighting...*, op. cit., figure 18.

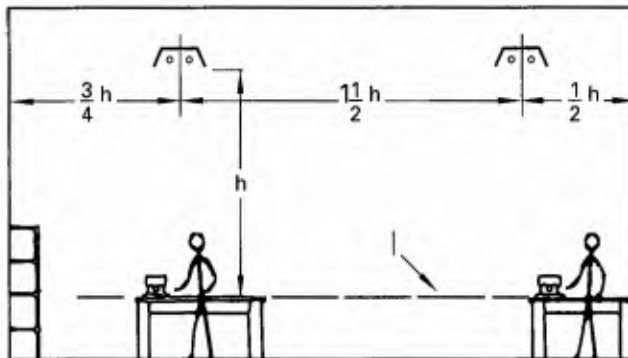
Figure 10. Need for general lighting



Some general lighting is always needed even when tasks are locally lit. (1) Uniform general lighting (2) Local supplementary lighting.

Source: ILO, CIS: *Artificial lighting...*, op. cit., figure 21.

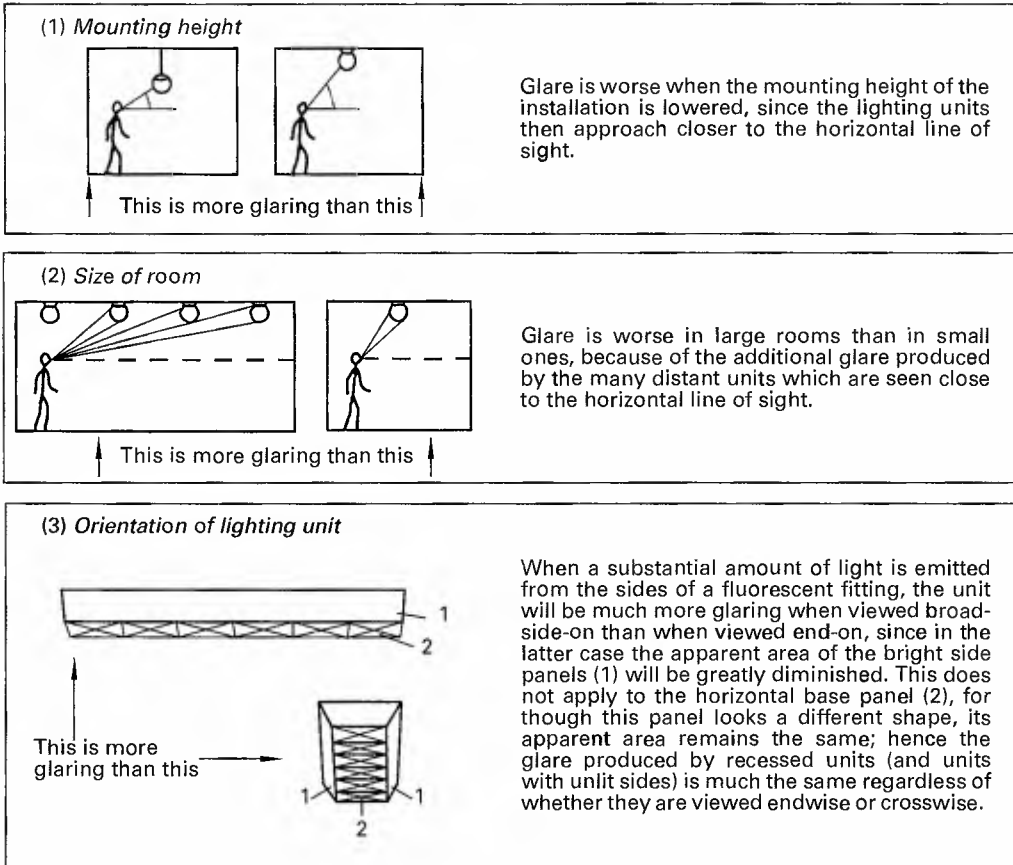
Figure 11. Maximum recommended spacing for industrial-type units



Measurements are to the centre point of the unit in all cases, and are expressed as a multiple of the mounting height h above the work plane (l). The $\frac{3}{4} h$ figure applies when there is a gangway next to the wall, whilst the $\frac{1}{2} h$ figure is used when people work close to the wall. For louvred units, maximum spacing between fittings should be reduced to $1\frac{1}{4} h$.

Source: ILO, CIS: *Artificial lighting...*, op. cit., figure 19.

Figure 12. Factors influencing the degree of glare produced by a given diffusing fitting (or a bare fluorescent lamp unit)



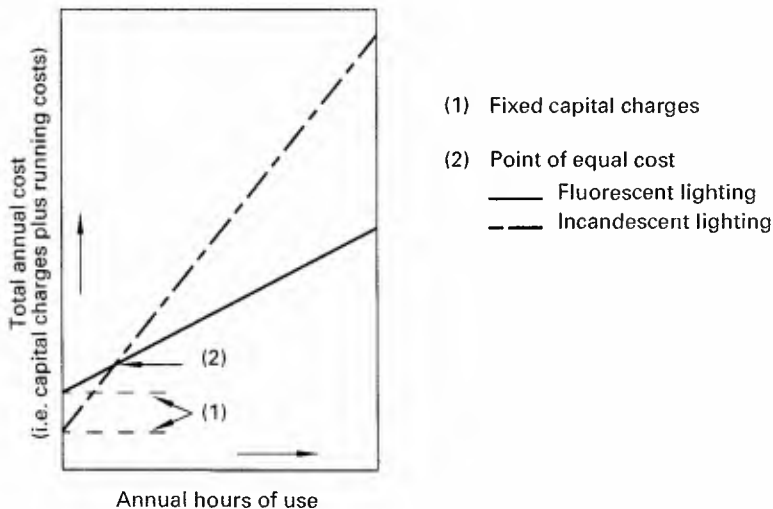
Source: ILO, CIS: *Artificial lighting...*, op. cit., table IV.

Provided that glare is avoided (figure 12), fluorescent lighting offers considerable potential for rational use. This type of lighting has particularly good colour-rendering properties and its annual cost (including depreciation and installation costs) falls, in relation to incandescent lighting, as the number of hours of use increases (figure 13). Thus the number of hours an installation is likely to be used per year should influence the type of lighting chosen. Lighting can be easily measured by a light meter. The light meter should be fitted with a detachable photo cell so as to read from a distance, thus avoiding interference by the person conducting the measurements.

Use of colours

Experience shows that the careful choice of interior colour schemes makes a valuable contribution to good lighting (figure 14). The colours used at the workplace have psychological effects which should not be overlooked. When the time comes to repaint workshops and offices it costs little to select pleasing rather than drab colours. The workers will see in this a clear sign that the management is attempting to make working conditions more pleasant.

Figure 13. Relative cost of incandescent and fluorescent lighting



Source: ILO, CIS: *Artificial lighting...*, op. cit., figure 1.

The colours of machinery and equipment are supplementary safety factors. Their importance has been recognized by the manufacturers of machine tools and electrical equipment.

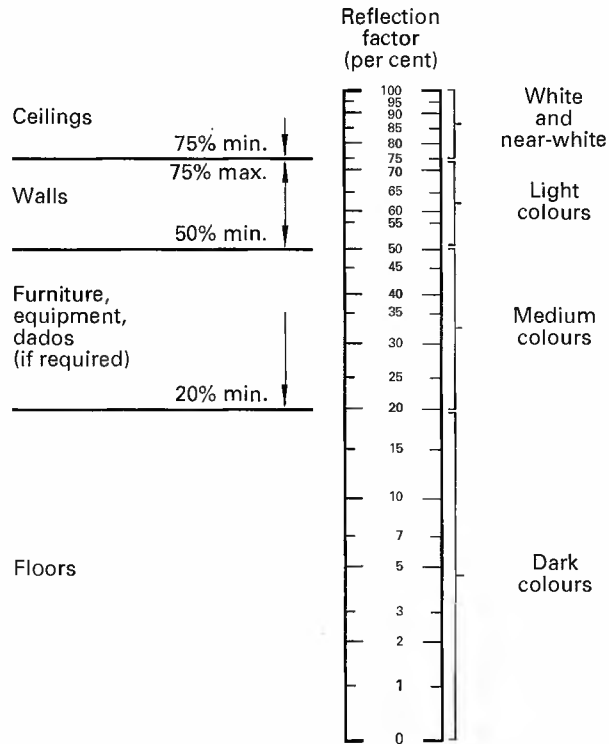
Control of lighting

In order to make the best use of lighting in the workplace, the following points should be taken into account:

- for uniform light distribution, install an independent switch for the row of lighting fixtures closest to the windows. This allows the lights to be switched on and off depending on whether or not natural light is sufficient;
- to prevent glare, avoid using highly shiny, glossy work surfaces;
- use localized lighting in order to achieve the desired level for a particular fine job;
- clean light fixtures regularly and follow a maintenance schedule so as to prevent flickering of old bulbs and electrical hazards due to worn out cables;
- avoid direct eye contact with the light sources. This is usually achieved by positioning them properly. The use of diffusers is also quite effective;
- for work with visual display units (VDUs):⁵

⁵ For further information on this subject, see ILO: *Working with visual display units*, Occupational Safety and Health Series, No. 61 (Geneva, 1989).

Figure 14. Recommended ranges of reflection factor for main interior surfaces



Source: ILO, CIS: *Artificial lighting...*, op. cit., figure 30.

- the general lighting level should be relatively low, not to exceed 500 lux (blinds or curtains may be used to prevent excessive daylight);
- avoid glare by suitable positioning of the VDU or other means;
- ensure that there are no reflected light sources seen by the user on the screen;
- the luminance and contrast of the screen must be adjustable and the characters must remain sharp;
- if additional lighting is needed, it must be adjustable and positioned in such a way as to avoid glare.

8. Noise and vibration⁶

Noise

High levels of mechanization, increased machine speeds, the density of machinery at the workplace and the lack, until recently, of detailed knowledge of the hazards and nuisance factor of noise have resulted, in many plants, in

50 ⁶ For further information on this subject, see ILO: *Protection of workers against noise and vibration in the working environment*, An ILO code of practice (Geneva, third impression (with modifications), 1984).

workers being exposed to noise levels which are nowadays considered excessive.

Noise means any disagreeable or undesired sound. Sound-level meters are used to measure the pressure variations producing audible sound. The practical unit for measuring noise is decibel (dB).

The human ear responds in different ways to sounds of different frequencies. The unit of frequency is hertz (Hz) and the ear responds over the approximate range of 20 to 20,000 Hz. The loudness of sounds, as judged by the human ear, depends on frequency as well as level. The ear is less sensitive to low and very high frequencies than to the middle range of frequencies from 1,000 to 8,000 Hz. A sound-level meter has an electronic network of standardized characteristics built into it to simulate this characteristic of the average ear. The generally accepted network for this approximation is the "A" Scale and measurements made during this weighting are labelled dB(A).

Noise is the cause of various problems. It impedes sound communication (figure 15), first, by the acoustical masking effect which every sound has on other sounds of the same frequency or immediately higher frequencies and which reduces the intelligibility of speech that is not more than 10 dB louder than the background noise; and, second, by temporarily raising the acoustic threshold in the event of exposure to a noise exceeding 78-80 dB (figure 16). Background noise may hinder communication or, by masking warning signals, may cause accidents. Its level should not exceed 60-70 dB(A) if anybody is to conduct a conversation at a normal distance.

Noise may cause sensori-motor, neuro-vegetative and metabolic disorders; it has been named as a cause of industrial fatigue, irritation, reduced productivity and occupational accidents.

Anyone who has done intellectual work, or work requiring intense concentration, in a noisy environment such as a weaving mill or a workshop full of automatic machines — even where the noise level does not reach levels which may cause occupational deafness — will know just how fatiguing noise can be. Intermittent noise from rams used for digging the foundations for heavy machines, riveting hammers, pile-drivers or large mechanical presses is particularly disturbing. Numerous investigations have shown that a reduction in the background noise is accompanied by a marked decrease in the number of errors and a significant improvement in production.

Prolonged exposure to noise above certain levels causes permanent damage to hearing and results in occupational deafness.

Loss of hearing is either temporary or permanent in nature depending upon the length and severity of noise exposure. A temporary hearing loss, lasting for a few seconds to a few days, may result from exposures to high-intensity noise for short durations. This is reversible and normal hearing will be restored. Much more serious regular and prolonged exposure to some kinds of noise of moderate intensity maintained through successive working days over a period of years, or a single short exposure to very high-intensity noise, may cause a loss of hearing which is permanent and irreversible and may even cause damage to the ears.

Figure 15. Distance at which the normal voice can be heard against background noise

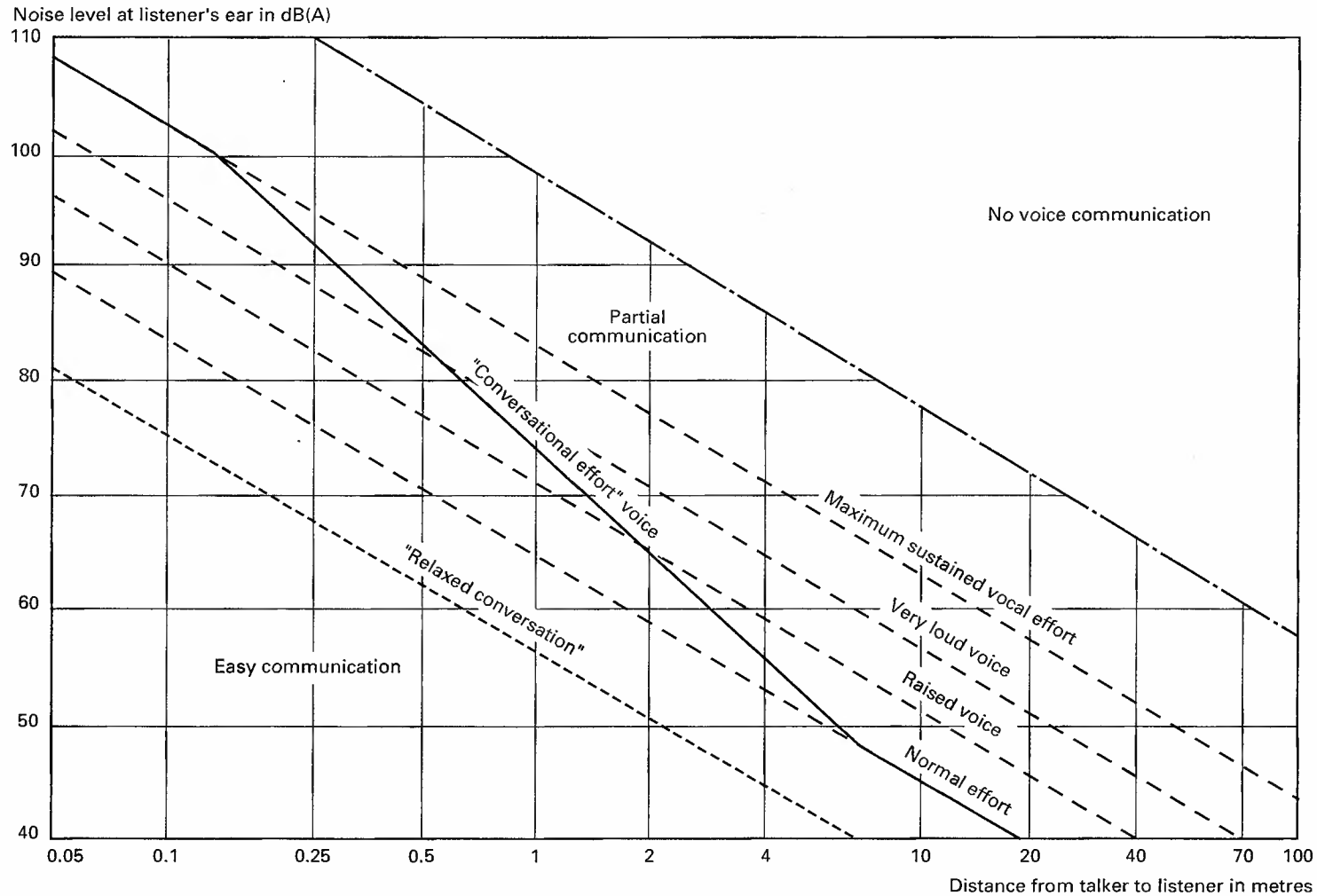
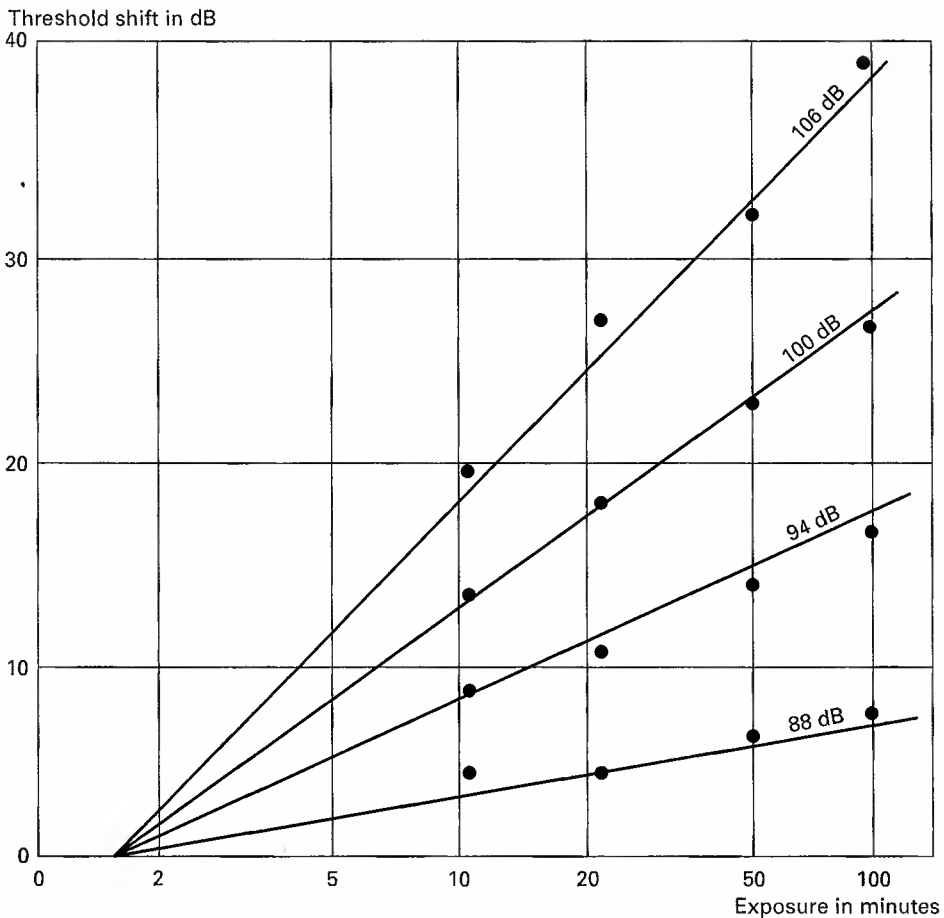


Figure 16. Temporary hearing threshold shift in dB as a function of duration of exposure to wide-band noise



Source: A. Glorig et al.: "Damage risk criteria and noise-included hearing loss", in *Archives of Otolaryngology* (Chicago, Illinois), Vol. 74, 1961, p. 413, Copyright 1961, American Medical Association.

It is considered that exposure to continuous noise levels of 90 dB(A) or above is dangerous to hearing; but the figure of 85 dB(A) is already a warning level which should not be exceeded. Special care should be taken in the case of impulse noise, i.e. a sound with a rise time of not more than 35 milliseconds to peak intensity (given as sound pressure in pascals (pa)) and a duration of not more than a second to the time when the level is 20 dB below the peak. Each time the sound level increases by 6 dB, the sound pressure doubles and the acoustic energy is quadrupled; thus it is considered that, for an increase of 3 to 5 dB in the sound level, the duration of exposure must be halved if the biological effect is to remain unchanged (table 4).

The most effective method of noise control is to reduce the noise at source by, for example, replacing noisy machines or equipment by less noisy ones; this means (as is always the case with preventive action) that these measures must be borne in mind at the design stage of a production process,

Table 4. Duration of continuous noise exposure which should not be exceeded to ensure the prevention of occupational deafness among the majority of workers

Daily duration of noise in hours	Noise level in dB(A) (measured "slow")
16	80
8	85
4	90
2	95
1	100
$\frac{1}{2}$	105
$\frac{1}{4}$	110
$\frac{1}{8}$	115

Source: American Conference of Governmental Industrial Hygienists (ACGIH): *Threshold limit values for chemical substances and physical agents in the workroom environment adopted by the ACGIH for 1987-88* (Cincinnati, Ohio).

the construction of a building or the purchase of equipment. Particular attention should be given to ventilation equipment since, in many workshops, recent concern about the prevention of atmospheric pollution at the workplace has led to the installation of ventilation equipment which, when in operation, has raised the background noise to 85 to 90 dB and above, even before the production machines are started up.

The second method is to prevent or reduce noise transmission by the installation of noise-absorbent barriers between the noise source and the worker and by the damping of structures which may be the source of secondary reverberation, or by isolating the noise source in separate premises or a sound-proofed enclosure (this may also require modification of the foundations to prevent the transmission of vibration through the floor). Where such measures are not applicable or are not sufficiently effective, it may be necessary to provide workers with sound-proofed cabins (ventilated or, where necessary, air-conditioned) from which they can operate the machines and do their work without having to enter the noisy environment except for short periods.

Where workers are systematically exposed to a noise level of 90 dB(A) for eight working hours, the duration of noise exposure should be reduced to bring the situation back within acceptable limits (table 4).

Personal noise protection consists of ear-plugs made from material such as glass fibre or foam plastic, or earmuffs which provide a reduction in noise of up to 20 dB; however, workers sometimes object to this type of protection. In fact, personal noise protection should be considered as no more than a provisional remedy until the workplace is permanently modified or whenever special conditions make its use necessary.

Workers who are systematically exposed to noise levels above the danger level should receive a periodic audiometric examination. This examination can help to identify at an early stage individuals whose hearing has been affected, possibly by exceptional susceptibility to noise, or failure to use hearing protectors provided to them, or use of incorrectly fitted or unsuitable protectors.

Vibration

Although only a limited number of workers are exposed to vibrations which constitute a health hazard, the necessary protective measures should not be neglected. The possibility of reducing vibration levels (e.g. dynamic balancing of rotating parts, use of vibration-absorbing mountings, providing heavy foundations) and reducing the effect of vibrations (e.g. use of vibration-damping handles for hand-held machines) should be explored first. Where this is not possible the period of exposure should be controlled. Persons exposed to vibrations should be subjected to periodic medical examinations.

9. Climatic conditions

Control of the climatic conditions at the workplace is paramount to the workers' health and comfort and to the maintenance of higher productivity. With excess heat or cold, workers may feel very uncomfortable, and their efficiency drops. In addition, this can lead to accidents.

The human body functions in such a way as to keep the central nervous system and the internal organs at a constant temperature. It maintains the necessary thermal balance by continuous heat exchange with the environment. The extent of this exchange depends, on the one hand, on air temperature, ventilation, humidity and radiant heat and, on the other, on body metabolism. During physical activity, metabolic values may be up to ten times as much as those encountered at rest. Under normal climatic conditions, in order to avoid over-heating (which sooner or later proves fatal), the heat that the body is continually producing must be dissipated in larger quantities when work is being done and in still larger quantities again if it is absorbing heat from a high-temperature environment. It is essential to avoid excessive heat or cold, and wherever possible to keep the climatic conditions optimal so that the body can maintain a thermal balance.

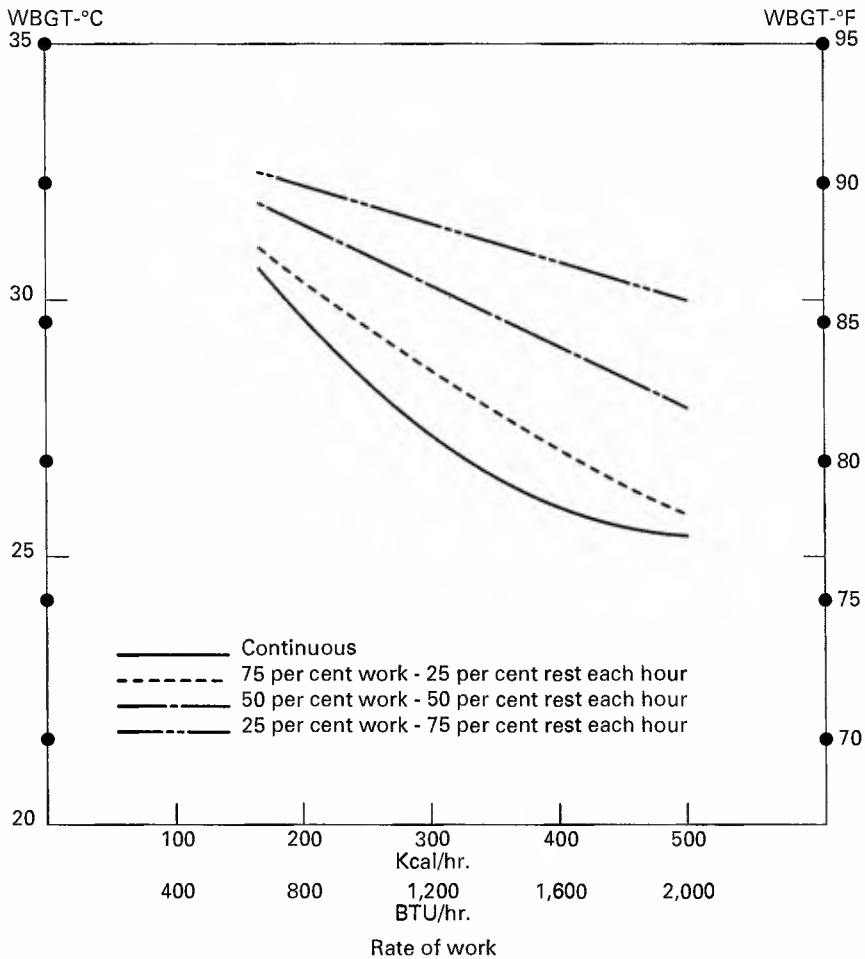
Working in a hot environment

Hot working environments are found almost everywhere. Work premises in tropical countries may, on account of general climatic conditions, be naturally hot. When sources of heat such as furnaces, kilns or hot processes are present, or when the physical workload is heavy, the human body may also have to deal with excess heat.

It should be noted that in such hot working environments sweating is almost the only way in which the body can lose heat. As the sweat evaporates, the body cools. There is a relationship between the amount and speed of evaporation and a feeling of comfort. The more intense the evaporation, the quicker the body will cool and feel refreshed. Evaporation increases with adequate ventilation.

However, when there is high relative humidity, evaporation is less effective in cooling the body. Certain climatic conditions, such as those in many tropical countries, and certain working environments such as those found in deep mines, textile mills and sugar refineries, expose the worker to a hot,

Figure 17. Limits of heat exposure



Source: ACGIH, op. cit.

humid environment with little possibility to cool through evaporation. Another working environment which is uncomfortable results from a combination of a hot, dry, “desert-like” heat combined with high air temperatures. This type of working environment can be found in iron and steel works, in foundries, around surface treatment furnaces and in glass works, hot-rolling mills and forges. In all cases it is necessary to consider thermal burden in relation to the energy expenditure required by the work. The more burdensome the climatic conditions, the longer the work breaks should be (figure 17).

Working in a cold environment

Working in cold environments was once restricted to non-tropical or highly elevated regions. Now, as a result of modern refrigeration, various groups of workers, even in tropical countries, are exposed to a cold environment.

Exposure to cold for short periods of time can produce serious effects, especially when workers are exposed to temperatures below 10 °C. The loss of body heat is uncomfortable and quickly affects work efficiency. To maintain a normal temperature in a cool or cold environment, the body tries to limit heat loss by shivering and slowing down the circulation of blood to the skin and extremities. Long exposures or extreme cold endanger survival owing to a drop in body temperature.

Work periods in cold environments should, where necessary, be alternated with work periods in normal temperature. Workers who must remain in the open in cold weather, such as construction workers, electrical line workers or fishermen, should always be provided with sheds or other facilities where they can re-warm themselves, sheltered from the weather. Workers should frequently take hot drinks. In non-heated cold locations, some degree of comfort can be achieved by localized heat, such as that provided by infra-red heaters, directed at the workers. This can increase the amount of time a worker can remain in cold premises without negative consequences to health and without loss of production.

Workers in cold climates and refrigerated premises should be well protected against the cold by wearing suitable clothes, including footwear, gloves and, most importantly, a hat. Normally, dressing in layers traps dead air and serves as an insulation layer, thus keeping the worker warmer.

Working in a wet environment

As has already been mentioned, high levels of humidity are poorly tolerated at high temperatures, in particular when there is a significant workload. The temperature (as indicated by the wet-bulb thermometer) at the workplace should not exceed 21°C (70°F). It is extremely difficult to keep within this limit in hot countries, in circumstances where (as in the textile industry) the process requires a high level of atmospheric humidity or (as in laundries, canning plants and various chemical plants) produces large quantities of steam. Excess steam should be prevented from spreading in the atmosphere by local exhaust where possible, and by controlling the quantity of steam introduced for humidification. Increasing air velocity will provide a degree of comfort in hot, humid, atmospheres.

Excessive humidity is also poorly tolerated in combination with low temperatures. Relative humidity should be kept within a range of 40 to 70 per cent. An inadequate amount of humidity in the air can also create problems. Excessively dry air can be a cause of respiratory tract diseases; consequently, this should be avoided in winter in overheated premises.

Control of the thermal environment

There are many ways of controlling the thermal environment. It is relatively easy to assess the effects of thermal conditions, especially when excessive heat or cold is an obvious problem. To solve the problem, however, consistent efforts using a variety of available measures are usually necessary. This is because the problem is linked with the general climate, which greatly affects

Table 5. Control of working climate

Type of work	°C	°F
Sedentary work	20-22	68-72
Light physical work in a seated position	19-20	66-68
Light work in a standing position (e.g. on machine-tools)	17-18	63-65
Moderate work in a standing position (e.g. assembly)	16-17	61-63
Heavy work in a standing position (e.g. drilling)	14-16	57-61

the workplace climate, production technology, which is often the source of heat or cold, and varying conditions of the work premises as well as work methods and schedules. Personal factors such as clothing, nutrition, personal habits, age and individual differences in response to the given thermal conditions also need to be taken into account in the attempt to attain the thermal comfort of workers.

In controlling the thermal environment, one or more of the following principles may be applied:

- regulating the workroom temperature by preventing outside heat or cold from entering (improved design of the roof, insulation material or installing an air-conditioned workroom. Air-conditioning is costly, especially in factories, but it is sometimes a worthwhile investment if an appropriate type is chosen);
- provision of ventilation in hot workplaces by increasing natural ventilation through openings or installing ventilation devices;
- separation of heat sources from the working area, insulation of hot surfaces and pipes, or placement of barriers between the heat sources and the workers;
- control of humidity with a view to keeping it at low levels, for example by preventing the escape of steam from pipes and equipment;
- provision of adequate personal protective clothing and equipment for workers exposed to excessive radiant heat or excessive cold (heat-protective clothing with high insulation value may not be recommended for jobs with long exposure to moderate or heavy work as it prevents evaporative heat loss);
- reduction of exposure time, for example by mechanization, remote control or alternating work schedules;
- insertion of rest pauses between work periods, with comfortable, if possible air-conditioned, resting facilities;
- ensuring a supply of cold drinking-water for workers in a hot environment and of hot drinks for those exposed to a cold environment.

Experience shows that, among the workers in a given work area, some would prefer more ventilation and others less, and some tend to feel cold while others feel at ease. Such differences often occur because the jobs being done by certain workers demand greater physical effort than those being done by others, or because some work in a draught and others in a confined work area.

58 Improved layout of work premises and workstations can often help provide

optimum climatic conditions for the majority of workers. It is useful to take into account the different air temperatures recommended for various types of work, as shown in table 5.

It is sometimes seen that in particular the heat at the workplace may still be excessive in spite of various available measures. In this case consideration should be given to drastic technical solutions, such as changing the production methods or processes, purchasing machines which do not contribute to excessive heat in the environment or providing air-conditioned workrooms.

Ventilation

The cubic volume of working premises can never be large enough to make ventilation unnecessary, since ventilation is the dynamic parameter that complements the concept of air space: for a given number of workers, the smaller the work premises the more intense should be the ventilation.

Ventilation must not be confused with air circulation: the first replaces contaminated air by fresh air, whereas the second merely moves the air without renewing it. Where the air temperature and humidity are high, merely to circulate the air is not only ineffective but, beyond certain limits, increases heat absorption by convection.

Workplace ventilation:

- disperses the heat generated by machines and people at work; consequently, where machines or workers are grouped together, ventilation should be intensified;
- dilutes atmospheric contamination (it is easy to calculate the quantity of air to be admitted, on the basis of the quantity of substances being released into the air and the maximum concentration that should be observed);
- maintains the feeling of air freshness.

In all, adequate ventilation should be looked upon as an important factor in maintaining the worker's health and productivity.

Except for confined spaces, all working premises have some minimum ventilation. However, to ensure the necessary air flow (which should not be lower than 50 cubic metres of air per hour per worker), air usually needs to be changed between four and eight times per hour in offices or for sedentary workers, between eight and 12 times per hour in workshops and as much as 15 to 30 or more times per hour for public premises and where there are high levels of atmospheric pollution or humidity.

The air speed used for workplace ventilation should be adapted to the air temperature and the energy expenditure: for sedentary work it should exceed 0.2 metre per second, but for a hot environment the optimum speed is between 0.5 and 1 metre per second. For arduous work it may be even higher. Certain types of hot work can be made tolerable by directing a stream of cold air at the workers. Ventilation, correctly used, is one of the most important technical means of making tolerable certain types of extremely arduous working conditions as encountered in deep mines and tropical countries, i.e. anywhere

where there is a combination of high atmospheric temperature and relative humidity.

Natural ventilation, obtained by opening windows or wall or roof air-vents, may produce significant air flows but can normally be used only in relatively mild climates. The effectiveness of this type of ventilation depends largely on external conditions that usually vary considerably. When ventilation is most needed, natural ventilation is often least effective; moreover, it is relatively difficult to regulate. In addition, for natural ventilation to be effective, the outlet vents must be correctly located and of sufficient size, especially in hot countries where ventilation apertures are, only too often, too small.

Where natural ventilation is inadequate, artificial ventilation should be used. A choice may be made between a blown-air system, an exhaust-air system or a combination of both ("push-pull" ventilation). Only "push-pull" ventilation systems allow for better regulation of air movement.

Where concentration of contaminants cannot be reduced by ventilation, local exhaust systems must be used. They usually include hoods or enclosures, ductwork leading to an exhaust fan, an air-cleaning device for air pollution abatement and, finally, discharge to the outside air. An essential point is to ensure that the exhausted air does not pass through the workers' breathing zone. Although the initial installation may be costlier, local exhaust ventilation is overall more economical and more efficient than general ventilation since it captures contaminants at the source and requires a much smaller volume of exhaust air to remove them from the workplace.

10. Exposure to toxic substances

The protection of workers' health against hazards due to the contamination of air at the workplace and the prevention of contamination of the work environment should be the concern of all those involved in the design and organization of work. Pollution of the work environment by airborne contaminants is caused by toxic substances released during the work process in the form of dust, gases, vapours or mists. Dust containing silica in stone processing, solvents used in cleaning work and sulphur dioxide or chlorine leaking from pipes are some examples of contamination. Exposure to toxic substances has both short- and long-term ill-effects on the human body, and should be prevented.

A first attempt should be made to remove or eliminate the hazard by controlling the release of toxic substances into the work environment. This is possible in many situations by measures such as substituting with a less hazardous substance, enclosing the processes emitting toxic substances and preventing leaks in joints of pipes. Providing local exhaust systems to remove the airborne contaminants at the source is also practical and viable in some cases. Introducing changes in the process itself (such as mechanical handling in place of manual handling or wet grinding in place of dry grinding) should also be considered.

The reduction of exposure time of workers can be a viable solution in cases where the worker is not required to be near the process continuously.

When the measures suggested above are not possible, the last resort should be to protect the worker through appropriate personal protective equipment adequate to the task.

Whenever there is a possibility of a toxic substance contaminating the work environment, steps should be taken to assess the levels of exposure. Instruments, equipment and standard methods are available for detection, sampling and evaluation of contaminants in the work environment. It is necessary to ensure that the exposure limits specified are not exceeded by implementing one or more of the methods described above. Exposure limits are derived from animal experiments, epidemiological data and field trials, and are specified by governments, research institutions and recognized bodies such as the American Conference of Governmental Industrial Hygienists (ACGIH). They are expressed in terms of time-weighted average (TWA), ceiling values (which must not be exceeded at any time) or short-term exposure levels (STEL, i.e. the highest concentration which should not be exceeded beyond 15 minutes during any shift). Periodic monitoring of the work environment is essential. It may be also necessary, in some cases, to confirm or supplement the findings by biological monitoring, for example by examination of blood or body fluids, and by medical examinations.

Apart from airborne contaminants (which enter the human body through inhalation), certain substances can enter the body through ingestion (food or drink contaminated with toxic substances — mainly attributable to poor personal hygiene practices) or through skin absorption. Mineral oils and solvents handled by workers can cause dermatitis of the skin by prolonged contact. Certain chemicals reach the blood through the skin and cause systemic disorders. Aniline causes cyanosis and benzene is known to affect blood cells through skin absorption.

Workers exposed to toxic substances should be subjected to periodic medical examinations. Records of medical examinations should be maintained and reviewed, to detect any changes or deterioration in the health status of workers and to ensure that effective measures are taken to protect their health.

11. Personal protective equipment

For certain severe occupational hazards, neither technical prevention nor administrative arrangements can ensure an adequate degree of protection. It is therefore necessary to institute a third level of defence, i.e. personal protective equipment. This type of equipment is justified in emergency situations such as a severe accident, a leak or a fire, or under exceptional circumstances such as those attending work in confined spaces. In other cases the provision and maintenance of this equipment may be expensive and some workers may resist its use. It is therefore advisable for representatives of the management and the workers to examine the matter jointly beforehand and to seek the opinion of the safety and health committee, where one exists.

Where there is no other effective means of protection, the enterprise must provide a sufficient quantity of suitable personal protective equipment, instruct

the workers in its correct use and ensure that it is worn. The choice of equipment should be made with the assistance of specialists, since advice is required both on the equipment's effectiveness and on its ergonomic characteristics, i.e. its adaptation to the worker's physical and functional characteristics.

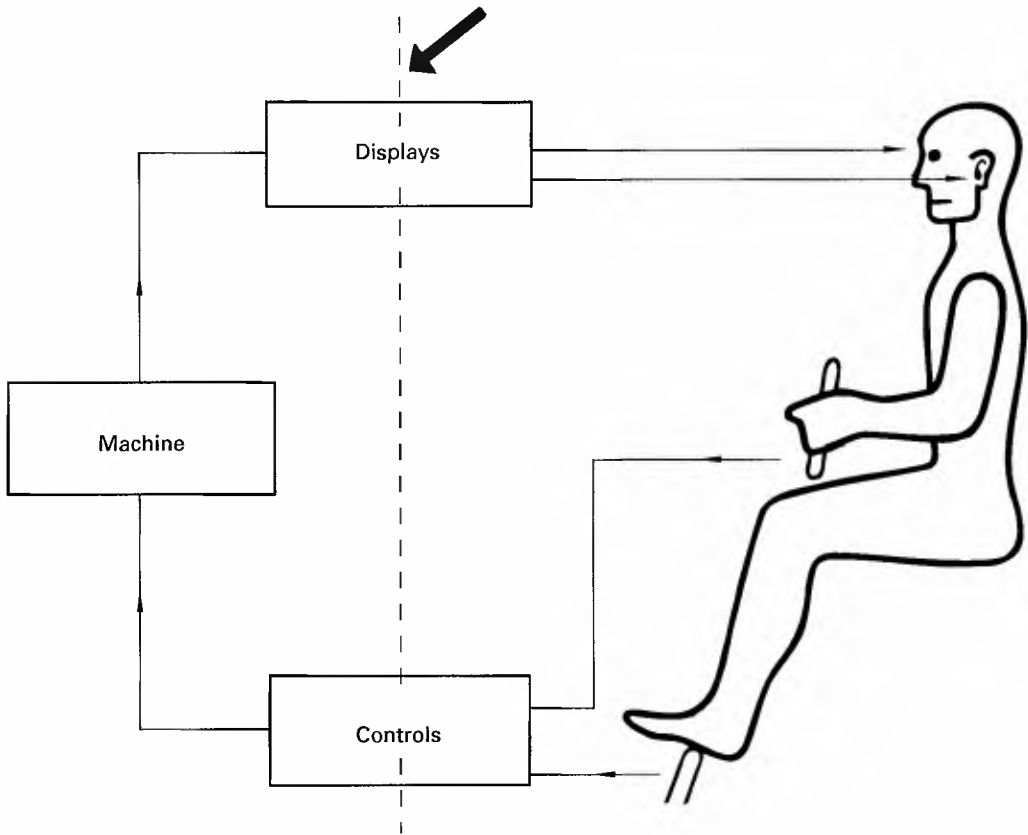
12. Ergonomics

The effects of health and safety on productivity cannot be properly discussed without touching on the concept of ergonomics. This term covers a field which in recent years has expanded to an extraordinary degree and whose boundaries overlap with other disciplines concerned with the study of work and its consequences for human beings. Ergonomics is concerned with: (a) the study of the individual operator or working team, and (b) the provision of data for design. The aims of ergonomics are, therefore, to enhance **functional effectiveness** while maintaining or improving **human welfare**. Ergonomic measures may also be defined as those that go beyond the mere protection of the workers' physical integrity and aim at ensuring their well-being through appropriate working conditions and the most suitable use of their physical characteristics and physiological and psychological capabilities. Thus, ergonomics is human centred. While the ergonomist has always in mind the **people** involved in the operation of any system, other professionals may well be interested in the **object** being produced or used (industrial designer); the **method** of work (work study practitioner); the **productivity** implications (industrial engineer); or the **safety** aspects (safety engineer).

For ergonomics, then, the task is to develop the most comfortable conditions for the worker as regards lighting, climate and noise level, to reduce the physical workload (in particular in hot environments), to facilitate psycho-sensorial functions in reading instrument displays, to make the handling of machine levers and controls easier, to make better use of spontaneous and stereotyped responses, to avoid unnecessary information recall efforts, and so on.

The interaction between operator and machine deserves particular attention, as this is an important aspect of work study. The so-called "interface" between the worker and the machine is symbolized in figure 18 by a dotted line. One relevant characteristic of any machine is the way that it conveys information to the operator. This information is provided through displays. There is an enormous variety of visual and auditory displays (see figure 19). Many ergonomic design aspects of these devices should be considered by the work study practitioner when studying the current working method. One important point is that the main aim of the displays is to establish a communication link between the machine and the worker and that this process can be enhanced or degraded depending upon the quality of the displays selected. While they can provide alternative ways of conveying information, new technologies can bring new problems and pose new constraints in the use of displays. Electronic displays require specific guidelines for their selection,

Figure 18. The operator/machine interface



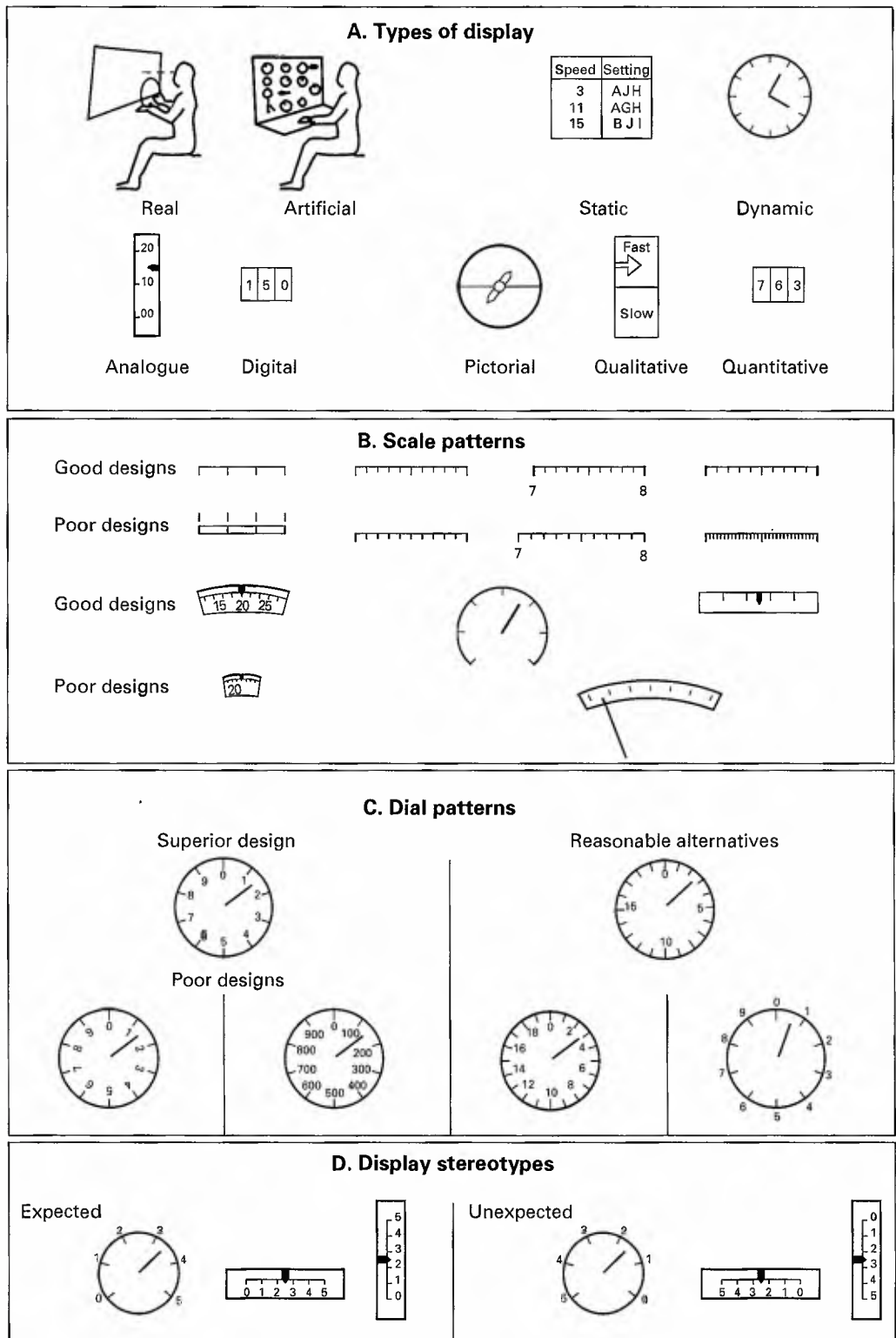
Source: Reproduced, by permission, from W. T. Singleton: *Introduction to ergonomics* (Geneva, WHO, 1972), p. 87.

installation and use. Singleton proposes some general principles concerning displays, some of which are as follows:⁶

- Display design must be based on a clear definition of the task and on an understanding of the way in which the particular kind of operator performs it.
- There are three kinds of display: pictorial, qualitative and quantitative (figure 19). Quantitative displays are only used when numbers are essential to the task.
- In most tasks the operator receives information both from a real work process and from an artificial display representing it. The artificial display must be so designed as to be compatible with the real display in terms of patterns and relative movements.
- When the information to be presented artificially has been assessed, it must be allocated:

⁶ See W. T. Singleton: *Introduction to ergonomics* (Geneva, World Health Organization, 1972), p. 77.

Figure 19. Ergonomic display design



- between the three sensory channels: visual, auditory and kinaesthetic (movement perception); and
 - between dynamic and static displays.
- In designing displays for maximum speed and minimum attention, use the kinaesthetic channel.
 - For maximum attention, use the auditory channel.
 - For maximum precision and agreement between operators, use the visual channel.

The other major aspect of machines concerns the way they are operated and controlled. Controls are instruments permitting manipulation of the machine, thus closing the operator-machine loop system. The analysis of control characteristics or requirements also provides very useful information to work study personnel. Many operating mistakes attributed to the worker could, in fact, be a system design error due to an inappropriate selection of the most adequate control type at the design stage of the machine.

Ergonomics is also concerned with the way a worker is able to control the running of operations (see figure 20). Basically there are two essential factors involved, time and space: the time it takes for a worker to exert control or react to a system out of control which could be matched with the motor skills of the worker; and the space available to permit freedom of movement when exerting control. The space needed is often underestimated by the system designers. One reason for this could be a static approach in designing the system. Work study practitioners are often faced with problems of this kind, in particular the very common lack of available space interfering with new work methods. Space requirements for a comfortable and safe body position at work should be derived from dynamic anthropometric considerations that take into account variations in the size of workers.⁷

13. Working time

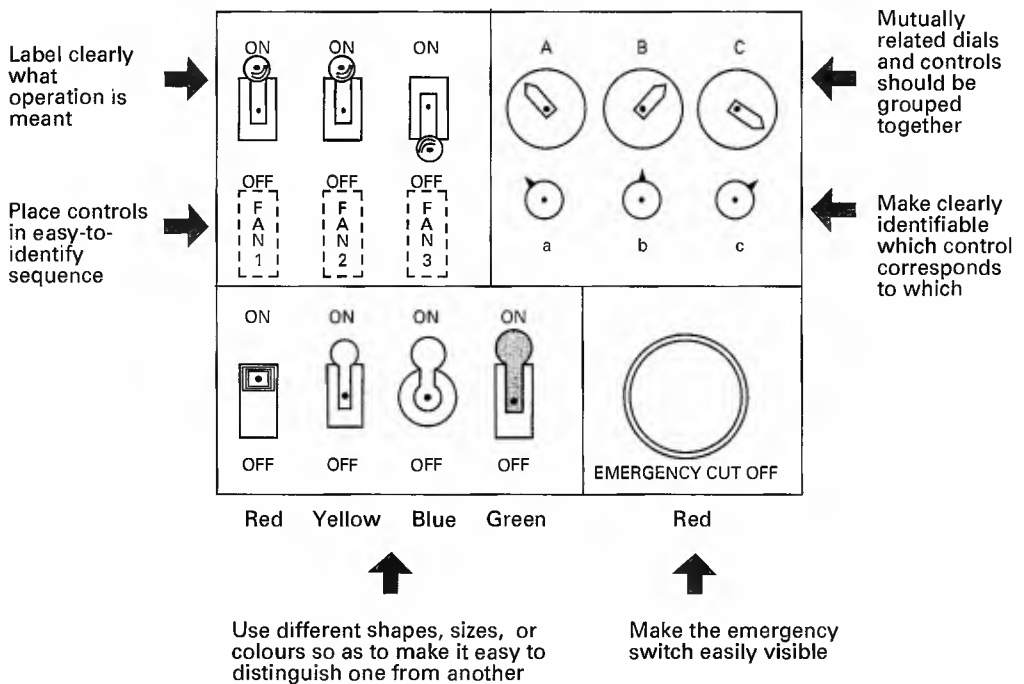
The definition of working time is an important consideration for work study practitioners. Any calculations of output must be done with due consideration to operations time and working time. Working time has in recent times become a subject of considerable importance and interest owing to the variations introduced to working standard hours.

Hours of work

The length of working time is of great importance to both workers and employers. There seems little doubt that where hours of work are very long, a shortening of these hours is accompanied by substantial productivity gains. In fact, the main hindrance to reductions in working time in such cases may be the illusion that workers can maintain a rapid pace of work throughout the shift.

⁷ For further details, see Hans W. Jürgens et al.: *International data on anthropometry*, Occupational Safety and Health Series No. 65 (Geneva, ILO, 1990).

Figure 20. Ergonomic design of controls



Source: Thurman et al., op. cit., figure 61.

Actual case studies with careful controls have almost always shown that average productivity rises rapidly as excessive hours are reduced. Long hours of work also increase the risks of occupational accidents, which are costly and lead to losses in productivity. At the same time, the exhaustion due to long hours prevents workers from participating in non-work activities and ultimately threatens their health, in particular if work involves heavy physical or mental strain or health risks.

In 1962 the International Labour Conference adopted the Reduction of Hours of Work Recommendation (No. 116), which promotes the progressive reduction of normal hours of work and establishes the standard of the 40-hour week. Indeed, normal hours have been steadily falling in industrialized countries and have reached 35 hours in some countries and industries. In many cases collective bargaining has had a greater influence than legislation on normal working hours.

Overtime

The issue of reducing long hours of work is directly related to attempts to curtail overtime, which are in turn based on arguments citing employment promotion as well as social or health grounds. Legislation varies considerably in the extent to which it allows normal hours of work to be exceeded in the form of overtime, which is remunerated at a higher rate than normal hours of

work. Most countries seek to limit overtime to a strictly necessary minimum by establishing daily, weekly, monthly or annual limits. Other restrictions take the form of authorization or reporting, and the universal application of an overtime premium. ILO Recommendation No. 116 recommends that special consideration should be given to young persons under 18 years of age, pregnant women and nursing mothers, and the disabled.

Breaks and rest pauses

It is now widely recognized that rest breaks during the working day prevent the accumulation of excessive fatigue and thus lead to higher productivity. Although recent technological progress has, generally speaking, reduced the arduousness of various types of physical work, it has often increased the psycho-physical workload by accelerating the work tempo and eliminating work preparation time. These changes have made it necessary to introduce breaks during the working day in order to dissipate fatigue and restore the worker's physical and nervous energy. Short, frequent breaks are the most effective because fatigue dissipates slowly once it has built up to high levels. During these breaks a person doing hard physical work should be able to stop work, sit down and if possible lie down; a person doing intellectual work should be able to move around and even do some light gymnastics. Interruptions for meals or those resulting from accidents should not be counted as breaks. The subject of relaxation allowances will be dealt with in Part Four devoted to work measurement.

Daily and weekly rest

For the same productivity and health considerations mentioned above, most countries have established minimum daily and weekly rest periods. They are two of the most important forms of workers' protection. About two-thirds of industrialized countries have explicit provisions on minimum periods of daily rest, typically 11 or 12 hours. Provisions for daily rest are often linked to restrictions on work at night. An uninterrupted rest period of at least 24 hours — frequently 36 hours and sometimes 48 hours — in each period of seven days is a requirement which is laid down in the legislation of all but a very few countries.

Night work

Numerous studies have shown that night work can be harmful to the health of workers, especially those who adjust poorly. Two major risks to the health of workers on night shifts have been identified: harmful effects on sleep and gastro-intestinal and other disorders related to changes in eating habits. Furthermore, continuous or frequent night work puts workers at a disadvantage with regard to participation in family life and social activities. Thus two instruments for the protection of night workers were established by the ILO in 1990: the Night Work Convention (No. 171) and Recommendation (No. 178). They call for specific measures to be taken for night workers relating to hours of work, rest periods, financial compensation, safety and health and social

services to protect their health, help them to meet their family and social responsibilities, provide opportunities for occupational advancement and compensate them appropriately. Special provisions are also made for women workers during at least 16 weeks before and after childbirth.

Flexible working-time arrangements

In recent years there has been a marked increase in interest in both traditional and new measures designed to schedule working time in ways that are economically efficient and which take into account the different needs and preferences of individual workers. Many factors have contributed to this, including changing attitudes towards work and leisure on the part of the working population in general, the influx of women into the labour market, technological progress, persistent unemployment, reductions in working time and international competition.

Employers are particularly interested in the extension of operating hours beyond the normal working day, often referred to as “delinking” or “uncoupling” of working hours from enterprise operating time. Longer operating time of equipment means that fixed capital costs can be distributed over a greater number of hours or units of output, thus lowering the portion accounted for by fixed capital in the price of the finished product. A more flexible use of working time also allows a closer adaptation of working time to daily, weekly or monthly fluctuations in demand.

Attitudes of workers towards flexible working hours are often favourable, if in return the total annual hours are reduced. Trade unions tend to draw a sharp distinction between flexibility of working time, which may have advantages for workers, and deregulation, which they strongly oppose.

Working-time arrangements in practice

Working-time arrangements are evolving very rapidly in practice. Many of those practices can be combined in innovative ways.

Staggered hours. A simple way of dealing with some of the problems of fixed schedules is to stagger the times of arrival and departure of workers. This method helps to overcome the congestion due to simultaneous arrivals and departures of workers, and it extends operating time. The staggering of hours is easiest to organize in cases where different parts of the enterprise can operate independently, at least for short periods.

Flexitime. Under flexitime systems, starting and finishing times and the time of the lunch break may be decided freely by the employees, provided that all employees are present during core time, which most often is reduced to two hours or so in the morning and in the afternoon. Employees find that flexitime helps to reduce stress resulting from conflicting demands of work, family and personal life. It eliminates daily anxiety about punctuality, reduces travel time and costs and allows more daytime participation in non-work activities. For employers, there are also advantages to flexitime. It may result in improved productivity because of greater motivation and better morale of employees; absenteeism declines as employees no longer have to deal with personal

matters during working hours; overtime costs are reduced; and, in addition, it facilitates recruitment, as flexitime is attractive to potential candidates. However, a number of management problems may arise with regard to internal communication and coordination. It may be difficult to provide proper supervision at all times of the day. Furthermore, problems of staffing may occur at certain times of the day or week. An investment in time-monitoring equipment may have to be made.

Compressed work-weeks. Under the compressed work-week system, working days are longer, but weeks are shorter. A 38-hour week, for example, could be worked as four nine-and-a-half-hour days. By rotating the days of work, it is possible to extend operating time to five or six days a week, without any employee working for more than four days a week, or part-time workers can be hired to cover the one or two extra days of the week. With longer working days, employers save on overhead costs and starting-up time. However, the long working day may cause a decline in performance in terms of quality and quantity at the end of the day, especially if work is monotonous and intense, and the risk of accidents is increased. Scheduling overtime is also difficult under such circumstances.

Shift work. Shift work is the most widespread means of extending operating hours. The main types of shift systems are discontinuous (morning and afternoon shifts only, on five or six days per week), semi-continuous (continuous during the week with a break at weekends) and continuous. In order to reduce night work as much as possible, some semi-continuous schedules eliminate the night shift on Friday evening. A few schedules provide for longer morning and afternoon shifts and shorter night shifts, or increase the number of shifts per 24-hour cycle.

Many scheduling possibilities exist for continuous shift systems. The classic example is the four-crew, three-shift system, in which three crews work eight hours each while the fourth crew is at rest, with rotation at regular intervals over a four-week period. This schedule averages out to a 42-hour work-week. In many countries normal weekly hours of work are now well below 42, and in some countries continuous shiftworkers are entitled to special reductions in hours; hence other shift systems are now often used. For example, in several countries five-crew systems are now common. These divide the 168 hours of the week among five crews, each working eight-hour shifts according to various rotation schedules. Three crews are at work while two are at rest, and consequently the average hours of work over a five-week period are lowered to 33.6.

The rotation of shifts is particularly important in continuous operations. On the basis of relatively recent studies of the circadian rhythm of the human body (occurring about once daily) and the social impact of different shift schedules, it is generally recommended that shifts should be rotated rapidly, every two or three days, and that the longest period of rest should follow the night shift.

For workers, continuous shift work is particularly arduous and disruptive for family and social life. For this reason restrictions on shift and night work

have been established in many countries. In addition, some compensation is provided. In several countries shiftworkers are entitled to premium pay, shorter hours, extra days of leave or earlier retirement. Trade unions often press for further improvements of the working conditions of shiftworkers, for example the provision of proper meals and rest facilities during the night, and demand that staffing be reduced to a minimum at night and weekends.

Hours-averaging, annual hours and related schemes. An innovative way of dealing with seasonal fluctuations is to establish working-time schedules which respect agreed normal hours of work on average but call on workers to put in more or fewer hours at particular times. A fully integrated annual hours system can include short, long and normal work-weeks plus arrangements for annual leave and holidays. Their scheduling can ensure that leave and short work-weeks occur in periods of slack demand and can provide scope for meeting individual working-time preferences. The economic advantages for employers are substantial: more efficient use of working time, savings on overtime, better service to clients, shorter delivery time, reduction of stocks, and so on. Such a system has the further advantage that permanent employees are used. They are usually better qualified for the job and are more efficient and motivated than temporary workers. On the other hand, greater efforts in time management and advance scheduling have to be made.

14. Work-related welfare facilities

Work-related welfare facilities offered at or through the workplace can be an important factor in attracting, retaining and motivating workers, and in preventing or reducing fatigue. Some facilities are very basic, but often ignored, such as drinking-water and toilets. Others may seem less necessary, but usually have an importance to workers far greater than their cost to the enterprise.⁸

Drinking-water. Safe, cool drinking-water is essential for all types of work, especially in a hot environment. Without it fatigue increases rapidly and productivity falls. Adequate drinking-water should be provided and maintained at convenient points, and clearly marked as "Safe drinking-water". Where possible it should be provided on tap; otherwise it should be kept in suitable vessels, renewed at least daily, and all practical steps taken to preserve the water and the vessels from contamination.

Sanitary facilities. Hygienic sanitary facilities should exist in all workplaces. They are particularly important where chemicals or other dangerous substances are used. Sufficient toilet facilities, with separate facilities for men and women workers, should be installed and conveniently located. Changing-rooms and cloakrooms should be provided. Washing facilities, such as washbasins with soap and towels, or showers, should be placed either within changing-rooms or close by.

⁸ Many practical ideas are given in J. E. Thurman et al.: *Higher productivity and a better place to work, Action manual* (Geneva, ILO, 1988).

First-aid and medical facilities. Facilities for rendering first-aid and medical care at the workplace in case of accidents or unforeseen sickness are directly related to the health and safety of the workers. First-aid boxes should be clearly marked and conveniently located. They should contain only first-aid requisites of a prescribed standard and should be in the charge of a qualified person. Apart from first-aid boxes, it is also desirable to have a stretcher and suitable means to transport injured persons to a centre where medical care can be provided.

Rest facilities. Rest facilities can include seats, rest-rooms, waiting-rooms and shelters. They help workers to recover from fatigue and to get away from a noisy, polluted or isolated workstation. A sufficient number of suitable chairs or benches with backrests should be provided and maintained, including seats for occasional rest of workers who are obliged to work standing up. Rest-rooms enable workers to recover during meal and rest breaks.

Feeding facilities. It is now well recognized that the health and work capacity of workers depend on an adequate, well-balanced diet. Therefore, some kind of facilities for workers to have light refreshments are needed. A full meal at the workplace is necessary when the workers live some distance away and when the hours of work are so organized that the meal breaks are short. A snack bar, buffet or mobile trolleys can provide tea, coffee and soft drinks, as well as light refreshments. Canteens or a restaurant can allow workers to purchase a cheap, well-cooked and nutritious meal for a reasonable price and eat in a clean, comfortable place, away from the workstation.

Child-care facilities. Many employers find that working mothers are especially loyal and effective workers, but they often face the special problems of caring for their children. It is for this reason that child-care facilities, including crèches and day-care centres, should be provided. These should be in secure, airy, clean and well-lit premises. Children should be looked after properly by qualified staff and offered food, drink, education and play at very low cost.

Recreational facilities. Recreational facilities offer workers the opportunity to spend their leisure time in activities likely to increase physical and mental well-being. They may also help to improve social relations within the enterprise. Such facilities can include halls for recreation and for indoor and outdoor sports, reading-rooms and libraries, clubs for hobbies, picnics and cinemas. Special educational and vocational training courses can also be organized.



PART TWO

Method study



Method study and the selection of jobs

1. The approach to method study

Method study was defined in Chapter 3. It may be useful, however, to recapitulate this definition.

Method study is the systematic recording and critical examination of ways of doing things in order to make improvements

As also mentioned in Chapter 3, the basic approach to method study consists of the following eight steps:

- 1 — *SELECT* the work to be studied and define its boundaries.
- 2 — *RECORD* the relevant facts about the job by direct observation and collect such additional data as may be needed from appropriate sources.
- 3 — *EXAMINE* the way the job is being performed and challenge its purpose, place, sequence and method of performance.
- 4 — *DEVELOP* the most practical, economic and effective method, drawing on the contributions of those concerned.
- 5 — *EVALUATE* different alternatives to developing a new improved method comparing the cost-effectiveness of the selected new method with the current method of performance.
- 6 — *DEFINE* the new method, as a result, in a clear manner and present it to those concerned, i.e. management, supervisors and workers.
- 7 — *INSTALL* the new method as a standard practice and train the persons involved in applying it.
- 8 — *MAINTAIN* the new method and introduce control procedures to prevent a drifting back to the previous method of work.

These eight steps (figure 6) constitute the logical procedure that a work study specialist could normally apply. In practice, however, the procedure is not as straightforward as it is presented here. For example, when measuring the results achieved by the new method one may find that the resulting cost-effectiveness may be negligible and does not warrant the added investment in time and effort to develop the perceived method. In this case the work study person may have to go back to the drawing-board to examine the job once more and try to develop another improved method.

In other circumstances experience with a new improved method may bring to the surface new problems, in which case the process of examination, development and subsequent steps has to be repeated again.

In the following chapters we will deal with each of the steps involved in studying the methods of work. The remaining part of this chapter will be devoted to the first step, namely selection of the work to be studied.

2. Selecting the work to be studied

One can argue that almost any operation in a work setting can be a candidate for an investigation with a view to improving the way it is carried out. Such an argument would present the work study specialist with an endless workload, some of which may not be very productive. However, by focusing attention on certain key operations, a work study specialist can achieve far-reaching results in a relatively short span of time. There are three factors that should be kept in mind when selecting a job.

1. Economic or cost-effective considerations.
2. Technical considerations.
3. Human considerations.

(1) **Economic considerations:** It is obviously a waste of time to start or to continue a long investigation if the economic importance of a job is small, or if it is one that is not expected to run for long. Questions that should always be asked are: "Will it pay to begin a method study of this job?" or "Will it pay to continue this study?"

Obvious choices for study are:

- A. Key profit-generating or costly operations, or ones with the largest scrap/waste rates.
- B. Bottlenecks which are holding up other production operations, or lengthy operations that consume a great deal of time.
- C. Operations involving repetitive work using a great deal of labour and ones that are likely to run for a long time.
- D. Movements of material over long distances between workstations, those involving the use of a relatively large proportion of labour or which require repeated handling of material.

One of the easiest techniques that can be used to identify key operations as listed in A above is the Pareto analysis (sometimes also referred to as "the ABC analysis of value analysis"). This analysis is named after an Italian

Table 6. Pareto analysis, step 1: Profit contribution of products

Product No.	Annual production	Profit per unit (\$)	Total profit generated by the product (\$)
1	7 000	0.6	4 200
2	1 200	4	4 800
3	1 600	3	4 800
4	800	40	32 000
5	3 200	0.05	1 600
6	7 200	0.5	3 600
7	4 000	0.25	1 000
8	2 400	1	2 400
9	1 400	20	28 000
10	4 000	0.9	3 600
11	1 800	6	10 800
12	2 000	3	6 000
13	6 000	0.6	3 600
14	1 600	8	12 800
15	1 600	3	4 800
16	5 000	0.8	4 000
17	1 200	50	60 000
18	8 000	0.5	4 000
19	1 200	5	6 000
20	5 000	0.4	2 000
			200 000

economist who noted that often a small number of items among a range of products account for the highest value. The same observation can be extended by saying that among all the operations in a given plant a small number account for the largest share of cost or of profit, or for that matter the largest percentage of waste.

To illustrate the point we will consider the following example.

Let us assume that a certain enterprise produces 20 different products. Each of these products generates a certain profit. By listing the annual production and profit contribution one obtains the results shown in table 6.

The next step consists of rearranging these items in descending order of importance according to profit. The result would then appear like the one shown in table 7.

From table 7 it can be seen that three products only, listed as "A items", account for 60 per cent of the profit. These are the most profitable and any improvement in methods of producing these particular products would reflect highly on profits. They would be a priority for study. Products listed under "B", which are seven in number, contribute 25 per cent of the profit. They could then assume a second importance, while products "C" would command the last priority since their contribution to profit is minimal. The same type of analysis can be conducted to determine "the most costly products or processes" or "the products or processes that yield the highest waste". Those would then become a priority for study by the work study specialist.

Table 7. Pareto analysis, step 2: Products arranged in descending order of their profit contribution

Product No.	Total profit (\$)	Pareto or ABC analysis
17	60 000	"A" items
4	32 000	Three items contribute
9	28 000	60% of the profit
		\$120 000
14	12 800	"B" items
11	10 800	Seven items contribute
12	6 000	25% of the profit
19	6 000	
2	4 800	
3	4 800	
15	4 800	
		50 000
1	4 200	"C" items
16	4 000	Ten items contribute
18	4 000	15% of the profit
6	3 600	
10	3 600	
13	3 600	
8	2 400	
20	2 000	
5	1 600	
7	1 000	
		\$30 000
	200 000	200 000

(2) **Technical or technological considerations:** One of the important considerations is the desire by management to acquire more advanced technology, whether in equipment or in processes. Thus management may want to computerize its office paperwork or its inventory system, or to introduce automation in the production operations. Before such steps are taken, a method study can point out the most important needs of the enterprise in this respect. For example, if paperwork leaves much to be desired and a good deal of unnecessary or unwarranted information or processes exist, computerizing the same method of work will do nothing much to improve the efficiency of the office. A common term used by information systems specialists in this case is "useless material in yields useless material out". The only thing that changes in this case as a result of computerization is that the same unneeded information will be produced at a higher rate. If, on the other hand, computerization is preceded by a method study, the process is then simplified a priori. The type of information needed is determined more clearly and even decisions on the choice of hardware and software are made more rationally. Method study then acts as a scouting operation prior to the introduction of more advanced

technology. The introduction of new technology should therefore constitute an important factor in the choice of methods of work to be investigated.

(3) **Human considerations:** Certain operations are often a cause of dissatisfaction by workers. They may induce fatigue or monotony or may be unsafe or clumsy to operate. The level of satisfaction should point to a need for method study. Thus an operation which may be perceived as effective by management may, on the other hand, generate a great deal of resentment by the workforce. If such operations are addressed by work study specialists as part of an overall work study programme, the benefits of work study can become more apparent to the workforce.

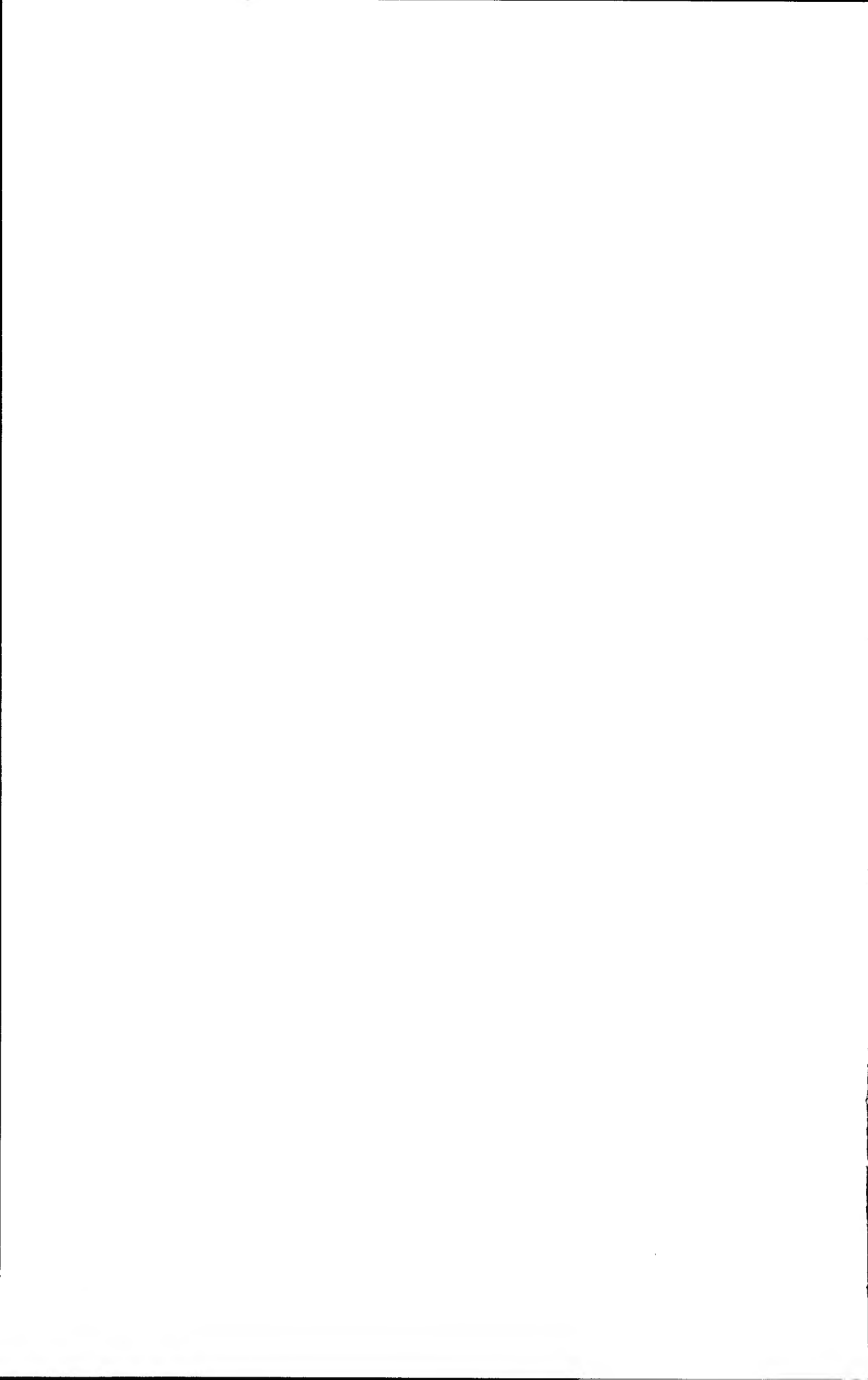
In a similar vein, a choice of a particular job for study may lead to unrest or ill-feeling. The advice given here is **to leave it alone**, however promising it may be from the economic point of view. If other jobs are tackled successfully and the study can be seen to benefit the people working on them, opinions will change and it will be possible, in time, to revert back to the original choice.

3. Limiting the scope of the work to be studied

One of the first decisions a work study specialist has to make is to define exactly the type of work to be studied, set up boundaries around it and decide what exactly it will encompass. To take an example, in the preceding section we used the Pareto analysis to select products or processes that are most profitable or most costly, or yield the most waste. The next logical question is to decide on the scope of our investigation with respect to each product or process. Do we wish to examine the whole sequence of operation that goes into producing that product, or only certain parts of it and in this case which part? Would it be more opportune, for example, to concentrate only on the movement of material or operators, or for that matter the handling of material?

To assist in making such decisions, it is important to understand thoroughly the problem at hand or the present situation before looking for solutions or improvements. Having a feel for the situation either from experience or by talking to the various people involved will provide the work study specialist with the clue to the limits of his or her investigation, at least in the initial stage. Once this is decided it should be adhered to. Further work may tempt the specialist to go into greater detail. This should be resisted, although these indications should be noted and tackled separately. In other words, the work study practitioner should not go first for a small one-operative job which may entail detailed study of the worker's movements and yield a saving of a few seconds per operation, unless the job is one that is repetitive. It is of little value to play around with split seconds and centimetres of movements when a great waste of time and effort is taking place as a result of poor layout or inappropriate handling of heavy materials.

As will become evident in the next chapters, defining the nature of the job to be selected for study and identifying its scope will predetermine the type of work study technique that will be used to study it. Thus certain types of chart may be used to record the sequence of work which could be different from those used to record the movement of a worker, say in an assembly operation.



Record, examine, develop

1. Record the facts

The next step in the basic procedure, after selecting the work to be studied, is to **record all the facts** relating to the existing method. The success of the whole procedure depends on the accuracy with which the facts are recorded, because they will provide the basis of both the critical examination and the development of the improved method. It is therefore essential that the record be clear and concise.

Recording serves essentially as a basis for subsequent analysis and examination. It is not an end in itself. Recording may be carried out in two phases: first, a rough sketch or charting of the job being studied to establish whether the recorded information is of use; and, second, a more formal and accurate chart or diagram to include in a report or presentation.

The usual way of recording facts is to write them down. Unfortunately, this method is not suited to recording the complicated processes which are so common in modern industry. This is particularly so when an exact record is required of every minute detail of a process or operation. To describe exactly everything that is done in even a very simple job which takes perhaps only a few minutes to perform would probably result in several pages of closely written script, which would require careful study before anyone reading it could be quite sure that he or she had grasped all the detail.

To overcome this difficulty other techniques or “tools” of recording have been developed, so that detailed information may be recorded precisely and at the same time in standard form, in order that it may be readily understood by all method study persons, in whatever factory or country they may be working.

The most commonly used of these recording techniques are **charts** and **diagrams**. There are several types of standard chart available, each with its own special purposes. They will be described in turn later in this chapter and in subsequent chapters. For the present it will be sufficient to note that the charts available fall into two groups:

- those which are used to record a **process sequence**, i.e. a series of events or happenings in the order in which they occur, but which do not depict the events to scale; and
- those which record **events**, also in sequence, but **on a time scale**, so that the interaction of related events may be more easily studied.

The names of the various charts are shown in table 8, which lists them in the two groups given above and also lists the types of diagram commonly used.

Table 8. The most commonly used method study charts and diagrams

A. CHARTS	Indicating process SEQUENCE Outline process chart Flow process chart — Worker type Flow process chart — Material type Flow process chart — Equipment type Two-handed process chart Procedure flowcharts
B. CHARTS	Using a TIME SCALE Multiple activity chart Simo chart
C. DIAGRAMS	Indicating MOVEMENT Flow diagram String diagram Cyclegraph Chronocyclegraph Travel chart

Diagrams are used to indicate movement and/or interrelationships of movements more clearly than charts can do. They usually do not show all the information recorded on charts, which they supplement rather than replace.

Process chart symbols

The recording of the facts about a job or operation on a process chart is made much easier by the use of a set of five standard symbols,¹ which together serve to represent all the different types of activity or event likely to be encountered in any factory or office. They thus serve as a very convenient, widely understood type of shorthand, saving a lot of writing and helping to show clearly just what is happening in the sequence being recorded.

The two principal activities in a process are **operation** and **inspection**. These are represented by the following symbols:



OPERATION

Indicates the main steps in a process, method or procedure. Usually the part, material or product concerned is modified or changed during the operation

It will be seen that the symbol for an operation is also used when charting a procedure, as for instance a clerical routine. An operation is said to take place when information is given or received, or when planning or calculating takes place.

¹ The symbols used throughout this book are those recommended by the American Society of Mechanical Engineers and adopted in BSI: *Glossary of terms used in management services*, BSI 3138 (London, 1991).

*INSPECTION*

Indicates an inspection for quality and/or check for quantity

The distinction between these two activities is quite clear:

An **operation** always takes the material, component or service a stage further towards completion, whether by changing its shape (as in the case of a machined part) or its chemical composition (during a chemical process) or by adding or subtracting material (as in the case of an assembly). An operation may equally well be a preparation for any activity which brings the completion of the product nearer.

An **inspection** does not take the material any nearer to becoming a completed product. It merely verifies that an operation has been carried out correctly as to quality and/or quantity. Were it not for human shortcomings, most inspections could be done away with.

Often a more detailed picture will be required than can be obtained by the use of these two symbols alone. In order to achieve this, three more symbols are used:

*TRANSPORT*

Indicates the movement of workers, materials or equipment from place to place

A **transport** thus occurs when an object is moved from one place to another, except when such movements are part of an operation or are caused by the operative at the workstation during an operation or an inspection. This symbol is used throughout this book whenever material is handled on or off trucks, benches, storage bins, and so on.

*TEMPORARY STORAGE OR DELAY*

Indicates a delay in the sequence of events: for example, work waiting between consecutive operations, or any object laid aside temporarily without record until required

Examples of **temporary storage or delay** are work stacked on the floor of a shop between operations, cases awaiting unpacking, parts waiting to be put into storage bins or a letter waiting to be signed.



PERMANENT STORAGE

Indicates a controlled storage in which material is received into or issued from a store under some form of authorization, or an item is retained for reference purposes

A **permanent storage** thus occurs when an object is kept and protected against unauthorized removal. The difference between a “permanent storage” and a “temporary storage or delay” is that a requisition, or other form of formal authorization, is generally required to get an article out of permanent storage but not out of temporary storage.

In this book, for the sake of simplicity, temporary storage or delay will be referred to as “delay”, and permanent storage as just “storage”.



Combined activities. When it is desired to show activities performed at the same time or by the same operative at the same workstation, the symbols for those activities are combined, e.g. the circle within the square represents a combined operation and inspection.

Figure 21 gives an example of the use of these symbols.

The outline process chart

It is often valuable to obtain a “bird’s-eye” view of a whole process or activity before embarking on a detailed study. This can be obtained by using an **outline process chart**.


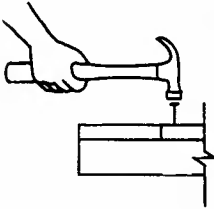
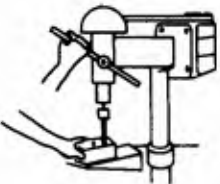











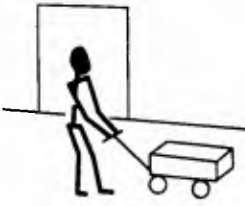



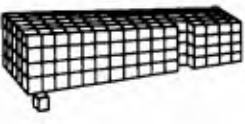

An outline process chart is a process chart giving an overall picture by recording in sequence only the main operations and inspections

In an outline process chart, only the principal operations carried out and the inspections made to ensure their effectiveness are recorded, irrespective of who does them and where they are performed. In preparing such a chart, only the symbols for “operation” and “inspection” are necessary.

In addition to the information given by the symbols and their sequence, a brief note of the nature of each operation or inspection is made beside the symbol, and the time allowed for it (where known) is also added.

An example of an outline process chart is given in figure 23. In order that the reader may obtain a firm grasp of the principles involved, the assembly represented on the chart is shown in a sketch (figure 22) and the operations charted are given in some detail below.

Figure 21. Method study symbols

ACTIVITY	EXAMPLE		
<p>OPERATION</p>  <p>A large circle indicates an operation, such as</p>	 <p>Drive nail</p>	 <p>Drill hole</p>	 <p>Type letter</p>
<p>TRANSPORT</p>  <p>An arrow indicates transport, such as</p>	 <p>Move material by truck</p>	 <p>Move material by hoist or elevator</p>	 <p>Move material by carrying (messenger)</p>
<p>INSPECTION</p>  <p>A square indicates an inspection, such as</p>	 <p>Examine material for quality or quantity</p>	 <p>Read steam gauge on boiler</p>	 <p>Examine printed form for information</p>
<p>DELAY</p>  <p>The letter D indicates a delay, such as</p>	 <p>Material in truck or on floor at bench waiting to be processed</p>	 <p>Employee waiting for elevator</p>	 <p>Papers waiting to be filed</p>
<p>STORAGE</p>  <p>A triangle indicates a storage, such as</p>	 <p>Bulk storage of raw material</p>	 <p>Finished product in warehouse</p>	 <p>Documents and records in storage vault</p>

Source: Ralph M. Barnes: *Motion and time study* (New York, © John Wiley, 7th ed., 1980) p. 62, figure 29. Reproduced by permission of John Wiley & Sons, Inc.

Example of an outline process chart: Assembling a switch rotor²

The assembly drawing (figure 22) shows the rotor for a slow make-and-break switch.

It consists of a spindle (1); a plastic moulding (2); and a stop pin (3).

In making an outline process chart it is usually convenient to start with a vertical line down the right-hand side of the page to show the operations and inspections undergone by the principal unit or component of the assembly (or compound in chemical processes) — in this case the spindle. The time allowed per piece in hours is shown to the left of each operation. No specific time is allowed for inspections as the inspectors are on time work.

The brief descriptions of the operations and inspections which would normally be shown alongside the symbols have been omitted so as not to clutter the figure.

The operations and inspections carried out on the spindle, which is made from 10 mm diameter steel rod, are as follows:

Operation 1 Face, turn, undercut and part off on a capstan lathe (0.025 hours).

Operation 2 Face opposite end on the same machine (0.010 hours).

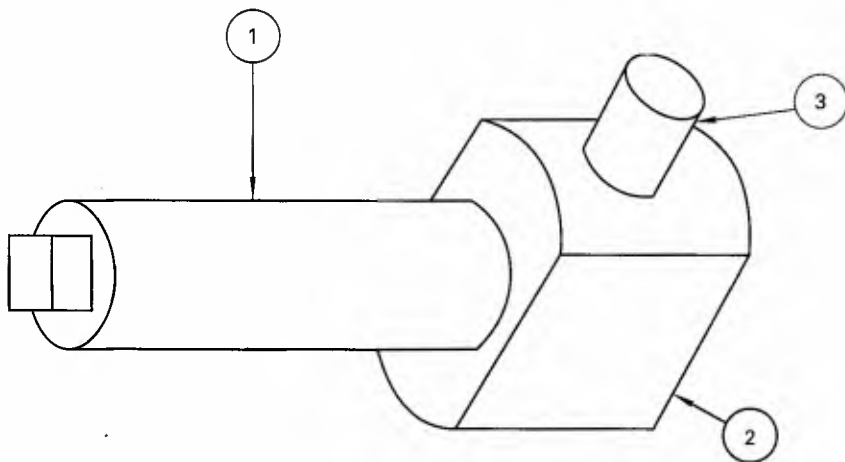
After this operation the work is sent to the inspection department for:

Inspection 1 Inspect for dimensions and finish (no time fixed). From the inspection department the work is sent to the milling section.

Operation 3 Straddle-mill four flats on end on a horizontal miller (0.070 hours).

Operation 4 Remove burrs at the burring bench (0.020 hours).

Figure 22. Switch rotor assembly



The work is returned to the inspection department for:

Inspection 2 Final inspection of machining (no time).

From the inspection department the work goes to the plating shop for:

Operation 5 Degreasing (0.0015 hours).

Operation 6 Cadmium plating (0.008 hours).

From the plating shop the work goes again to the inspection department for:

Inspection 3 Final check (no time).

The plastic moulding is supplied with a hole bored concentric with the longitudinal axis.

Operation 7 Face on both sides, bore the cored hole and ream to size on a capstan lathe (0.080 hours).

Operation 8 Drill cross-hole (for the stop pin) and burr on two-spindle drill press (0.022 hours).

From the drilling operation the work goes to the inspection department for:

Inspection 4 Final check dimensions and finish (no time).

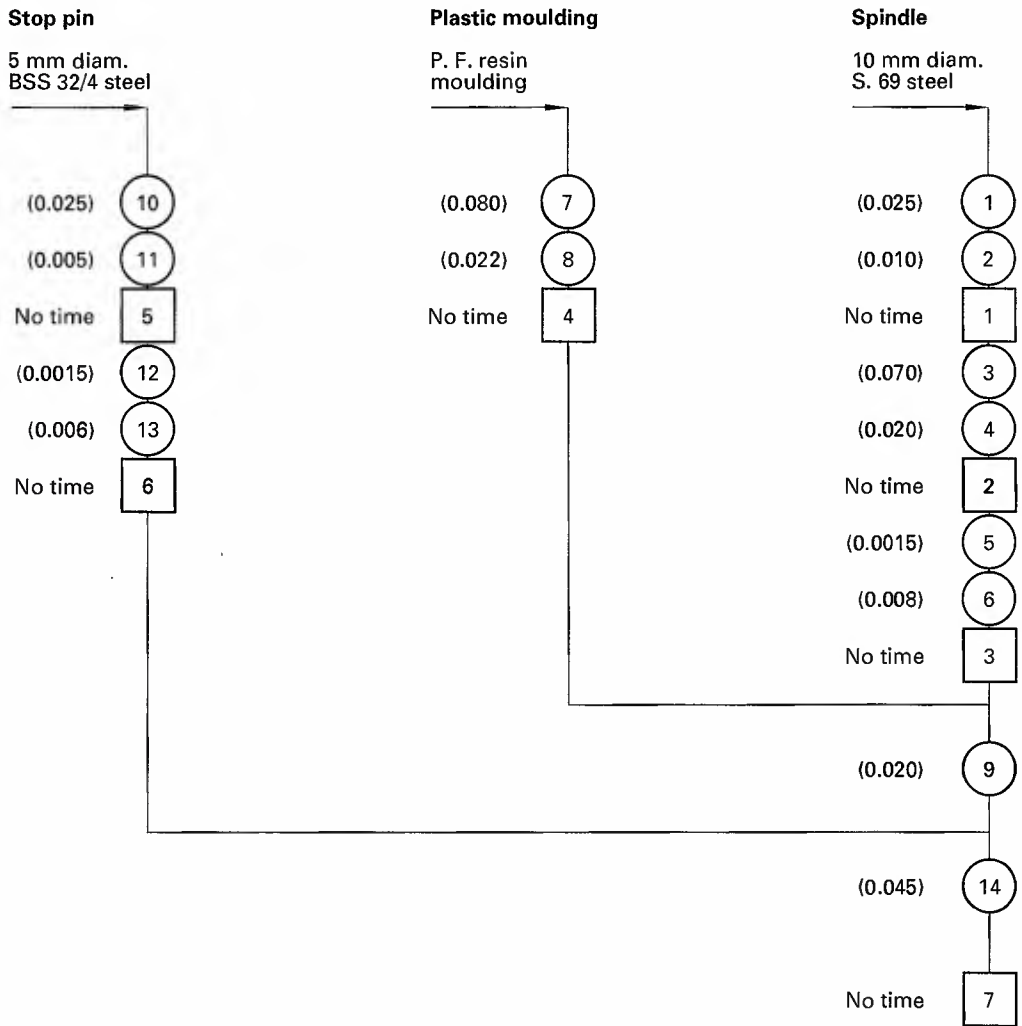
It is then passed to the finished-part stores to await withdrawal for assembly.

It will be seen from the chart that the operations and inspections on the moulding are on a vertical line next to that of the spindle. This is because the moulding is the first component to be assembled to the spindle. The stop-pin line is set farther to the left, and if there were other components they would be set out from right to left in the order in which they were to be assembled to the main item.

Note especially the method of numbering the operations and inspections. It will be seen that both operations and inspections start from 1. The numbering is continuous from one component to another, starting from the right, to the point where the second component joins the first. The sequence of numbers is then transferred to the next component on the left and continues through its assembly to the first component until the next assembly point, when it is transferred to the component about to be assembled. Figure 23 makes this clear. The assembly of any component to the main component or assembly is shown by a horizontal line from the vertical operation line of the minor component to the proper place in the sequence of operations on the main line. (Sub-assemblies can, of course, be made up of any number of components before being assembled to the principal one; in that case the horizontal joins the appropriate vertical line which appears to the right of it.) The assembly of the moulding to the spindle, followed by the operation symbol and number, is clearly shown in the figure.

Operation 9 Assemble the moulding to the small end of the spindle and drill the stop-pin hole right through (0.020 hours).

Figure 23. Outline process chart: Switch rotor assembly



Once this has been done the assembly is ready for the insertion of the stop pin (made from 5 mm diameter steel rod) which has been made as follows:

Operation 10 Turn 2 mm diameter shank, chamfer end and part off on a capstan lathe (0.025 hours).

Operation 11 Remove the “pip” on a lisher (0.005 hours).

The work is then taken to the inspection department.

Inspection 5 Inspect for dimensions and finish (no time).

After inspection the work goes to the plating shop for:

Operation 12 Degreasing (0.0015 hours).

Operation 13 Cadmium plating (0.006 hours).

The work now goes back to the inspection department for:

88 *Inspection 6* Final check (no time).

It then passes to the finished-part stores and is withdrawn for:

Operation 14 Stop pin is fitted to assembly and lightly riveted to retain it in position (0.045 hours).

Inspection 7 The completed assembly is finally inspected (no time).

It is then returned to the finished-parts store.

In practice, the outline process chart would bear against each symbol, beside and to the right of it, an abbreviated description of what is done during the operation or inspection. These entries have been left out of figure 23 so that the main sequence of charting may be seen more clearly.

Figure 24 shows some of the conventions used when drawing outline process charts. In this instance the subsidiary component joins the main part after inspection 3, and is assembled to it during operation 7. The assembly undergoes two more operations, numbers 8 and 9, each of which is performed four times in all, as is shown by the "repeat" entry. Note that the next operation after these repeats bears the number 16, not 10.

As was explained earlier in this chapter, the outline process chart is intended to provide a first "bird's-eye" view of the activities involved, for the purpose of eliminating unnecessary ones or combining those that could be done together. It is usually necessary to go into detail greater than the outline process chart provides. In the following pages the flow process chart will be described and its use as a tool of methods improvement illustrated.

Flow process charts

Once the general picture of a process has been established, it is possible to go into greater detail. The first stage is to construct a **flow process chart**.

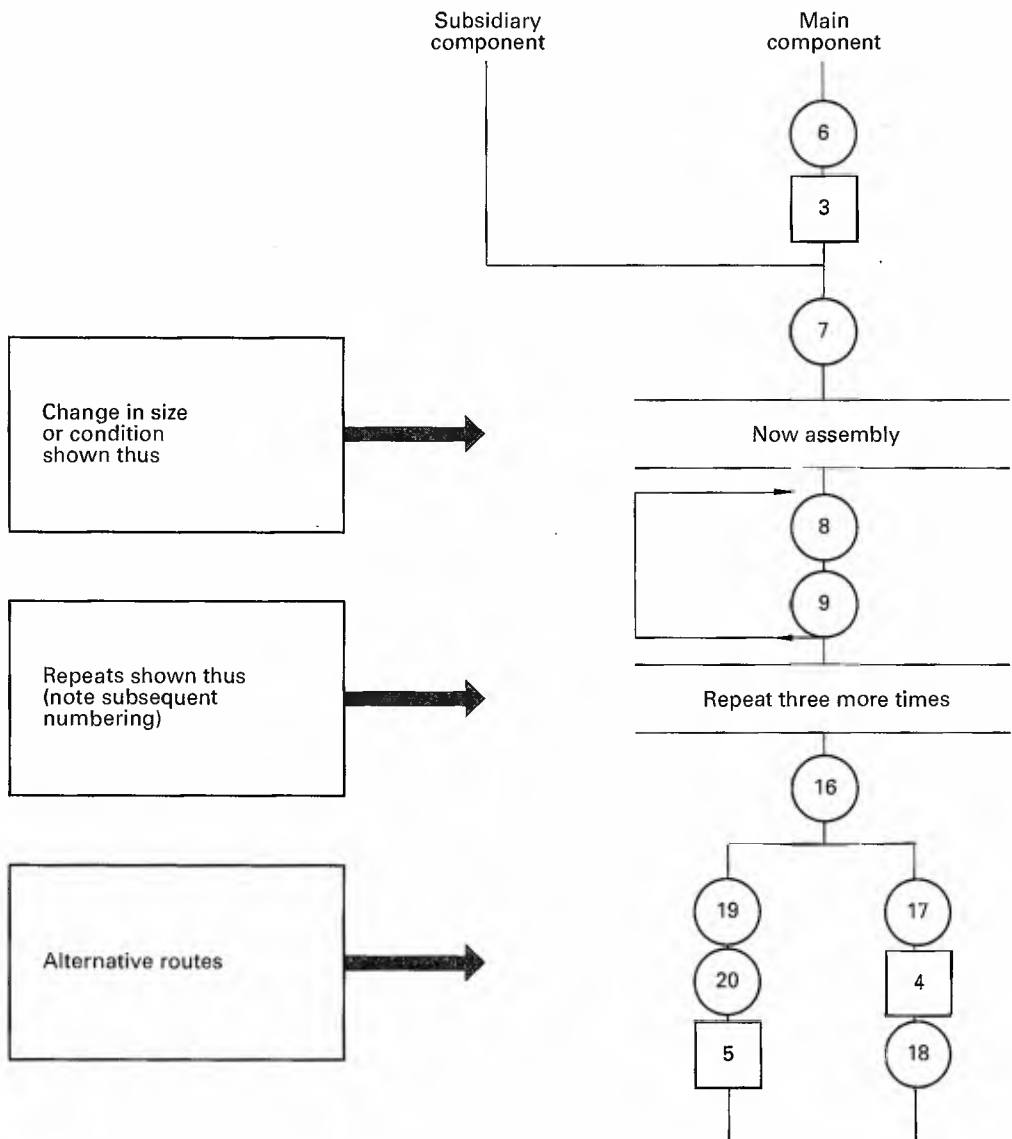
A flow process chart is a process chart setting out the sequence of the flow of a product or a procedure by recording all events under review using the appropriate process chart symbols.

- Flow process chart — Worker type: A flow process chart which records what the operator does.
- Flow process chart — Material type: A flow process chart which records how material is handled or treated.
- Flow process chart — Equipment type: A flow process chart which records how the equipment is used.

A flow process chart is prepared in a manner similar to that in which the outline process chart is made, but using, in addition to the symbols for "operation" and "inspection", those for "transport", "delay" and "storage".

Whichever type of flow process chart is being constructed, the same symbols are always used and the charting procedure is very similar. (It is customary to use the active voice of verbs for entries on worker-type charts, and the passive voice on material-type and equipment-type charts. This

Figure 24. Some charting conventions



convention is more fully explained in Chapter 8, section 3.) In fact, it is usual to have only one printed form of chart for all three types, the heading bearing the words "Worker/material/equipment type", the two words not required being deleted.

Because of its greater detail, the flow process chart does not usually cover as many operations per sheet as may appear on a single outline process chart. It is usual to make a separate chart for each major component of an assembly, so that the amount of handling, delays and storages of each may be independently studied. This means that the flow process chart is usually a single line.

An example of a material-type flow process chart constructed to study what happened when a bus engine was stripped, degreased and cleaned for inspection is given in figure 25. This is an actual case recorded at the workshop of a transport authority in a developing country. After discussing the principles of flow process charting and the means of using them in the next few pages, we shall go on to consider this example in detail. Worker-type charts are discussed in Chapter 8.

When flow process charts are being made regularly, it is convenient to use printed sheets similar to that shown in figure 26. (In charts of this kind the five symbols are usually repeated down the whole length of the appropriate columns. This has not been done in the charts presented in this book, which have been simplified to improve clarity.) This also ensures that the work study person does not omit any essential information. In figure 26 the operation just described on the chart in figure 25 is set down again.

Before we go on to discuss the uses of the flow process chart as a means of examining critically the job concerned with a view to developing an improved method, there are some points which must always be remembered in the preparation of process charts. These are important because process charts are the most useful tool in the field of method improvement; whatever techniques may be used later, the making of a process chart is always the first step.

- (1) Charting is used for recording because it gives a complete picture of what is being done and helps the mind to understand the facts and their relationship to one another.
- (2) Charts are an important means of illustrating clearly to everyone concerned the way the job is being carried out. Although supervisors and workers may not be trained in the use of a particular recording technique, they can understand a chart or diagram sufficiently to confirm that it represents the "time" situation and can often see the inefficiencies inherent in a chart which, for example, includes a large number of delay or transport symbols.
- (3) The details which appear on a chart must be obtained from **direct observation**. Once they have been recorded on the chart, the mind is freed from the task of carrying them, but they remain available for reference and for explaining the situation to others. Charts must not be based on memory but must be prepared **as the work is observed** (except when a chart is prepared to illustrate a proposed new method). Details which have been recorded should be reviewed and confirmed with the

Figure 25. Flow process chart: Engine stripping, cleaning and degreasing

Chart No. 1	Sheet No. 1	of 1	Method: Original
Product: Bus engines			Operative(s):
			Location: Degreasing shop
Process: Stripping, degreasing and cleaning used engines			Charted by:
			Approved by: Date:

Distance (m)	Symbol	Activity	Type of activity
	▽	In old-engine stores	
	1 □	Picked up engine by crane (electric)	Non-productive
24	2 □	Transported to next crane	"
	3 □	Unloaded to floor	"
	4 □	Picked up by second crane (electric)	"
30	5 □	Transported to stripping bay	"
	6 □	Unloaded to floor	"
	①	Engine stripped	Productive
	②	Main components cleaned and laid out	"
	①	Components inspected for wear; inspection report written ..	Non-productive
3	7 □	Parts carried to degreasing basket	"
	8 □	Loaded for degreasing by hand-operated crane	"
1.5	9 □	Transported to degreaser	"
	10 □	Unloaded into degreaser	"
	③	Degreased	Productive
	11 □	Lifted out of degreaser by crane	Non-productive
6	12 □	Transported away from degreaser	"
	13 □	Unloaded to ground	"
	①	To cool	"
12	14 □	Transported to cleaning benches	"
	④	All parts completely cleaned	Productive
9	15 □	All cleaned parts placed in one box	Non-productive
	②	Awaiting transport	"
	16 □	All parts except cylinder block and heads loaded on trolley ..	"
76	17 □	Transported to engine inspection section	"
	18 □	Parts unloaded and arranged on inspection table	"
	19 □	Cylinder block and head loaded on trolley	"
76	20 □	Transported to engine inspection section	"
	21 □	Unloaded on ground	"
237.5	③	Stored temporarily awaiting inspection	"

supervisor. This confirmation has two aims. First, it ensures that the facts are correct. Second, it strengthens the bond between the work study person and the supervisor, who appreciates that his or her opinion is valuable to the investigation.

- (4) A high standard of neatness and accuracy should be maintained in preparing fair copies of charts constructed from direct observation. The charts will be used in explaining proposals for standardizing work or improving methods. An untidy chart will always make a bad impression and may lead to errors.
- (5) To maintain their value for future reference and to provide as complete information as possible, all charts should carry a heading giving the following information (see figure 26):
 - (a) the name of the product, material or equipment charted, with drawing numbers or code numbers;
 - (b) the job or process being carried out, clearly stating the starting-point and the end point, and whether the method is the present or proposed one;
 - (c) the location in which the operation is taking place (department, factory, site, etc.);
 - (d) the chart reference number, sheet number and the total number of sheets;
 - (e) the observer's name and, if desired, that of the person approving the chart;
 - (f) the date of the study;
 - (g) a key to the symbols used. This is necessary for the benefit of anyone who may study the chart later and who may have been accustomed to using different symbols. It is convenient to show these as part of a table summarizing the activities in the present and proposed methods (see figure 26);
 - (h) a summary of distance, time and, if desired, cost of labour and material, for comparison of old and new methods.
- (6) Before leaving the chart, check the following points:
 - (a) Have the facts been correctly recorded?
 - (b) Have any over-simplifying assumptions been made (e.g. is the investigation so incomplete as to be inaccurate)?
 - (c) Have all the factors contributing to the process been recorded?

So far we have been concerned only with the "record" stage. We must now consider the steps necessary to **examine critically** the data recorded.

2. Examine critically: The questioning technique

The questioning technique is the means by which the critical examination is conducted, each activity being subjected in turn to a systematic and progressive series of questions

The five sets of activities recorded on the flow process chart fall naturally into two main categories, namely:

- those in which something is actually happening to the material or workpiece under consideration, i.e. it is being worked upon, moved or examined; and
- those in which it is not being touched, being either in storage or at a standstill owing to a delay.

Activities in the first category may be subdivided into three groups:

- MAKE READY activities** required to prepare the material or workpiece and set it in position ready to be worked on. In the example in figure 25 these are represented by the loading and transporting of the engine to the degreasing shop, transporting it to the cleaning benches, etc.
- DO operations** in which a change is made in the shape, chemical composition or physical condition of the product. In the case of the example these are the dismantling, cleaning and degreasing operations. Some “do” operations may be further classified as “key” operations. For example, deburring a machined part is a “do” operation but not a “key” one since it would not be performed if no machining were carried out.
- PUT AWAY activities** during which the work is moved aside from the machine or workplace. The “put away” activities of one operation may be the “make ready” activities of the next — as, for example, transport between operations from the degreaser to the cleaning benches. Putting parts into storage, putting letters into an “Out” tray and inspecting finished parts are other examples.

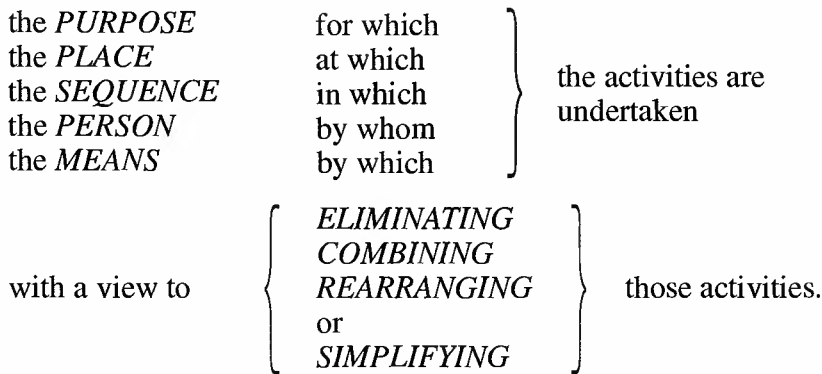
It will be seen that, while “make ready” and “put away” activities may be represented by “transport” and “inspection” symbols, “do” operations can only be represented by “operation” symbols.

The aim is obviously to have as high a proportion of “do” operations as possible, since these are the only ones which carry the product forward in its progress from raw material to completion. (“Do” operations in non-manufacturing industries are those operations which actually carry out the activity for which the organization exists, for example the act of selling in a shop or the act of typing in an office.) These are “productive” activities; all others, however necessary, may be considered as “non-productive”, including storages and delays which represent tied-up capital that could have been used to further the business.

An alternative approach is to first examine the necessity of “key” operations. If these can be removed, associated “do” (but non-“key”) and non-productive operations will automatically be removed.

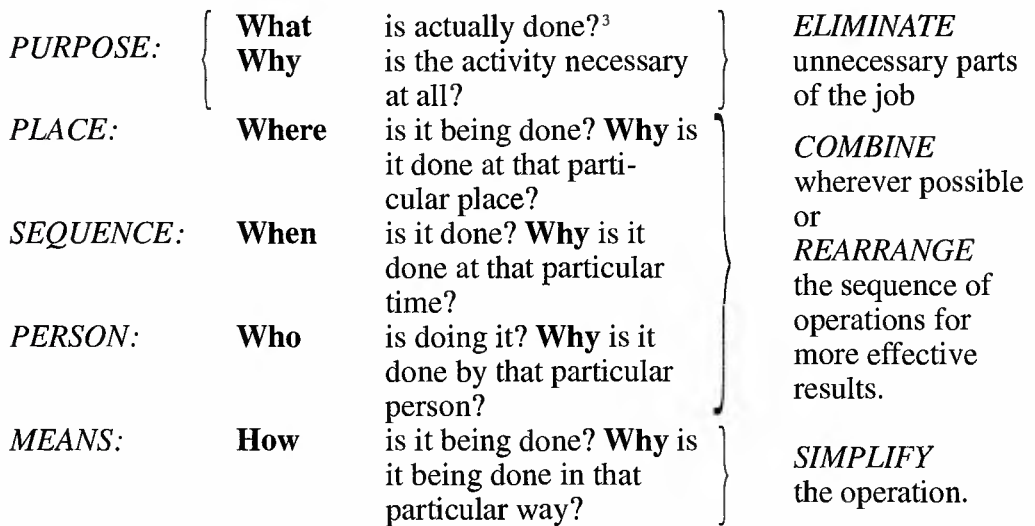
The primary questions

The questioning sequence used follows a well-established pattern which examines:



In the first stage of the questioning technique, the purpose, place, sequence, person and means of every activity recorded are systematically queried, and a reason for each reply is sought.

The primary questions therefore are:



The secondary questions

The secondary questions cover the second stage of the questioning technique, during which the answers to the primary questions are subjected to further query to determine whether possible alternatives of place, sequence, persons and/or means are practicable and preferable as a means of improvement upon the existing method

Thus, during this second stage of questioning (having asked already, about every activity recorded, what is done and why is it done), the method

³ Many investigators use the question: What is actually achieved?

study person goes on to inquire: What **else** might be done? And, hence: What **should** be done? In the same way, the answers already obtained on place, sequence, person and means are subjected to further inquiry.

Combining the two primary questions with the two secondary questions under each of the headings "purpose, place", etc., yields the following list, which sets out the questioning technique in full:

- PURPOSE:* **What** is done?
 Why is it done?
 What **else** might be done?
 What **should** be done?
- PLACE:* **Where** is it done?
 Why is it done **there**?
 Where **else** might it be done?
 Where **should** it be done?
- SEQUENCE:* **When** is it done?
 Why is it done **then**?
 When **might** it be done?
 When **should** it be done?
- PERSON:* **Who** does it?
 Why does **that** person do it?
 Who **else** might do it?
 Who **should** do it?
- MEANS:* **How** is it done?
 Why is it done **that** way?
 How **else** might it be done?
 How **should** it be done?

These questions, in the above sequence, must be asked systematically every time a method study is undertaken. They are the basis of successful method study.

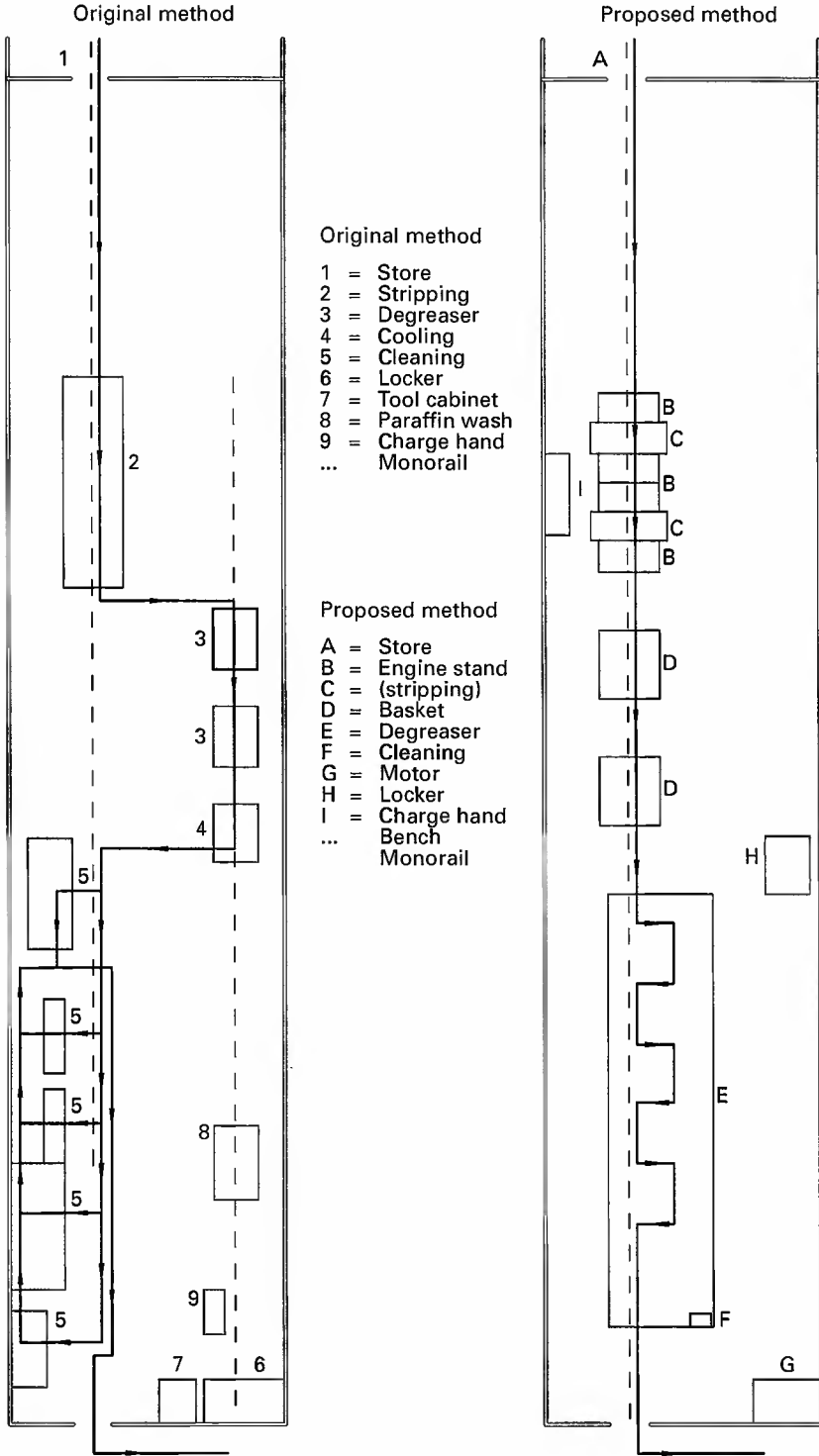
Example: Engine stripping, cleaning and degreasing

Let us now consider how the method study people who prepared the flow process chart in figure 25 set about examining the record of facts which they had obtained in order to develop an improved method. Before doing so, we shall transfer the same record to a standard flow process chart form (figure 26) with the necessary information on the operation, location, and so on, duly filled in.

To help the reader to visualize the operation, a flow diagram showing the layout of the degreasing shop and the path taken by the engine in its journey from the old-engine stores to the engine-inspection section is given in figure 27. It is evident from this that the engine and its parts follow an unnecessarily complicated path.

Examination of the flow process chart shows a very high proportion of "non-productive" activities. There are in fact only four operations and one inspection, while there are 21 transports and three delays. Out of 29 activities, excluding the original storage, only five can be considered as "productive".

Figure 27. Flow diagram: Engine stripping, cleaning and degreasing



Detailed examination of the chart leads to a number of questions. For example, it will be seen that an engine being transported from the old-engine stores has to change cranes in the middle of its journey. Let us apply the questioning technique to these first transports:

- Q. **What** is done?
A. The engine is carried to the stripping bay.
- Q. **How** is this being done?
A. By an electric crane. The engine is then placed on the ground and picked up by another crane to be transported to the stripping bay.
- Q. **Why** is this done?
A. Because the engines are stored in such a way that they cannot be directly picked up by the monorail crane which runs through the stores and degreasing shop.
- Q. What **else** might be done?
A. The engines could be stored so that they are immediately accessible to the monorail crane, which could then pick them up and run directly to the stripping bay.
- Q. What **should** be done?
A. The above suggestion should be adopted.

In the event this suggestion was adopted, and as a result three "transports" were eliminated (see figure 28).

Let us continue the questioning technique.

- Q. **Why** are the engine components cleaned **before** going to be degreased since they are again cleaned after the grease is removed?
A. The original reason for this practice has been forgotten.
- Q. **Why** are they inspected at this stage, when it must be difficult to make a proper inspection of greasy parts and when they will be inspected again in the engine-inspection section?
A. The original reason for this practice has been forgotten.

This answer is very frequently encountered when the questioning technique is applied. On many occasions, activities are carried out for reasons which are important at the time (such as temporary arrangements to get a new shop going quickly in the absence of proper plant and equipment) and are allowed to continue long after the need for them has passed. If no satisfactory reason why they should be continued can be given, such activities must be ruthlessly eliminated.

The next questions which arise refer to the loading into the degreaser. Here it appears to have been necessary to transport the parts 3 metres in order to put them into the degreaser basket. **Why** cannot the degreaser basket be kept near at hand? Cannot the parts be put straight into the degreaser basket as the engine is dismantled?

The above example illustrates how the questioning technique can be applied. The questions and answers may sometimes look rather childish as they are set out above, but in the hands of an experienced investigator the questioning is very rapid. Sticking to the very rigid sequence ensures that no point is overlooked. And, of course, starting with the most searching scrutiny of the operation itself

What is done? and why is it necessary?

ensures that time is not wasted on details if the whole operation should not be necessary, or if its fundamental purpose could be achieved in some better way.

It will be seen from the summary illustrated in figure 28 showing the improved method that there have been considerable reductions in the number of "non-productive" activities. The number of "operations" has been reduced from four to three by the elimination of the unnecessary cleaning, and the inspection carried out directly after it has also been eliminated. "Transports" have been reduced from 21 to 15 and the distances involved have also been cut from 237.5 to 150 metres — a saving of over 37 per cent in the travel of each engine. In order not to complicate this example, times of the various activities have not been given, but a study of the two flow process charts will make it evident that a great saving in the time of operation per engine has been achieved.

In the following example, we show how time recording can be introduced in a flow process chart which in this case is also combined with a flow diagram. As in the previous case, the answers given below are sample answers only to illustrate the use of the questioning technique. In practice it is rare that one arrives directly at the right answer. It is more likely that a number of alternatives will be thought of and developed before an evaluation is made as to the best alternative.

Example of the use of a flow diagram with a flow process chart: Receiving and inspecting aircraft parts⁴

The flow diagram in figure 29 shows the original layout of the receiving department of an aircraft factory. The path of movement of the goods from the point of delivery to the storage bins is shown by the broad line. It will be noticed that the symbols for the various activities have been inserted at the proper places. This enables anyone looking at the diagram to imagine more readily the activities to which the goods are subjected.

RECORD

The sequence of activities is one of unloading from the delivery truck cases containing aircraft parts (which are themselves packed individually in cartons), checking, inspecting and marking them before putting them into store. These cases are slid down an inclined plane from the tail of the truck, slid across the floor to the "unpacking space" and there stacked one on top of

⁴This example has been taken, with some adaptation, from *Simplification du travail* (the French version of a handbook produced by the North American Aviation Company Inc., Texas Division) (Paris, Editions Hommes et Techniques, 2nd ed., 1950).

another to await opening. They are then unstacked and the lid removed. The delivery notes are taken out and the cases are loaded one at a time on a hand truck, by which they are taken to the receiving bench. They are placed on the floor beside the bench. After a short delay they are unpacked; each piece is taken out of its carton and checked against the delivery note. It is then replaced in its carton; the cartons are replaced in the case and the case is moved to the other side of the receiving bench to await transport to the inspection bench. Here the case is again placed on the floor until the inspectors are ready for it. The parts are again unpacked, inspected, measured and replaced as before. After a further short delay the case is transported to the marking bench. The parts are unpacked, numbered and repacked in the cartons and the case, which after another delay is transported by hand truck to the stores and there placed in bins to await issue to the assembly shops. The complete sequence has been recorded on a flow process chart (figure 30).

□ *EXAMINE* critically

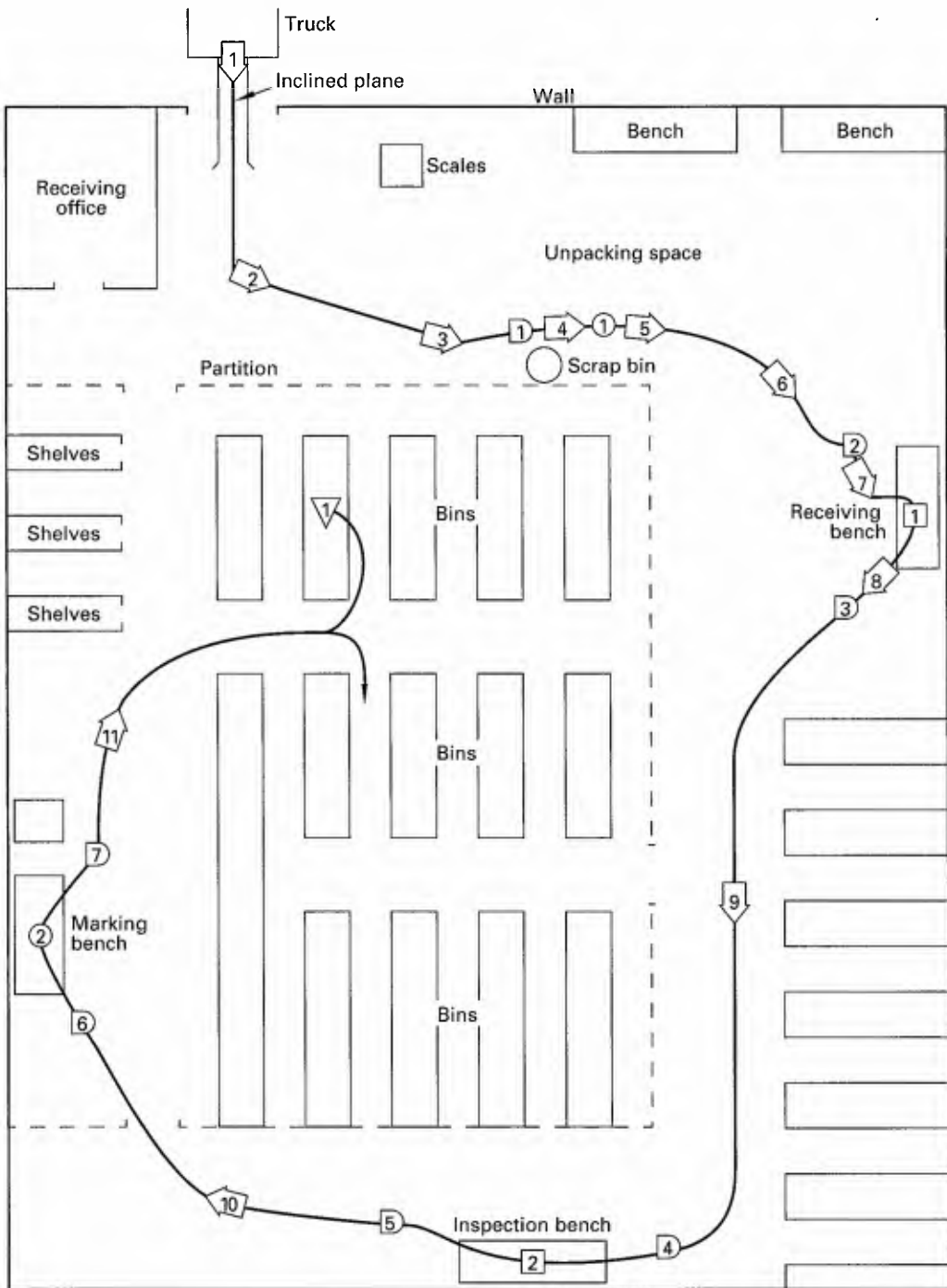
A study of the flow diagram (figure 29) shows immediately that the cases take a very long and roundabout path on their journey to the bins. This could not have been seen from the flow process chart alone. The chart, however, enables the various activities to be recorded and summarized in a manner not conveniently possible on the diagram.

A critical examination of the two together, using the questioning technique, at once raises many points which demand explanation, such as:

- Q. **Why** are the cases stacked to await opening when they have to be unstacked in 10 minutes?
- A. Because the delivery truck can be unloaded faster than work is cleared.
- Q. What **else** could be done?
- A. (a) The work could be cleared faster.
(b) Space could be provided to leave the cases unstacked.
- Q. **Why** are the reception, inspection and marking points so far apart?
- A. Because they happen to have been put there.
- Q. Where **else** could they be?
- A. They could be all together.
- Q. Where **should** they be?
- A. Together at the present reception point.
- Q. **Why** does the case have to go all round the building to reach the stores?
- A. Because the door of the stores is located at the opposite end from the delivery point.

No doubt the reader who examines the flow diagram and the flow process chart carefully will find many other questions to ask. There is evidently much room for improvement. This is a real-life example of what happens when a series of activities is started without being properly planned. Examples with as much waste of time and effort can be found in factories all over the world.

Figure 29. Flow diagram: Inspecting and marking incoming parts (original method)



□ *DEVELOP* the improved method

The solution arrived at by the work study person in this factory can be seen in figures 31 and 32. It is clear that among the questions asked were those suggested above, because it will be seen that the case is now slid down the inclined plane from the delivery truck and put straight on a hand truck. It is transported straight to the “unpacking space”, where it is opened while still on the truck and the delivery note is taken out. It is then transported to the receiving bench, where, after a short delay, it is unpacked and the parts are put on the bench. The parts are counted and checked against the delivery note. The inspection and numbering benches have now been placed beside the reception bench so that the parts can be passed from hand to hand for inspection, measuring and then numbering. They are finally replaced in their cartons and repacked in the case, which is still on the truck.

It is evident that the investigators were led to ask the same question as we asked, namely: “Why does the case have to go all round the building to reach the stores?” Having received no satisfactory answer, they decided to make a new doorway into the stores opposite the benches, so that the cases could be taken in by the shortest route.

It will be seen from the summary on the flow process chart (figure 32) that the “inspections” have been reduced from two to one, the “transports” from 11 to six and the “delays” (or temporary storages) from seven to two. The distance travelled has been reduced from 56.2 to 32.2 metres.

The number of work-hours involved has been calculated by multiplying the time taken for each item of activity by the number of workers involved, e.g. “trucked to reception bench” = 5 minutes \times 2 labourers = 10 work-minutes. Delays are not included as they are caused by operatives being otherwise occupied. In the improved method the inspector and stores labourer are considered to be working simultaneously on inspecting and numbering respectively, and the 20 minutes therefore become 40 work-minutes. Labour cost is reckoned at an average of US\$5.20 per hour for all labour. The cost of making a new doorway is not included, since it will be spread over many other products as well.

3. Develop the improved method

There is an old saying that to ask the right question is to be halfway towards finding the right answer. This is especially true in method study. In using the questioning sequence given in this chapter, namely the following:

What should be done?

Where should it be done?

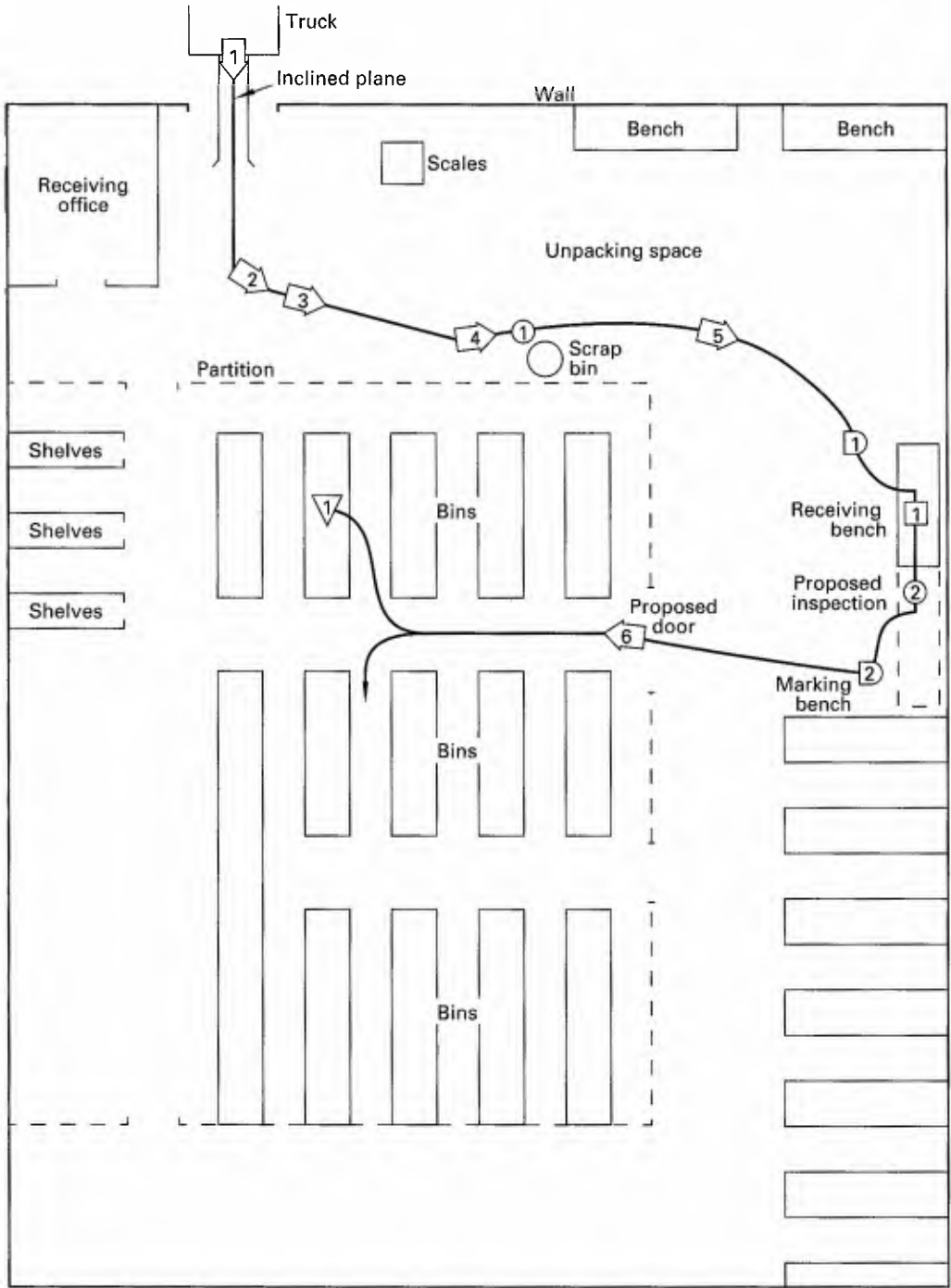
When should it be done?

Who should do it?

How should it be done?

one can develop a fairly good notion about the shortcomings of the present operation and the possibilities of a new improved method begins to emerge. In

Figure 31. Flow diagram: Inspecting and marking incoming parts (improved method)



many cases, however, the solution is not all that obvious and further investigation may be needed elsewhere. It is therefore unwise to rush into solutions before investigating these other related areas. For example, a simplification in the design of the product or proper use of raw material can save considerably on times of operations. Other issues related to proper layout or to materials handling can also produce the same effect. It is for this reason that work study specialists should be aware of the range of techniques that are available to them in developing a new improved method. These are referred to in Part Three of this book.

Eventually, and with practice in using the questioning technique, the work study person develops an inquisitive attitude which is constantly pursuing efficiency.

Once the step of developing a new method is accomplished, it is recorded on a corresponding chart. In our two previous examples this would be a flow process chart, so that it can be compared with the original method and checked to make sure that no point has been overlooked. This will enable entries to be made in the "summary" of the total number of activities taking place under both methods, the savings in distance and time which may be expected to accrue from the change and the possible cost savings which will result (figures 28 and 32).

Movement of workers in the working area

1. Movement of workers and material

There are many types of activity in which workers move at irregular intervals between a number of points in the working area, with or without material. This situation occurs very often in industry and commerce, and even in the home. In manufacturing concerns it occurs when:

- bulk material is being fed to or removed from continuous process, and is stored around the process;
- an operative is looking after two or more machines;
- labourers are delivering materials to or removing work from a series of machines or workplaces.

Outside manufacturing operations, examples of its occurrence are:

- in stores and shops where a variety of materials are being removed from or put away into racks or bins;
- in restaurant and canteen kitchens during the preparation of meals;
- in control laboratories where routine tests are carried out at frequent intervals.

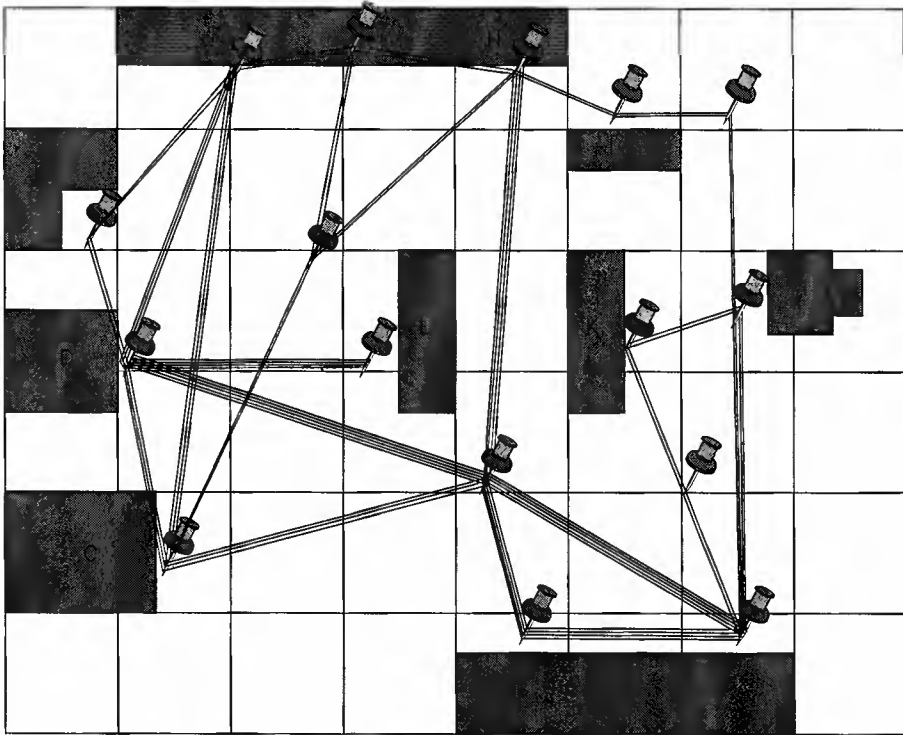
2. The string diagram

One technique for recording and examining this form of activity is the **string diagram**. It is one of the simplest of the techniques of method study and one of the most useful.

The string diagram is a scale plan or model on which a thread is used to trace and measure the path of workers, material or equipment during a specified sequence of events

The string diagram (figure 33) is thus a special form of flow diagram, in which a string or thread is used to measure distance. Because of this it is necessary that the string diagram be drawn correctly to scale, whereas the ordinary flow diagram will probably be drawn only approximately to scale,

Figure 33. A string diagram



with pertinent distances marked on it so that scaling off is unnecessary. The string diagram is started in exactly the same way as all other method studies: by recording all the relevant facts from direct observation. Like the flow diagram, it will most often be used to supplement a flow process chart, the two together giving the clearest possible picture of what is actually being done. As always, the flow process chart will be examined critically in order to make sure that all unnecessary activities are eliminated before a new method is developed.

A string diagram can be used to plot the movements of materials, and this is sometimes done, especially when a work study person wants to find out easily just how far the materials travel. We could have constructed a string diagram for each of the examples in the last chapter, but this was not necessary. The simple flow diagram showed all that was needed, and was quicker to prepare for the circumstances illustrated. The string diagram is most often used, however, for plotting the movements of workers, and it is this application which is considered in the examples given in the present chapter.

The work study person proceeds to follow the worker being investigated as he or she moves from point to point in doing the job. (If the working area is a fairly small one which can be seen as a whole from one point, he or she can watch the worker without moving.) The study person notes methodically each point to which the worker moves and, if the journeys are fairly long, the times of arrival and departure. It will save a good deal of writing if the observer codes the various machines, stores and other points of call by numbers, letters or other means.

Figure 34. A simple movement study sheet

Movement study sheet				
Chart No. 1 Sheet No. 1 of 2			Operative(s):	
Operation: <i>Transport biscuit tiles</i>				
<i>from inspection to storage</i>			Charted by:	
<i>bins and unload into bins</i>			Date:	
Location: <i>Biscuit warehouse</i>			Cross-reference: <i>String diagrams</i>	
				1 and 2
1 Time dep.	2 Time arr.	3 Time elapsed	4 Move to	5 Notes
			<i>Inspection bench (I)</i>	
			<i>to Bin 4</i>	
			<i>/</i>	<i>13</i>
			<i>/</i>	<i>5</i>
			<i>/</i>	<i>32</i>
			<i>/</i>	<i>18</i>

The form of study sheet required is very simple. A sample of the headings required is given in figure 34. Continuation sheets need only give columns 1, 2, 3, 4 and 5.

The recording of movements will continue for as long as the work study person thinks is necessary to obtain a representative picture of the worker's movements, which may be a few hours, a day, or even longer. The study person must be sure that he or she has noted **all** the journeys made by the worker and has seen them made enough times to be sure of their relative frequency. Insufficient study may produce a misleading picture, since the work study person may only have watched the worker during a part of the complete cycle of activities while using only a few of his or her various paths of movement. Later in the cycle he or she may not use these at all but use others a great deal. Once the study person is satisfied that he or she has a true picture — which should be checked with the worker concerned to make sure that there is nothing else which is usually done that has not been observed — the string diagram may be constructed.

A scale plan of the working area similar to that required for a flow diagram must be made (the same plan may be used so long as it has been

accurately drawn). Machines, benches, stores and all points at which calls are made should be drawn in to scale, together with such doorways, pillars and partitions as are likely to affect paths of movements. The completed plan should be attached to a softwood or composition board, and pins driven into it firmly at every stopping point, the heads being allowed to stand well clear of the surface (by about 1 cm). Pins should also be driven in at all the turning-points on the route. A measured length of thread is then taken and tied round the pin at the starting-point of the movements (the inspection bench (I) in figure 33). It is then led around the pins at the other points of call in the order noted on the study sheet until all the movements have been dealt with.

The result is an overall picture of the paths of movement of the operative, those which are most frequently traversed being covered with the greatest number of strings, the effect being as in figure 33.

It will be seen from the sketch that certain paths — in particular those between A and D, A and H, and D and L — are traversed more frequently than the others. Since most of these points are at a fair distance from one another, the diagram suggests that critical examination is called for, with a view to moving the work points which they represent closer together.

It will be remembered that the thread used was measured before the study person started to make the diagram. By measuring the length remaining and subtracting this from the total length, the length used can be found. This will represent, to scale, the distance covered by the worker. If two or more workers are studied over the same working area, different coloured threads may be used to distinguish between them.

The **examination** of the diagram and the **development** of the new layout can now proceed on the same lines as with a flow diagram, with templates being used and the pins and templates being moved around until an arrangement is found by which the same operations can be performed with a minimum movement between them. This can be ascertained by leading the thread around the pins in their new positions, starting from the same point and following the same sequence. When the thread has been led around all the points covered by the study, the length left over can again be measured. The difference in length between this and the thread left over from the original study will represent the reduction in distance travelled as a result of the improved layout. The process may have to be repeated several times until the best possible layout (i.e. the layout with which the minimum length of thread is used) is achieved.

The string diagram is a useful aid in explaining proposed changes to management, supervisors and workers. If two diagrams are made, one showing the original layout and one the improved layout, the contrast is often so vivid — particularly if brightly coloured thread is used — that the change will not be difficult to “sell”. Workers especially are interested in seeing the results of such studies and discovering how far they have to walk. The idea of reducing one’s personal effort appeals to almost everyone!

The following example shows this technique as applied to the movements of labourers storing tiles after inspection.

Example of a string diagram: Storing tiles after inspection

RECORD

In the operation studied in this example, "biscuit" tiles (i.e. tiles after first firing and before glazing) are unloaded from kiln trucks on to the bench, where they are inspected. After inspection they are placed on platforms according to size and type. The loaded platforms are taken on hand-lift trucks to the concrete bins where the tiles are stored until required for glazing. The original layout of the store is shown in figure 35.

It was decided to make a study using a string diagram to find out whether the arrangement, which appeared to be a logical one, was in fact the one involving the least transport. Studies were made of a representative number of kiln truck loads. This was because the types of tile on each truck varied somewhat, although 10 cm×10 cm and 15 cm×15 cm plain tiles formed by far the largest part of each load.

A form of the type shown in figure 34 above was used for recording the information. Only a portion is shown, since the nature of the record is obvious. (The bin numbers are those shown in figure 35.)

It will be seen that, in this case, times were not recorded. It is more useful to record times when long distances are involved (such as in trucking between departments of a factory).

The string diagram was then drawn up in the manner shown (figure 35). The width of the shaded bands represents the number of threads between any given points and hence the relative amount of movement between them.

EXAMINE critically

A study of the diagram shows at once that the most frequent movement is up the 10 cm×10 cm and 15 cm×15 cm rows of bins. The bin into which any particular load of tiles is unloaded depends on which are full or empty (tiles are constantly being withdrawn for glazing). Travel in the case of the 10 cm×10 cm and 15 cm×15 cm tiles may therefore be anywhere up or down the rows concerned.

It is equally obvious that the "special feature" tiles (used for decorative purposes in comparatively small numbers) are handled only rarely, and are generally placed by the inspectors on one truck and delivered to several bins at once. Deliveries of tiles other than those mentioned are fairly evenly distributed.

DEVELOP the new layout

The first step in developing the new layout is to locate the bins containing the most handled tiles as near as possible to the inspection bench and those containing "special feature" tiles as far away as possible. This certainly spoils the tidy sequence and may, for a time, make tiles a little more difficult to find; however, the bins, which have concrete partitions between them about 1 metre high, can carry cards with the contents marked on them. The cards can be seen from a distance, and the arrangement will soon be memorized by the workers. After a number of arrangements had been tried out, the one shown in figure 36

Figure 35. String diagram: Storing tiles (original method)

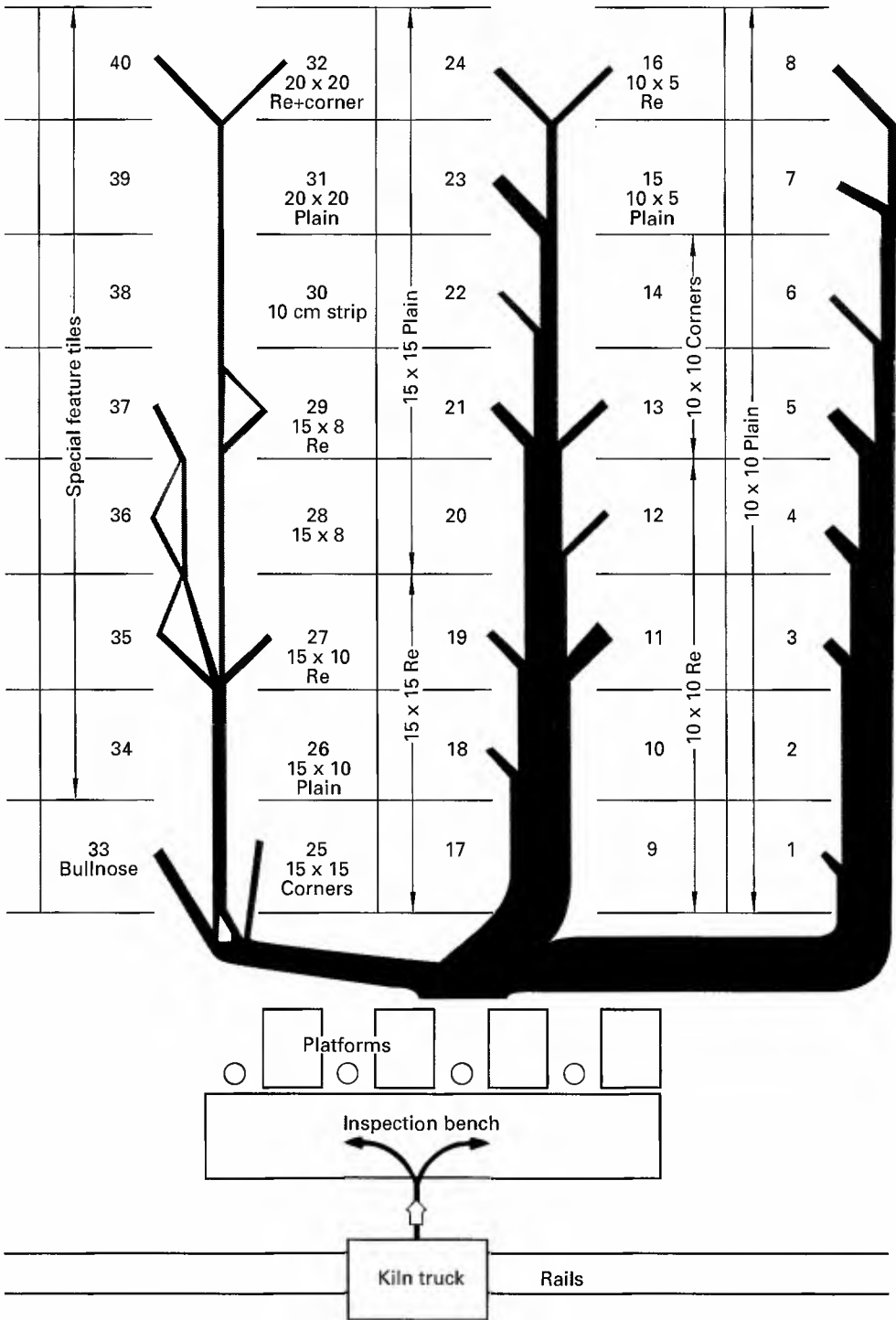
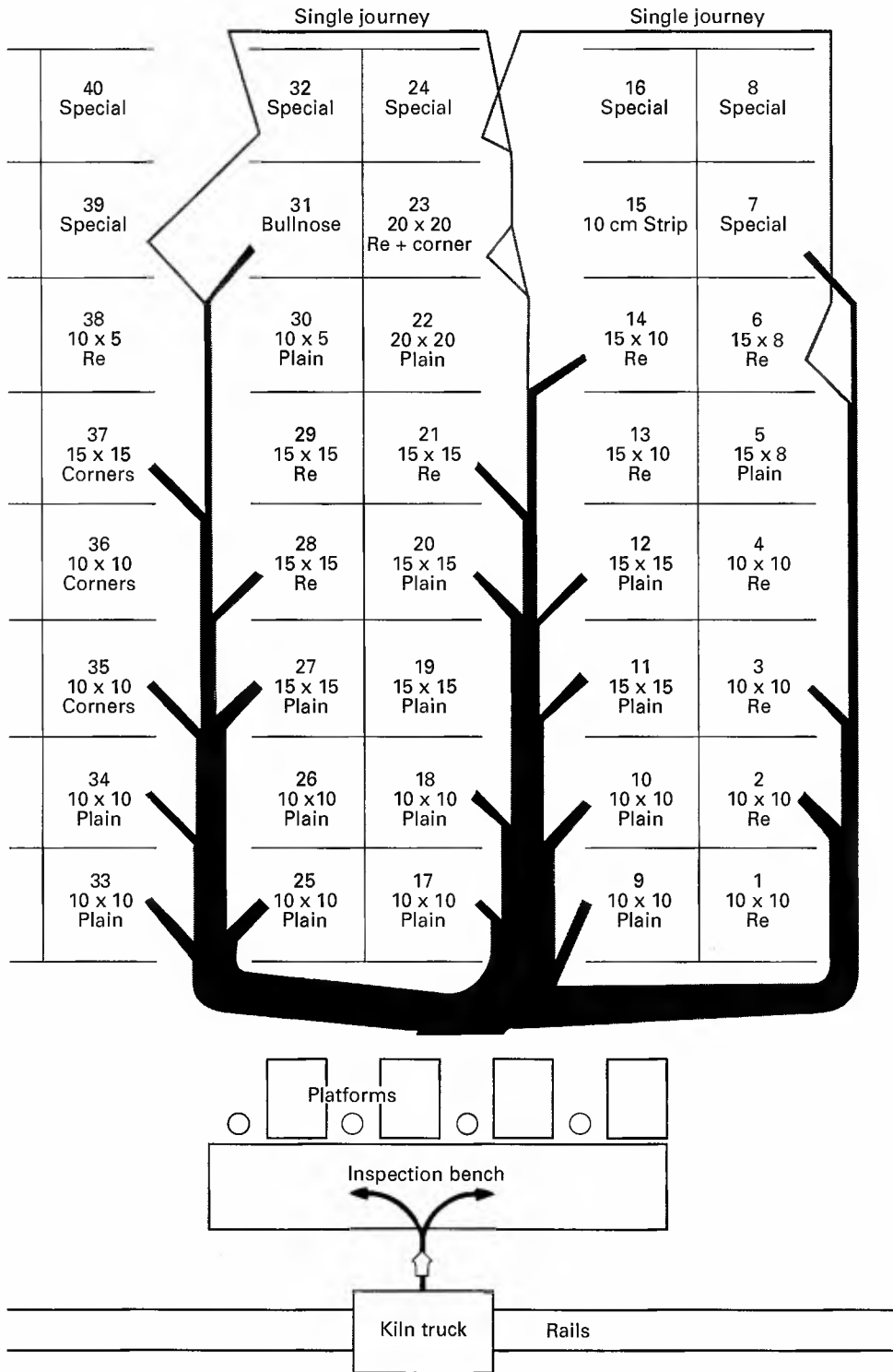


Figure 36. String diagram: Storing tiles (improved method)



proved to be the most economical of transport time. The distances covered were reduced from 520 to 340 metres, a saving of 35 per cent.

3. The worker-type flow process chart

In table 8 in Chapter 7 six different types of process chart were listed. The outline process chart was described in Chapter 7, and the two-handed process chart and procedure flowchart will be dealt with in Chapters 9 and 11 respectively. The other three are flow process charts:

Flow process chart — Worker type

Flow process chart — Material type

Flow process chart — Equipment type

Several examples of material-type flow process charts have already been given (figures 26 and 28 and figures 30 and 32 in Chapter 7). We shall now deal with worker-type flow process charts.

A worker-type flow process chart is a flow process chart which records what the worker does

The same techniques as have been used to follow materials through the operations and movements which they undergo can be used to record the movements of a person. Worker-type flow process charts are frequently used in the study of jobs which are not highly repetitive or standardized. Service and maintenance work, laboratory procedure and much of the work of supervisors and executives can be recorded on charts of this type. Since the charts follow one individual or a group performing the same activities in sequence, the standard flow process chart forms can be used. It is usually essential to attach to the worker-type flow process chart a sketch showing the path of movement of the worker while he or she is carrying out the operation charted.

The charting procedure used in compiling a worker-type flow process chart is almost exactly the same as that used on material-type flow process charts. There is one slight difference, however — a useful charting convention which helps to distinguish worker-type charts from the other two flow process charts, and which will be found quite natural in practice.

The definition of the worker-type chart given above states that it records what the worker **does**. The definitions of the other two flow process charts, however, state that they record (material type) how material is **handled** or **treated**, and (equipment type) how the equipment is **used**. The definitions thus reflect the charting practice, which is to use mainly the **active voice** on worker-type charts, and mainly the **passive voice** on the other two. The convention, which has been followed on all the flow process charts illustrated in this book, will be clear from the following examples of typical entries:

Flow process charts

Worker type	Material type
Drills casting	Casting drilled
Carries to bench	Carried to bench
Picks up bolt	(bolt) Picked up
Inspects for finish	Finish inspected

An example of a worker-type flow process chart applied to hospital activities is given below.

Example of a worker-type flow process chart: Serving dinners in a hospital ward

RECORD

Figure 37 shows the layout of a hospital ward containing 17 beds. When dinners were served by the original method, the nurse in charge of the ward fetched a large tray bearing the first course, together with the plates for the patients, from the kitchen. The food was usually contained in three dishes, two of which held vegetables and the third the main dish. The nurse placed the tray on the table marked "Serving table" in the diagram. She set the large dishes out on the table, served one plate with meat and vegetables and carried it to bed 1. She returned to the serving table and repeated the operation for the remaining 16 beds. The paths which she followed are shown by the **full** lines in the diagram. When she had served all the patients with the first course, she returned to the kitchen with the tray and the empty dishes, collected the dishes and plates for the second course and returned to the ward. She then repeated the complete operation, replacing the plates emptied by the patients with plates containing their portions of the second course and returning the used plates to the serving table, where she stacked them. Finally she made a tour of the ward, collecting up the empty plates from the second course, and carried everything on the tray back to the kitchen. (To avoid confusion on the diagram, the final collection of empty plates is not shown. In both the original and the improved method the distance covered and the time taken are the same, since it is possible for her to carry several plates at a time and move from bed to bed.) The operation has been recorded in part on the flow process chart in figure 38 but only enough has been shown to demonstrate to the reader the method of recording, which it will be seen is very similar to that used for material-type flow process charts, bearing in mind that it is a person and not a product that is being followed. As an exercise readers may wish to work out the serving cycles for themselves on the basis provided by the diagram. The dimensions of the ward are given. It is, of course, possible to complete the worker-type flow process chart in much greater detail if desired.

EXAMINE critically

A critical examination of the flow process chart in conjunction with the diagram suggests that there is considerable room for improvement. The first "Why?" which may come to mind is: "Why does the nurse serve and carry only

Figure 37. Flow diagram: Serving dinners in a hospital ward

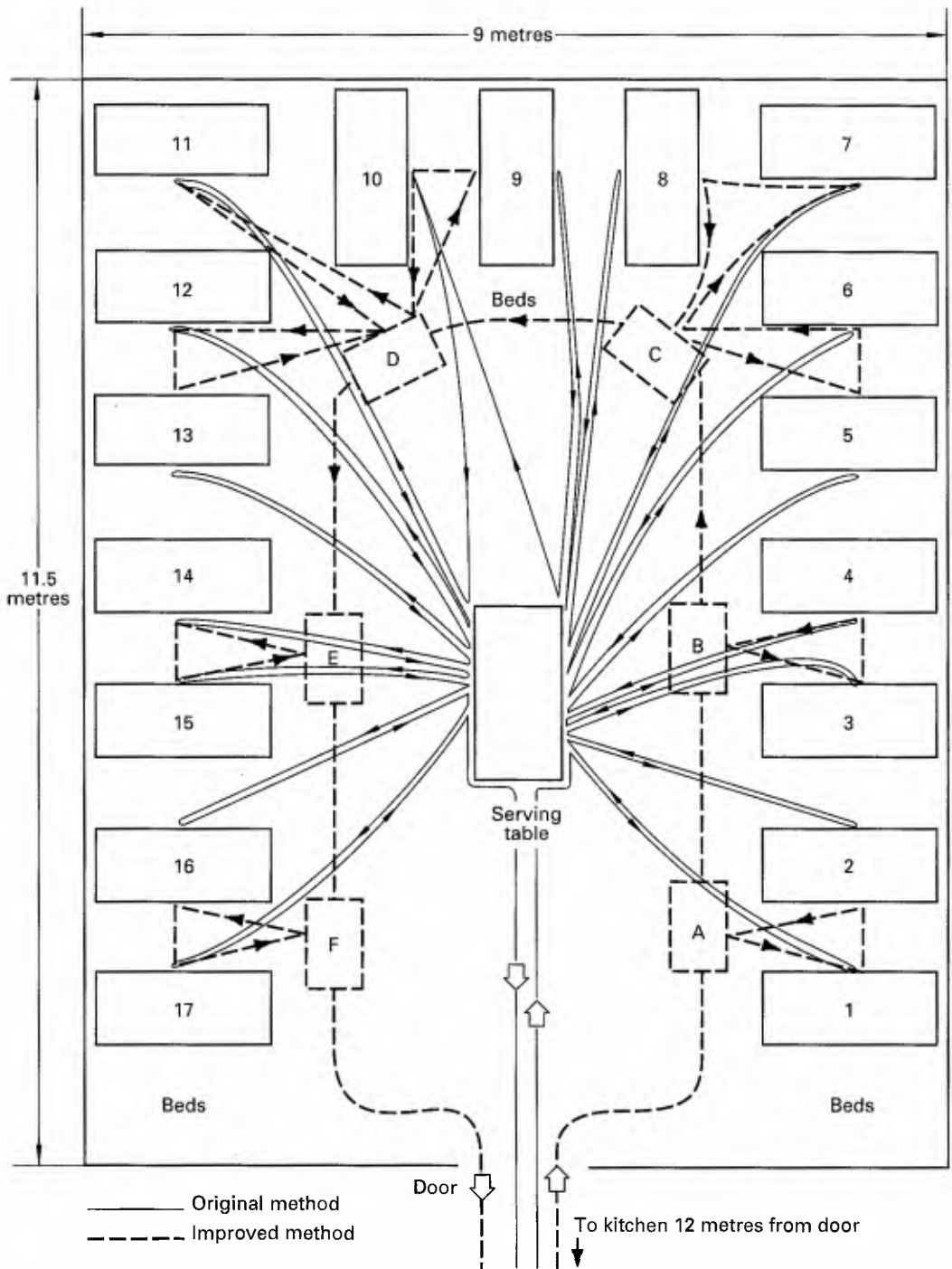


Figure 38. Flow process chart — Worker type: Serving dinners in a hospital ward

Flow process chart		Worker/Material/Equipment type							
Chart No. 7	Sheet No. 1 of 1	Summary							
Subject charted: <i>Hospital nurse</i>	Activity		Present	Proposed	Saving				
	Operation ○		34	18	16				
Transport ▷		60	72	(-12)					
Delay □		-	-	-					
Inspection ◻		-	-	-					
Storage ▽		-	-	-					
Method: Present/Proposed		Distance (m)	436	197	239				
Location: <i>Ward L</i>		Time (work-h)	39	28	11				
Operative(s):		Cost	-	-	-				
Clock No.		Labour	-	-	-				
Charted by: Date:		Material (<i>Trolley</i>)	-	\$24	-				
Approved by: Date:		Total (<i>Capital</i>)	-	\$24	-				
Description	Qty.	Dist- ance (m)	Time (min.)	Symbol					Remarks
				○	▷	□	◻	▽	
Original method									
<i>Transports first course and plates – kitchen to serving table on tray</i>	17	16	.50						<i>Awkward load</i>
<i>Places dishes and plates on table</i>	17	-	.30						
<i>Serves from three dishes to plate</i>	-	-	.25						
<i>Carries plate to bed 1 and returns</i>	1	7.3	.25						
<i>Serves</i>	-	-	.25						
<i>Carries plate to bed 2 and returns</i>	1	6	.23						
<i>Serves</i>	-	-	.25						
<i>(Continues until all 17 beds are served. See figure 37 for distances)</i>									
<i>Service completed, places dishes on tray and returns to kitchen</i>	-	16	.50						
<i>Total distance and time, first cycle</i>			192	10.71	17	20	-	-	-
<i>Repeats cycle for second course</i>			192	10.71	17	20	-	-	-
<i>Collects empty second course plates</i>			52	2.0	-	20	-	-	-
<i>Total</i>			436	23.42	34	60			
Improved method									
<i>Transports first course and plates – kitchen to position A – trolley</i>	17	16	.50						<i>Serving trolley</i>
<i>Serves two plates</i>	-	-	.40						
<i>Carries two plates to bed 1; leaves one; carries one plate from bed 1 to bed 2; returns to position A</i>	2	[1.5] [0.6] [1.5]	.25						
<i>Pushes trolley to position B</i>	-	3.0	.12						
<i>Serves two plates</i>	-	-	.40						
<i>Carries two plates to bed 3; leaves one; carries one plate from bed 3 to bed 4; returns to position B</i>	2	[1.5] [0.6] [1.5]	.25						
<i>(Continues until all 17 beds are served. See figure 37 and note variation at bed 11)</i>									
<i>Returns to kitchen with trolley</i>	-	16	.50						
<i>Total distance and time, first cycle</i>			72.5	7.49	9	26			
<i>Repeats cycle for second course</i>			72.5	7.49	9	26			
<i>Collects empty second course plates</i>			52	2.00	-	20			
Total			197	16.98	18	72			

one plate at a time? How many could she carry?" The answer is almost certainly: "At least two." If she carried two plates at a time, the distance she would have to walk would be almost halved. One of the first questions asked would almost certainly be: "Why is the serving table there, in the middle of the ward?" followed, after one or two other questions, by the key questions: "Why should it stand still? Why can it not move round? Why not a trolley?" This leads straight to the solution which was adopted.

□ *DEVELOP the new method*

It will be seen from the **broken** line in the diagram (representing the revised path of movement of the nurse when provided with a trolley) and from the flow process chart that the final solution involves the nurse serving and carrying two plates at a time (which also saves a small amount of serving time).

The result, as will be seen from the process chart, is a reduction of over 54 per cent in the total distance walked in serving and clearing away the dinners (the saving is 65 per cent if the distance walked in removing the second-course plates, which is the same in both the old and the new methods, is excluded).

What is important here in this very simple example is not so much the reduction in cost, which is very small, as the fact that the nurse's fatigue, resulting from the considerable distance which she had to walk within the ward and while carrying the loaded tray to and from the kitchen, is lessened.

4. The multiple activity chart

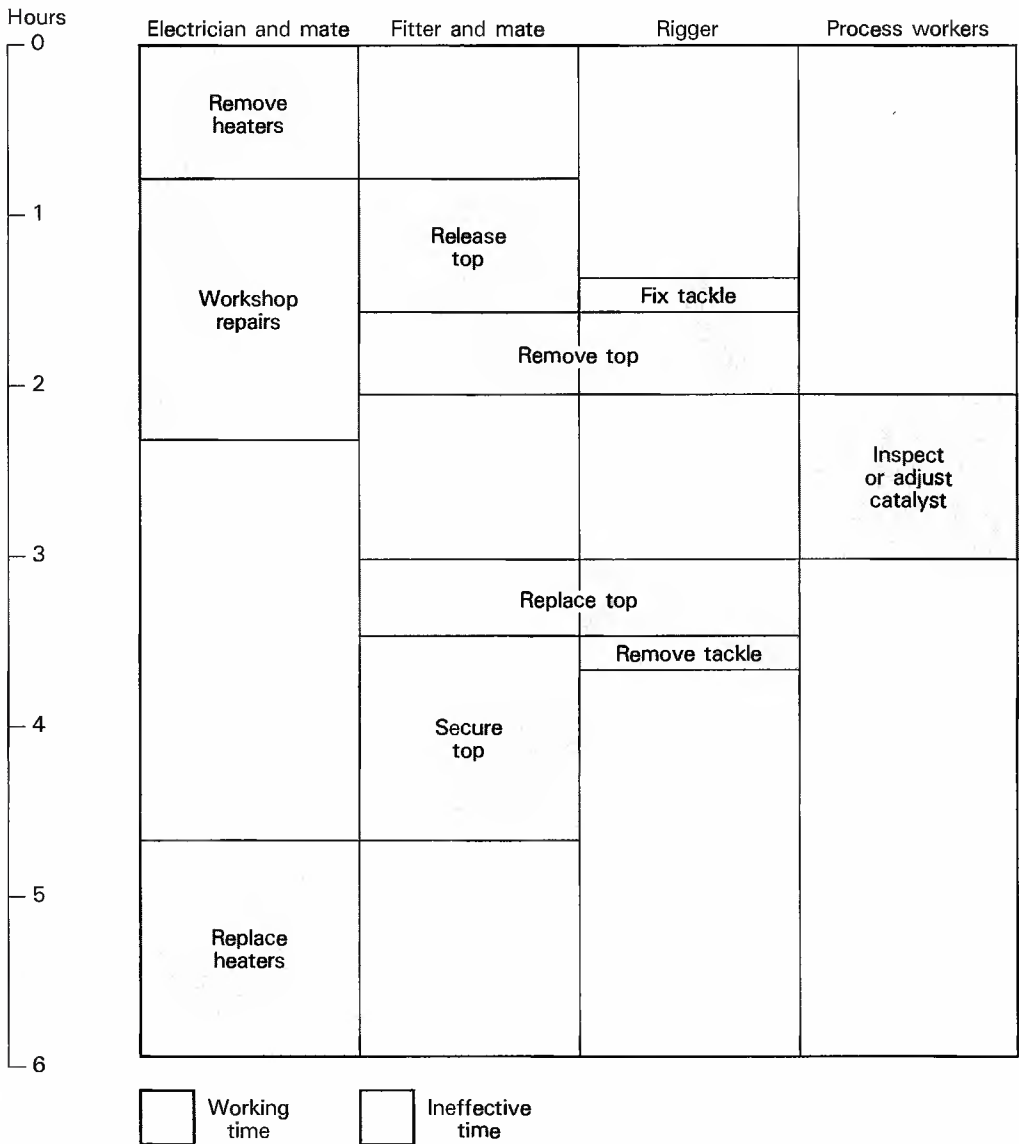
We come now to the first of the charts listed in table 8 which use a time scale — the **multiple activity chart**. This is used when it is necessary to record on one chart the activities of one subject in relation to another.

A multiple activity chart is a chart on which the activities of more than one subject (worker, machine or item of equipment) are each recorded on a common time scale to show their interrelationship

By using separate vertical columns, or bars, to represent the activities of different operatives or machines against a common time scale, the chart shows very clearly periods of idleness on the part of any of the subjects during the process. A study of the chart often makes it possible to rearrange these activities so that such ineffective time is reduced.

The multiple activity chart is extremely useful in organizing teams of operatives on mass-production work, and also on maintenance work when expensive plant cannot be allowed to remain idle longer than is absolutely necessary. It can also be used to determine the number of machines which an operative or operatives should be able to look after.

Figure 39. Multiple activity chart: Inspection of catalyst in a converter (original method)



In making a chart, the activities of the different operatives or of the different operatives and machines are recorded in terms of working time and idle time. These times may be recorded by ordinary wristwatch, by stop-watch or by electronic timing, according to the duration of the various periods of work and idleness (i.e. whether they are a matter of minutes or seconds). Extreme accuracy is not required, but timing must be accurate enough for the chart to be effective. The times are then plotted in their respective columns in the manner shown in figure 39.

The use of the multiple activity chart can best be shown by an example.

Example of a multiple activity chart applied to team work: Inspection of catalyst in a converter¹

RECORD

This is an application in the field of plant maintenance and is useful in showing that method study is not confined to repetitive or production operations.

During the "running-in" period of a new catalytic converter in an organic chemical plant, it was necessary to make frequent checks on the condition of the catalyst. In order that the converter should not be out of service for any longer than was strictly necessary during these inspections, the job was studied.

In the original method the removal of the top of the vessel was not started until the heaters had been removed, and the replacement of the heaters was not started until the top had been completely fixed. The original operation, with the relationships between the working times of the various workers, is shown in figure 39.

EXAMINE critically

It will be seen from this chart that, before the top of the vessel was removed by the fitter and his or her mate, the heaters had to be removed by the electrician and his or her mate. This meant that the fitters had to wait until the electricians had completed their work. Similarly, at the end of the operation the heaters were not replaced until the top had been replaced, and the electricians had to wait in their turn. A critical examination of the operation and questioning of the existing procedure revealed that in fact it was not necessary to wait for the heaters to be removed before removing the top.

DEVELOP the new method

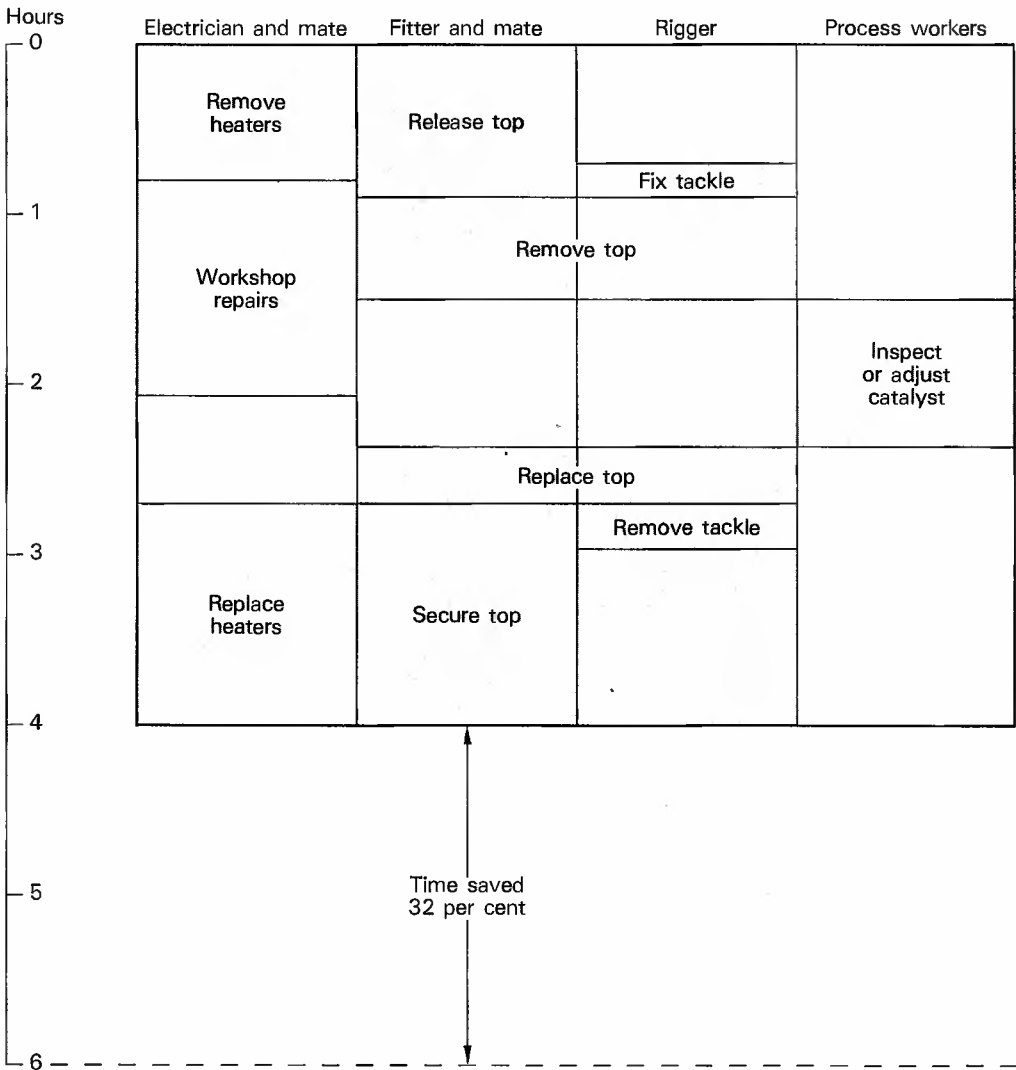
Once this had been determined, it was possible to arrange for the top to be unfastened while the heaters were being removed and for the heaters to be replaced while the top was being secured in place. The result appears on the chart in figure 40.

It will be seen that the idle time of the electrician and fitter and their respective mates has been substantially reduced, although that of the rigger remains the same. Obviously the rigger and the process workers will be otherwise occupied before and after performing their sections of the job and are not, in fact, idle while the heaters and cover are being removed or replaced. The saving effected by this simple change was 32 per cent of the total time of the operation.

The simple form of multiple activity chart shown here can be constructed on any piece of paper having lines or squares which can be used to form a time scale. It is more usual, however, to use printed or duplicated forms, similar in general layout to the standard flow process charts, and to draw vertical bars to represent the activities charted. Figures 41, 42 and 43 show multiple activity charts drawn on printed forms.

¹ Adapted from an example in *Method study*, a handbook issued by Imperial Chemical Industries Ltd., Work Study Department.

Figure 40. Multiple activity chart: Inspection of catalyst in a converter (improved method)



The multiple activity chart can also be used to present a picture of the operations performed simultaneously by a worker and one or more machines. The chart may be drawn in the manner shown in figure 41, with the vertical activity bars close to each other down the middle of the sheet. In this way the beginning and end, and hence the duration, of every period of activity of either worker or machine are clearly seen in relation to one another. By a study of these activities it is possible to determine whether better use can be made of the operative's time or of the machine time. In particular, it offers a means of determining whether a worker minding a machine, whose time is only partly occupied, can manage to service another machine, or whether the increase in ineffective time of the two machines will offset any gain to be obtained from employing the worker's time more fully. This is an important question in those

Figure 41. Multiple activity chart — Worker and machine: Finish mill casting (original method)

Multiple activity chart								
Chart No. 8		Sheet No. 1		Of 1		Summary		
Product				Cycle time		Present	Proposed	Saving
B. 239 casting						(min.)		
Drawing No. B. 239/1				Worker		2.0		
Process: Finish mill second face				Machine		2.0		
				Working				
				Worker		1.2		
				Machine		0.8		
Machine(s): Cincinnati No. 4 vertical miller		Speed 80 r.p.m.	Feed 15 in./min.	Idle				
				Worker		0.8		
				Machine		1.2		
				Utilization				
Operative:		Clock No. 1234		Worker		60%		
Charted by:		Date:		Machine		40%		
Time (min.)	Worker			Machine			Time (min.)	
0.2	Removes finished casting; cleans with compressed air						0.2	
0.4	Gauges depth on surface plate						0.4	
0.6	Breaks sharp edge with file; cleans with compressed air					Idle	0.6	
0.8	Places in box; obtains new casting						0.8	
1.0	Cleans machine with compressed air						1.0	
1.2	Locates casting in fixture; starts machine and auto feed						1.2	
1.4							1.4	
1.6	Idle					Working Finish mill second face	1.6	
1.8							1.8	
2.0							2.0	
2.2							2.2	
2.4							2.4	
2.6							2.6	
2.8							2.8	
3.0							3.0	
3.2							3.2	
3.4							3.4	
3.6							3.6	
3.8							3.8	

Figure 42. Multiple activity chart — Worker and machine: Finish mill casting (improved method)

Multiple activity chart						
Chart No. 9	Sheet No. 1	Of 1	Summary			
Product B. 239 casting			Present	Proposed	Saving	
Drawing No. B. 239/1			Cycle time (min.)			
Process: Finish mill second face			Worker	2.0	1.36	0.64
			Machine	2.0	1.36	0.64
Machine(s): Cincinnati No. 4 vertical miller			Working			
			Worker	1.2	1.12	0.08
			Machine	0.8	0.8	—
Speed 80 r.p.m. Feed 15 in./min.			Idle			
			Worker	0.8	0.24	0.56
Operative: Clock No. 1234			Machine	1.2	0.56	0.64
			Utilization			Gain
Charted by: Date:			Worker	60%	83%	23%
			Machine	40%	59%	19%
Time (min.)	Worker		Machine		Time (min.)	
0.2	Removes finished casting				0.2	
0.4	Cleans machine with compressed air; locates new casting in fixture; starts machine and auto feed			Idle	0.4	
0.6					0.6	
0.8	Breaks edge of machined casting with file; cleans with compressed air				0.8	
1.0	Gauges depth on surface plate				1.0	
1.2	Places casting in box; picks up new casting and places by machine			Working Finish mill second face	1.2	
1.4					1.4	
1.6	Idle				1.6	
1.8					1.8	
2.0					2.0	
2.2					2.2	
2.4					2.4	
2.6					2.6	
2.8					2.8	
3.0					3.0	
3.2					3.2	
3.4					3.4	
3.6					3.6	
3.8					3.8	

countries where human resources are more readily available than machines and other capital equipment.

Example of a multiple activity chart recording worker and machine: Finish mill casting on a vertical miller

RECORD

Figure 41 represents a common form of worker-and-machine multiple activity chart recording the operation of a vertical milling machine finish-milling one face of a cast iron casting parallel to the opposite face, which is used for locating it in the fixture. This is a very simple example, typical of the sort of operation carried out every day in an engineering shop.

The heading of the chart records the usual standard information, with one or two additions. The graduated scale on the edge of the chart can be made to represent any scale of time required; in this case one large division equals 0.2 of a minute. The making of the chart and noting of the operations are self-evident and should not require further explanation.

EXAMINE critically

It will be seen from figure 41, which represents the method by which the operative was doing the job before the study was made, that the machine remains idle during nearly three-quarters of the operation cycle. This is due to the fact that the operative is carrying out all his or her activities with the machine stopped, but remains idle while the machine is running on an automatic feed.

Examination of the chart shows that the work carried out by the operative can be divided into two parts: that which must be done with the machine stopped, such as removing and locating the workpiece, and that which can be done while the machine is running, such as gauging. It is obviously an advantage to do as much as possible while the machine is running as this will reduce the overall operation cycle time.

DEVELOP the new method

Figure 42 shows the improved method of operation. It will be seen that gauging, breaking the edges of the machined face with a file, placing the casting in the box of finished work, picking up an unmachined casting and placing it on a work table ready to locate in the fixture are now all done while the machine is running. A slight gain in time has been made by placing the boxes with the finished work and the work to be done next to one another, so that one casting can be put away at the same time as the new one is lifted from its box. The cleaning of the machined casting with compressed air has been deferred until after the sharp edges have been broken down, thus saving an extra operation.

The result of this rearrangement, which has involved no capital outlay, is a saving of 0.64 of a minute, a gain of 32 per cent in the productivity of the milling machine and operative.

The next example is one of a multiple activity chart recording the activities of a team of workers and a machine.

Example of multiple activity chart recording the activities of a team of workers and a machine: Feeding bones to a crusher in a glue factory

This simple but nevertheless interesting example of a combined teamwork and machine chart (figure 43) is applied to the feeding of sorted bones from a storage dump to a crushing machine in a glue factory in a developing country.

The original layout of the working area is shown in figure 44. Raw material in the form of animal bones of all sorts was brought by the suppliers to one of the dumps labelled "Bones", 80 metres from the bone crusher. The crusher was fed by means of a small trolley running on rails.

RECORD

Workers sorted the bones into "soft" and "hard" types. The selected bones were carried to a heap, ready for loading by two workers into the trolley. The loading was done by hand. These two workers were idle during the time that the trolley was being pushed to the crusher, emptied into it and brought back. Two other workers pushed the trolley; they were idle while it was being loaded.

The following figures relate to the activities of the loaders, the trolley and the crushing machine during eight cycles, which lasted 117.5 minutes.

Trolley loading time 7 min. (2 workers)

Trolley to crusher, empty and return 7 min. (2 workers)

Trolley load 250 kg

Weight transported in 117.5 minutes $8 \times 250 = 2,000$ kg

Crusher waiting time 37.75 min.

A chart (figure 43) has been made relating the activities of the crusher, trolley, trolley operatives and loaders. From this it will be seen that 10 minutes of the crusher waiting time was taken up in replacing a broken belt; however, after the belt was repaired, the crusher ran continuously for 16.5 minutes instead of the usual 10, because a fresh trolley load was ready for it. If a normal 4 minutes of idleness is allowed, the net idleness due to the broken belt becomes only 6 minutes.

EXAMINE critically

A critical examination of the chart shows at once that the crusher was normally idle for 31.75 out of 111.5 minutes (37.75 out of 117.5 minutes if the 6 minutes' breakdown time is included), or 28.5 per cent of the possible working time. Each of the two groups of workers (loaders and trolley operatives) was idle for 50 per cent of its available time. The first question that might arise in the mind of someone studying the diagram and chart is: "Why cannot the trolley operatives load the trolley?"

The answer to this question is that, if they did so, they would get no rest and would have to work continuously just to keep the crusher going for the same percentage of its time as at present. There would be a saving of manpower but no improvement in the productivity of the plant. In any case, no one can work for three or four hours on end without some rest, especially when engaged on heavy work such as loading and pushing the trolley, where the allowance would normally be 25 per cent or possibly more of the total time

Figure 43. Combined team work and machine multiple activity chart: Crushing bones (original method)

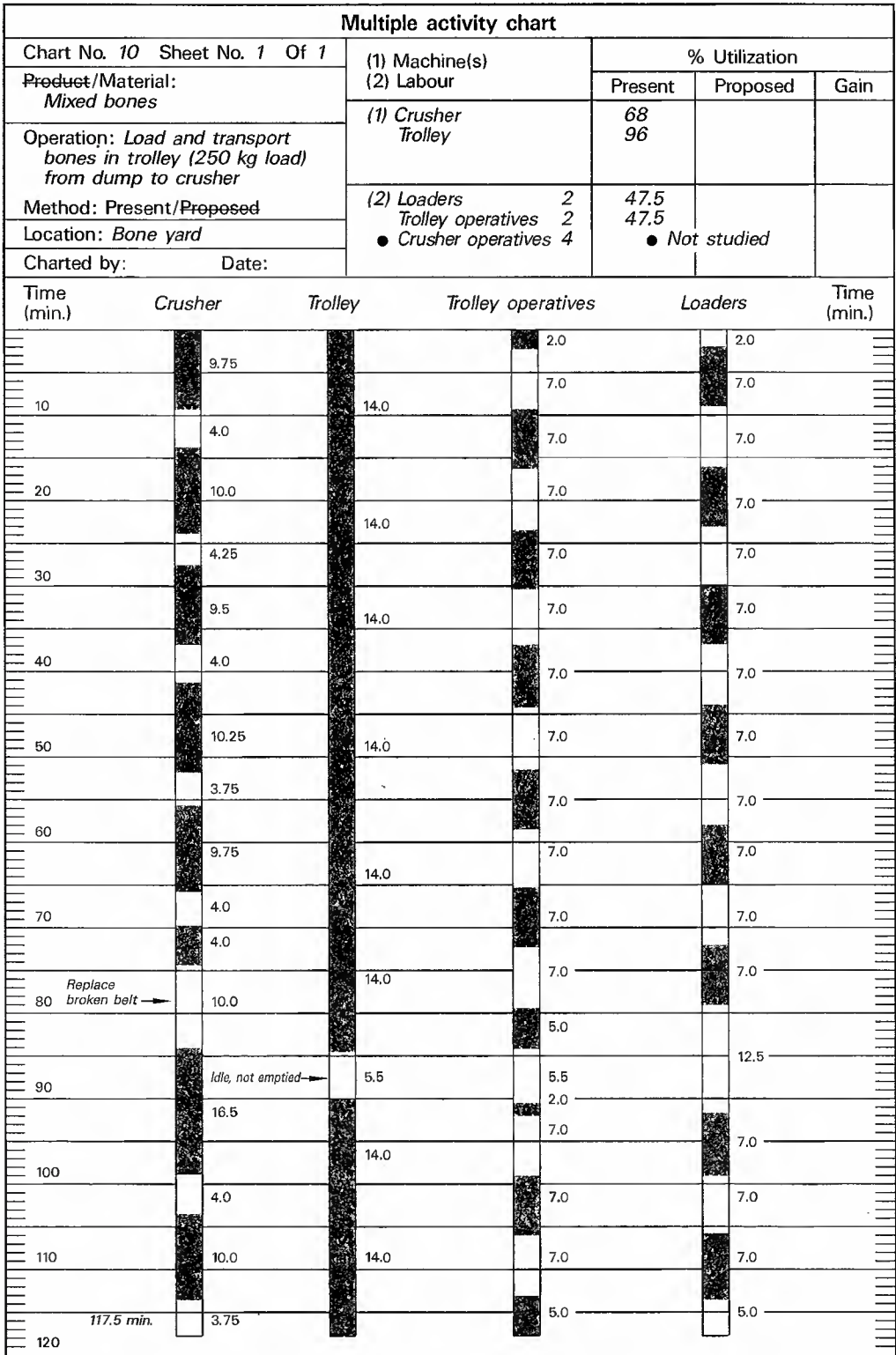
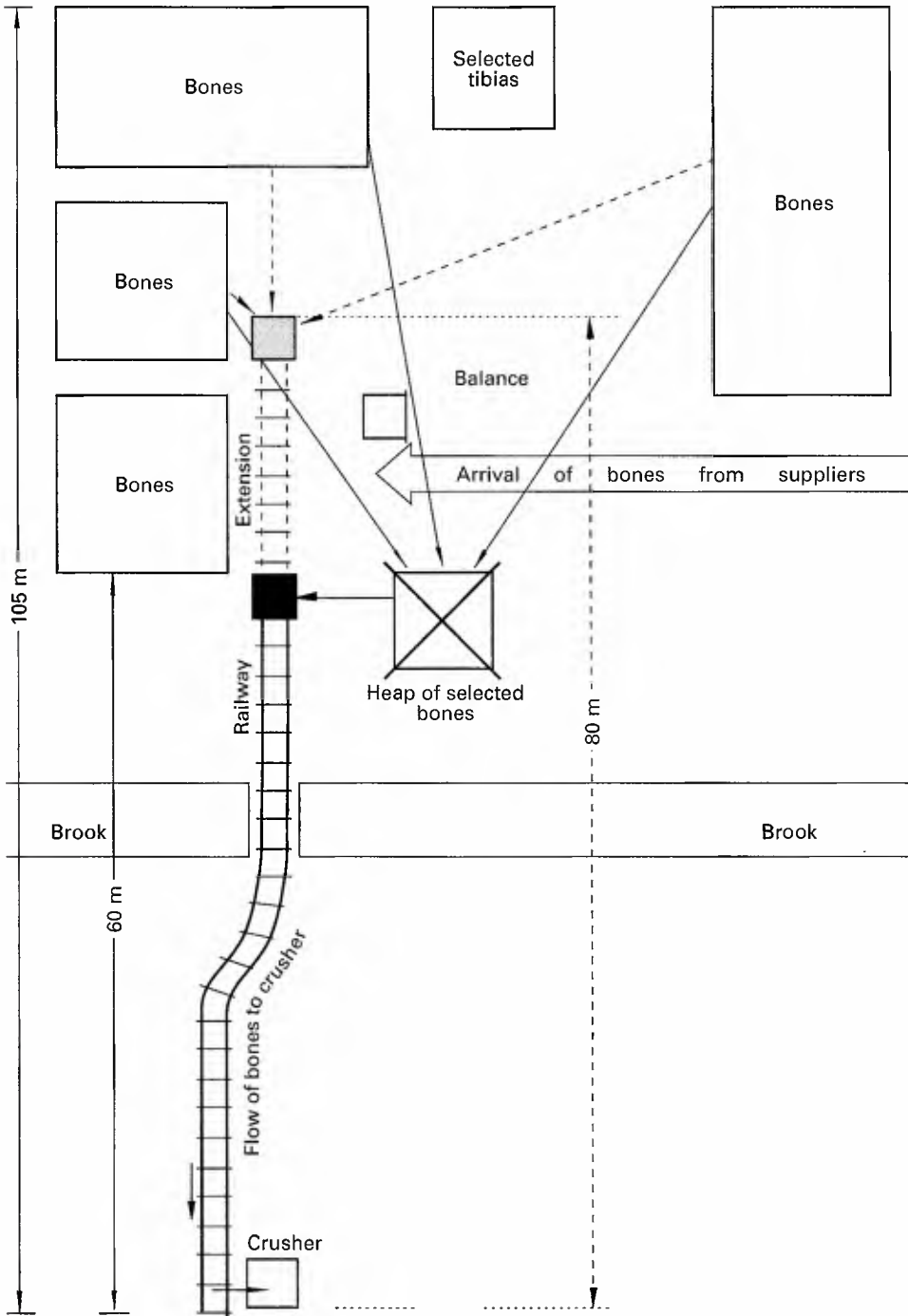


Figure 44. Crushing bones: Layout of working area



allowed for the job (for the treatment of relaxation allowances see Chapter 23). If the two trolley operatives took their relaxation allowances, the productivity of the crusher would be still lower.

A study of the diagram of the working area and of the information given above shows that the workers sorting the bones at the dumps labelled "Bones" have to carry the sorted bones from the points where they are working to the "Heap of selected bones", so that they can be loaded into the trolley. This raises the question: "Why cannot the bone sorters load the sorted bones straight into the trolley?"

The answer is that they could do so, if the rails were extended another 20 metres to the bone dumps.

This eliminates the loaders but still leaves the problem of the 4 minutes of idle time of the crusher, while it is waiting for the trolley to return with a load. There are more bone sorters than loaders and they can load the trolley more quickly; if each trolley load were reduced, it would take less time to load and would require less effort to push. In this way it might be possible to keep up with the cycle of the crusher. The load was therefore reduced to 175 kilograms. Waiting time was eliminated.

DEVELOP the improved method

The line of crosses in figure 44 shows the extension of the rails to the bone dumps. The loaders who were eliminated were transferred to other work in the factory. This was probably made possible by the fact that, as will be seen, the crusher output rose substantially as a result of the change of method.

Figure 45 is the multiple activity chart showing the improved method. It will be seen from this that the percentage running time of the crusher has considerably improved.

Performance figures are now:

Trolley loading time 1 min.

Trolley to crusher, empty and return 6 min.

Trolley load 175 kg

Weight transported in 117.5 minutes $15 \times 175 = 2,625$ kg

Crusher waiting time 6 min.

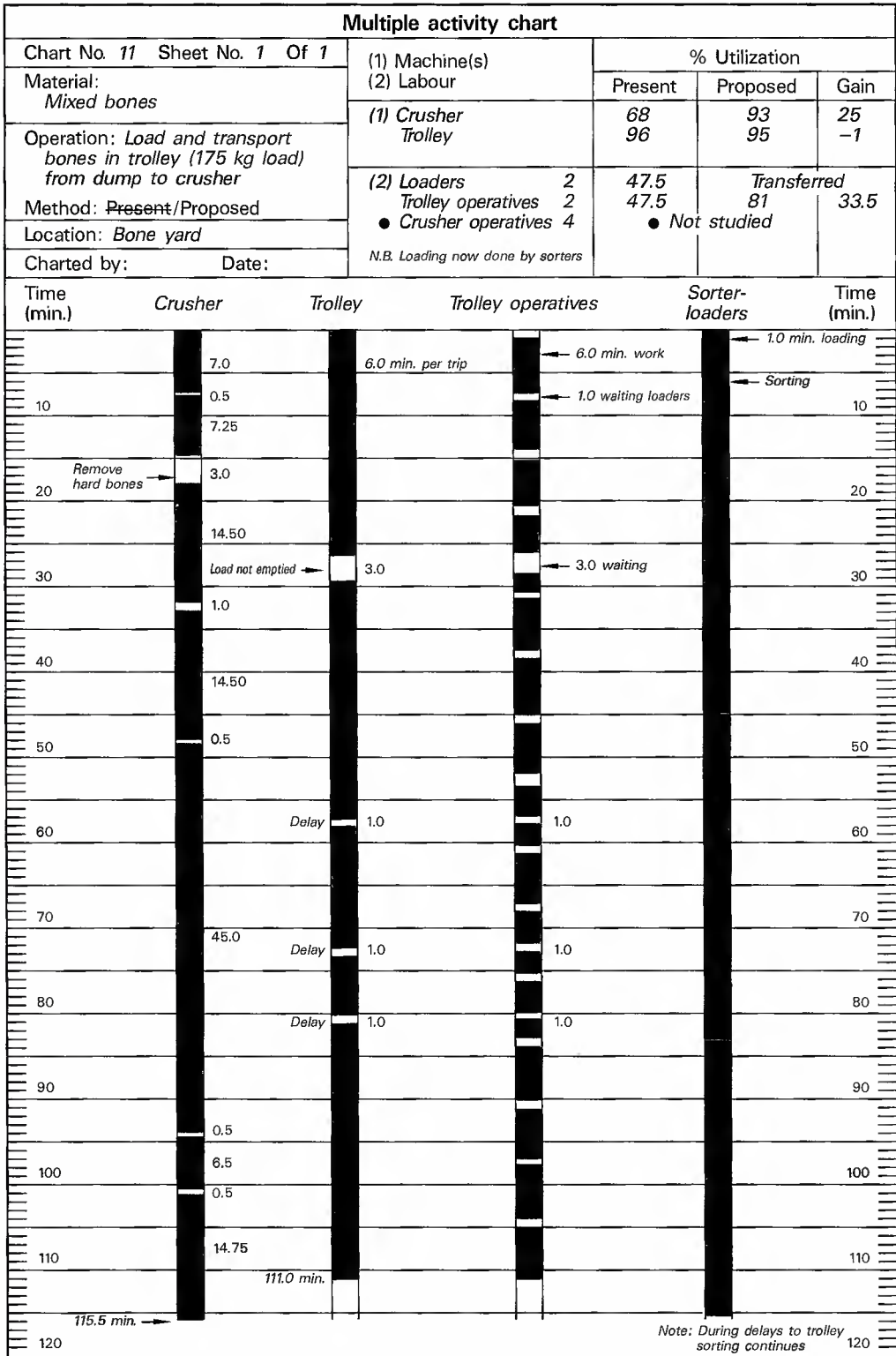
The crusher waiting time will be seen from the chart to include 3 minutes for clearing hard bones — an abnormal occurrence. If this time is excluded to enable the original and improved performances to be compared, the overall time during which the crusher is available for action is 112.5 minutes. The increase in output from the crusher over almost identical periods is 625 kilograms; the increase in productivity of the crusher is 29.5 per cent.

Two labourers out of eight have been released for other work; the labour productivity has therefore increased by

$$\left(\frac{2,625 \times 8}{2,000 \times 6} - 1 \right) \times 100 = 75 \text{ per cent.}$$

The space formerly occupied by the "Heap of selected bones" is now available for other uses.

Figure 45. Combined team work and machine multiple activity chart: Crushing bones (improved method)



This example is a dramatic illustration of the manner in which the productivity of land, plant and labour can be increased by method study properly and systematically applied, at a cost of only 20 metres of light railway track.

5. The travel chart

The string diagram is a very neat and effective way of recording for critical examination the movement of workers or materials about the work area, especially when readily understood “before” and “after” models are needed to help in presenting the merits of a proposed change. String diagrams do take rather a long time to construct, however, and when a great many movements along complex paths are involved the diagram may end up looking like a forbidding maze of criss-crossing lines. When the movement patterns are complex, the **travel chart** is a quicker and more manageable recording technique.

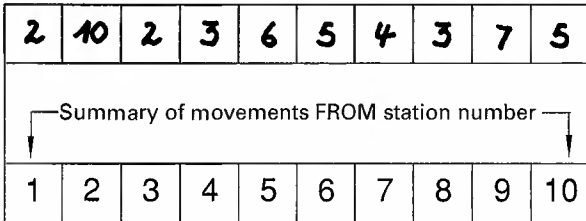
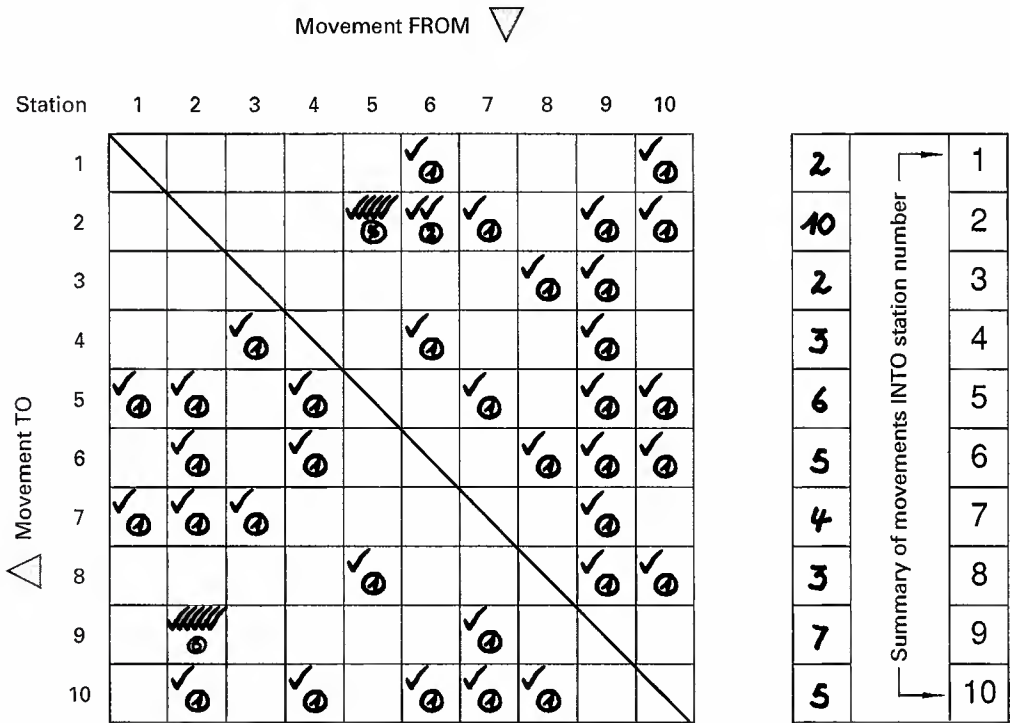
A travel chart is a tabular record for presenting quantitative data about the movements of workers, materials or equipment between any number of places over any given period of time

Figure 46 shows a typical travel chart. It records the movements of a messenger delivering papers or information to the various desks and workstations in an office. The layout of the office, showing the relative positions of the workstations, is sketched beneath the travel chart.

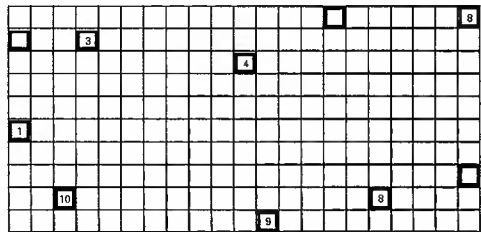
The travel chart is always a square, having within it smaller squares. Each small square represents a workstation — that is, in the present example, a place visited by the messenger. There are ten stations, and so the travel chart is drawn with ten small squares across, numbered 1 to 10 from left to right, and ten small squares down, again numbered 1 to 10 going down. Thus for ten workstations the travel chart contains a total of $10 \times 10 = 100$ small squares, and has a diagonal line drawn across it from top left to bottom right.

The squares from left to right along the top of the chart represent the places **from where** movement or travel takes place: those down the left-hand edge represent the stations **to which** the movement is made. For example, consider a movement from station 2 to station 9. To record this, the study person enters the travel chart at the square numbered 2 along the top of the chart, runs a pencil down vertically through all the squares underneath this one until he or she reaches the square which is horizontally opposite the station marked 9 on the left-hand edge. This is the terminal square, and the study person will make a mark in that square to indicate one journey from station 2 to station 9. All journeys are recorded in the same way, always starting at the top in the square of departure, always travelling vertically downwards, and always ending in the square opposite the station of arrival, as read from the left-hand

Figure 46. Travel chart: Movements of messenger in office



Layout sketch of office showing location of stations



edge. Of course, the study person does not actually trace in the path over which the pencil moves but just places a small tick or other mark in the terminal square to record the journey.

To make the recording method completely clear, let us suppose that the messenger travelled the following route: 2 to 9 to 5 to 3 and back to 2. The journey from 2 to 9 will be marked by a tick as described above. To enter the journey from 9 to 5, the study person will return to the top of the chart, select square 9, move down the column below this until he or she reaches the square opposite 5 on the left-hand edge, and record the movement by a tick there. To the top again to select square 5, down from there to that opposite 3; another tick for that journey. Finally, up to the top once more to select square 3, and down to that opposite number 2 for the recording of the final leg of the messenger's walk.

Example of a travel chart: Movement of messenger in an office

□ RECORD

The first stage of the recording process, that is when the method study person observes the movement of the messenger actually in the office, can be carried out very simply on a study sheet similar to that shown in figure 47. Once the stations visited have been numbered and keyed to a sketch of the workplace, the entries recording the journeys made require very little writing.

The travel chart is then compiled in the method study office. After all the movements have been entered on the chart with ticks, the ticks in each small square are added up, the total being entered in the square itself. The movements are then summarized, in two ways. Down the right-hand side of the chart, the number of movements **into** each station is entered against the square representing the station, as read from the left-hand edge. Underneath the chart, the number of movements **from** each station is recorded, this time under the relevant squares as read off the top of the chart.

In the chart in figure 46 there were two movements **into** station 1, as can be seen by running an eye across the line of squares against station 1 on the left-hand edge. Similarly, in the next horizontal line of squares, that opposite station 2, there are altogether ten movements shown, **into** station 2. For the movements **from** stations, the totalling is carried out vertically: it will be seen that there were ten movements from station 2, as shown in the column of squares under station 2 at the top of the chart. With very little practice, the chart and its summaries can be compiled extremely quickly — much quicker than it takes to describe what is done.

In figure 46 the summary of movements **into** each station shows the same number of movements as those recorded at the bottom as being made **from** that station, indicating that the messenger finished at the same station as he or she started out from when the study commenced. If he or she had finished somewhere else (or if the study had been broken off when he or she was somewhere else), there would have been one station where there was one more movement in than the number of movements out, and this would be where the study finished.

Figure 47. A simple study sheet

STUDY SHEET														
Department:	<i>Mining</i>								Section	<i>/</i>		Study No.	<i>147</i>	
Equipment:	<i>Lift Truck: Pallets</i>								Sheet:	<i>/</i>		of <i>2</i>		
Operation:	<i>Move 25-litre cans of material to mining machines and then to inspection (station)</i>								Taken by:	<i>CBA</i>		Date:		
<i>From</i>	<i>2</i>	<i>9</i>	<i>7</i>	<i>4</i>	<i>3</i>	<i>9</i>	<i>6</i>	<i>1</i>	<i>9</i>	<i>6</i>	<i>3</i>	<i>2</i>	<i>9</i>	
<i>To</i>	<i>9</i>	<i>7</i>	<i>4</i>	<i>3</i>	<i>9</i>	<i>6</i>	<i>1</i>	<i>9</i>	<i>6</i>	<i>3</i>	<i>2</i>	<i>9</i>	<i>7</i>	
<i>No. of cans</i>	<i>10</i>	<i>-</i>	<i>20</i>	<i>10</i>	<i>-</i>	<i>30</i>	<i>10</i>	<i>-</i>	<i>30</i>	<i>10</i>	<i>-</i>	<i>30</i>	<i>-</i>	
<i>From</i>	<i>7</i>	<i>1</i>	<i>6</i>	<i>4</i>	<i>9</i>	<i>8</i>	<i>2</i>	<i>5</i>	<i>9</i>	<i>7</i>	<i>2</i>	<i>5</i>	<i>9</i>	
<i>To</i>	<i>1</i>	<i>6</i>	<i>4</i>	<i>9</i>	<i>8</i>	<i>2</i>	<i>5</i>	<i>9</i>	<i>7</i>	<i>2</i>	<i>5</i>	<i>9</i>	<i>6</i>	
<i>No. of cans</i>	<i>10</i>	<i>20</i>	<i>-</i>	<i>30</i>	<i>40</i>	<i>20</i>	<i>30</i>	<i>40</i>	<i>10</i>	<i>20</i>	<i>10</i>	<i>30</i>	<i>40</i>	
<i>From</i>	<i>6</i>	<i>1</i>	<i>9</i>											
<i>To</i>	<i>1</i>	<i>9</i>	<i>6</i>											
<i>No. of cans</i>	<i>-</i>	<i>30</i>	<i>30</i>											

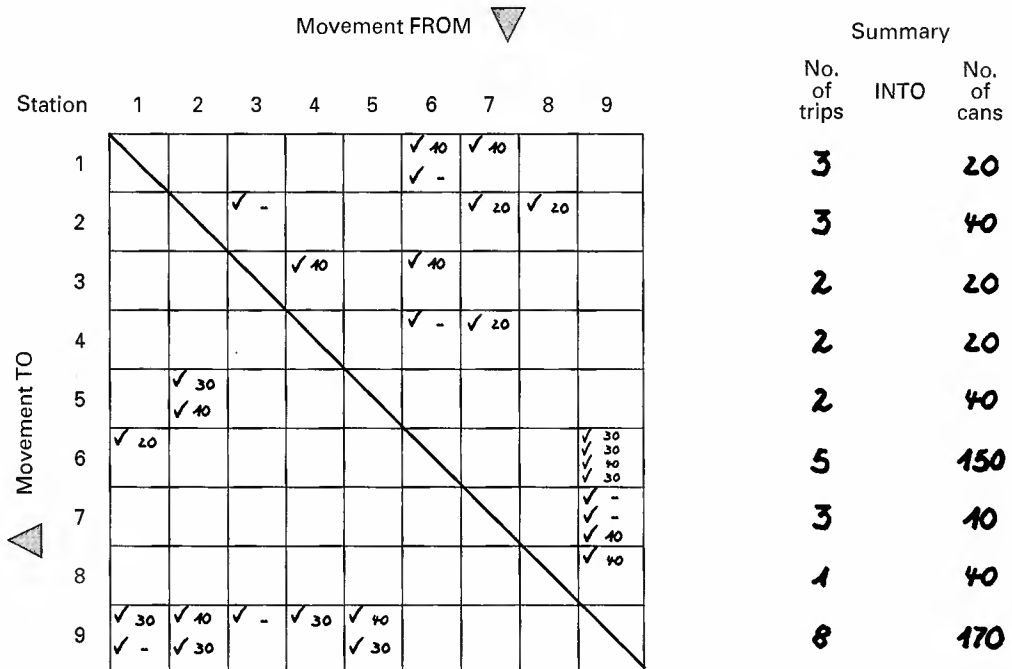
EXAMINE critically

An examination of the chart shows that ten journeys have been made into station 2, seven into station 9 and six into station 5. These are the busiest stations. A scrutiny of the body of the chart helps to confirm this: there were six journeys from station 2 to station 9, and five from station 5 to station 2. The busiest route is 5-2-9. This suggests that it would be better to locate these stations next to each other. It might then be possible for the clerk at station 5 to place finished work directly into the in-tray at station 2, and the clerk there to pass his or her work on to station 9, thus relieving the messenger of a good deal of travelling.

Example of a weighted travel chart: Material handling

A variation on the travel chart is the **weighted travel chart**. This records movements over a given time period (normally one shift or one day) and, in

Figure 48. Weighted travel chart: Material handling



Summary

No. of trips	3	4	2	2	2	4	3	1	8
FROM									
No. of cans	50	80	-	40	70	20	50	20	180

addition to recording journeys made between locations, shows the volume or weight of materials moved. Thus, each time a journey is recorded the volume or weight of the material is also recorded. At the end of the time period, the total traffic volume between each set of locations is entered on the tabular chart and used as the basis of examination.

An example of a weighted travel chart compiled as part of a material-handling study is shown in figure 48. In the shop in which the study was made, eight mixing machines were used to mix materials in different proportions, the final mixtures being taken to an inspection bench (station 6). The mixes were transported in 25-litre cans, which were placed on pallets and moved by a low lift truck.

RECORD

Movements were recorded on the shop floor on a study sheet of the type shown in figure 47. The entries show not only the journeys made but also the number of cans carried on each trip. In the travel chart shown in figure 48 there are nine stations, the eight mixing machines and the inspection bench. The travel chart was made exactly as in the previous example, except that in this instance the number of cans delivered was also entered in the destination squares, beside the ticks for the journeys, and both journeys and cans delivered have been summarized. It will be seen that, for instance, two journeys were made from station 5 to station 9, one with a load of 40 cans and the other with 30.

 EXAMINE critically

Not much can be learned from the study sheet, except that seven of the 29 trips made were run without any load, and that the size of load varied from ten to 40 cans. The travel chart, however, shows at once that stations 6 and 9 are busy ones. Five trips were made to station 6, with a total of 150 cans being delivered. (Station 6 was the inspection bench.) Four of these trips were from station 9, bringing in a total of 130 cans. The largest number of trips, and the greatest quantity of cans, was from station 9 to the inspection bench, suggesting that this route might be laid out so that it would be as short as possible. It might be possible to install a roller conveyor between these points, thus relieving the lift truck of a great deal of work.

Eight trips were made into station 9, to deliver 170 cans. The cans came from stations 1, 2, 4 and 5, one trip without load being made from station 3. Stations 1, 2, 4 and 5 appear to feed station 9, which sends its work on to the inspection bench (longer study might be necessary to confirm this). If so, there would be a case for modifying the layout of the shop in order to bring these stations closer together, when roller conveyors might allow gravity to do most of the transporting between them. In this example there is no sketch of the shop layout or table of distances between stations, both of which are essential complements to a travel chart.

It is interesting to note that four trips were made from station 2, but only three into the station; and that only four were made from station 6, although five were made into it. This is because the study started at station 2 and finished at the inspection bench.



Methods and movements at the workplace

1. General considerations

In this book we have gradually moved from the wide field of the productivity of industry as a whole to considering in a general way how the productivity of workers and machines can be improved through the use of work study. Still moving from the broader to the more detailed approach, we have also examined procedures of a general nature for improving the effectiveness with which complete sequences of operations are performed and with which material flows through the working area. Turning from materials to workers, we have discussed methods of studying the movements of persons around the working area and the relationships between men or women and machines or workers working together in groups. We have done so following the principle that the broad method of operation must be put right before we attempt improvements in detail.

The time has now come to look at one worker working at a workplace, bench or table and to apply to him or her the principles which have been laid down and the procedures shown in the examples given.

In considering the movements of workers and materials on the larger scale, we have been concerned with the more efficient use of existing plant and machinery (and, where possible, materials) through the elimination of unnecessary idle time, the more effective operation of processes and the more efficient use of the services of labour through the elimination of unnecessary and time-consuming movement within the working area of factory, department or yard.

As our example (Chapter 8) of the trolley operative's need for relaxation shows, the factor of fatigue affects the solution of problems even when we are dealing with areas larger than the individual workplace. But when we come to study individuals at the workplace, the way in which they apply their effort and the amount of fatigue resulting from their manner of working become primary factors affecting their productivity.

Before embarking on a detailed study of an operative doing a job at a single workplace, it is important to make certain that the job is in fact necessary and is being done as it should be done. The questioning technique must be applied as regards:

PURPOSE

To ensure that the job is necessary.

PLACE

To ensure that it is being done where it should be done.

 SEQUENCE

To ensure that it is in its right place in the sequence of operations.

 PERSON

To ensure that it is being done by the right person.

Once these have been verified and it is certain that the job cannot be eliminated or combined with another operation, it is possible to go on to determine the

 MEANS

by which the job is being done

and to simplify them as much as is economically justified.

Later in this chapter we shall consider the recording techniques adopted to set out the detailed movements of an individual at his or her workplace in ways which facilitate critical examination and the development of improved methods, in particular the **two-handed process chart**, as well as the **PTS chart** which will be referred to in Part Four of this book. Before doing this, however, it is appropriate to discuss the principles of motion economy and a number of other matters which influence the design of the workplace itself, so as to make it as convenient as possible for the worker to perform his or her job.

2. The principles of motion economy

There are a number of "principles" concerning the economy of movements which have been developed as a result of experience and which form a good basis for the development of improved methods at the workplace. They may be grouped under three headings:

A. Use of the human body

B. Arrangement of the workplace

C. Design of tools and equipment

They are useful in shop and office alike and, although they cannot always be applied, they do form a very good basis for improving the efficiency and reducing the fatigue of manual work. The ideas expounded by Professor Barnes¹ are described here in a somewhat simplified fashion.

A. Use of the human body

When possible:

- (1) The two hands should begin and complete their movements at the same time.
- (2) The two hands should not be idle at the same time except during periods of rest.
- (3) Motions of the arms should be symmetrical and in opposite directions and should be made simultaneously.

¹ See Ralph M. Barnes: *Motion and time study: Design and measurement of work* (New York and London, John Wiley, 7th ed., 1980), Chs. 15-17.

- (4) Hand and body motions should be made at the lowest classification at which it is possible to do the work satisfactorily (see section 3 below).
- (5) Momentum should be employed to help the worker, but should be reduced to a minimum whenever it has to be overcome by muscular effort.
- (6) Continuous curved movements are to be preferred to straight-line motions involving sudden and sharp changes in direction.
- (7) "Ballistic" (i.e. free-swinging) movements are faster, easier and more accurate than restricted or controlled movements.
- (8) Rhythm is essential to the smooth and automatic performance of a repetitive operation. The work should be arranged to permit easy and natural rhythm whenever possible.
- (9) Work should be arranged so that eye movements are confined to a comfortable area, without the need for frequent changes of focus.

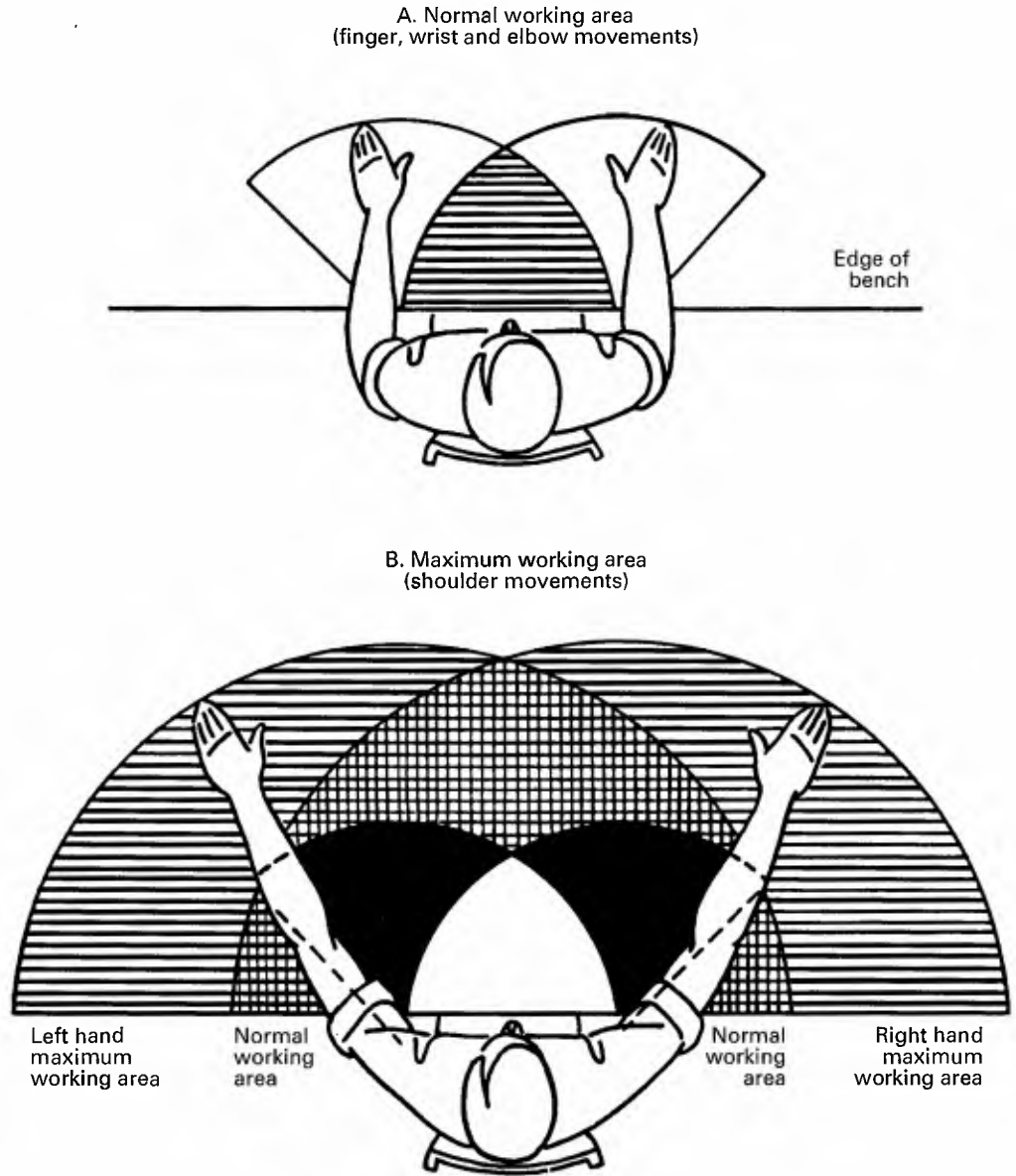
B. Arrangement of the workplace

- (1) Definite and fixed stations should be provided for all tools and materials to permit habit formation.
- (2) Tools and materials should be pre-positioned to reduce searching.
- (3) Gravity feed, bins and containers should be used to deliver the materials as close to the point of use as possible.
- (4) Tools, materials and controls should be located within the maximum working area (see figure 49) and as near to the worker as possible.
- (5) Materials and tools should be arranged to permit the best sequence of motions.
- (6) "Drop deliveries" or ejectors should be used wherever possible, so that the operative does not have to use his or her hands to dispose of the finished work.
- (7) Provision should be made for adequate lighting, and a chair of the type and height to permit good posture should be provided. The height of the workplace and seat should be arranged to allow alternate standing and sitting.
- (8) The colour of the workplace should contrast with that of the work and thus reduce eye fatigue.

C. Design of tools and equipment

- (1) The hands should be relieved of all work of "holding" the workpiece where this can be done by a jig, fixture or foot-operated device.
- (2) Two or more tools should be combined wherever possible.
- (3) Where each finger performs some specific movement, as in typewriting, the load should be distributed in accordance with the inherent capacities of the fingers.
- (4) Handles such as those on cranks and large screwdrivers should be so designed that as much of the surface of the hand as possible can come into contact with the handle. This is especially necessary when considerable force has to be used on the handle.

Figure 49. Normal and maximum working areas



- (5) Levers, crossbars and handwheels should be so placed that the operative can use them with the least change in body position and the greatest “mechanical advantage”.

These “principles”, which reflect those discussed in Chapter 5, can be made the basis of a summary “questionnaire” which will help, when laying out a workplace, to ensure that nothing is overlooked.

Figure 49 shows the normal working area and the storage area on the workbench for the average operative. As far as possible, materials should not be stored in the area directly in front of him or her, as stretching forwards

involves the use of the back muscles, thereby causing fatigue. This has been demonstrated by physiological research.

3. Classification of movements

The fourth "rule" of motion economy in the use of the human body calls for movements to be of the lowest classification possible. This classification is built up on the pivots around which the body members must move, as shown in table 9.

Table 9. Classification of movements

Class	Pivot	Body member(s) moved
1	Knuckle	Finger
2	Wrist	Hand and fingers
3	Elbow	Forearm, hand and fingers
4	Shoulder	Upper arm, forearm, hand and fingers
5	Trunk	Torso, upper arm, forearm, hand and fingers

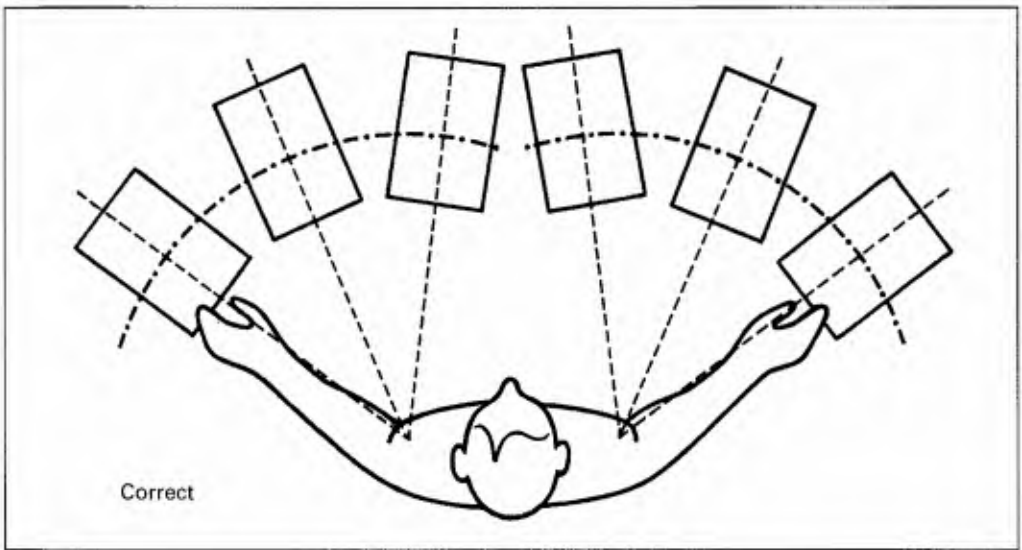
It is obvious that each movement above Class 1 will involve movements of all classes below it. Thus the saving in effort resulting from using the lowest class possible is obvious. If, in laying out the workplace, everything needed is placed within easy reach, this will minimize the class of movement which the work itself requires from the operative.

4. Further notes on workplace layout and simplification of movements

A few general notes on laying out the workplace may be useful.

- (1) If similar work is being done by each hand, there should be a separate supply of materials or parts for each hand.
- (2) If the eyes are used to select material, as far as possible the material should be kept in an area where the eyes can locate it without there being any need to turn the head.
- (3) Use semi-circular arrangements in preference to circular arrangements (see figure 50).
- (4) Design the workplace using ergonomic principles. In a sitting position a recommended posture is shown in figure 51.
- (5) The nature and the shape of the material influence its position in the layout. Use various bins such as those shown in figure 52 to accommodate material.

Figure 50. Semi-circular and circular working arrangement



This is a correct and better arrangement than a circular arrangement

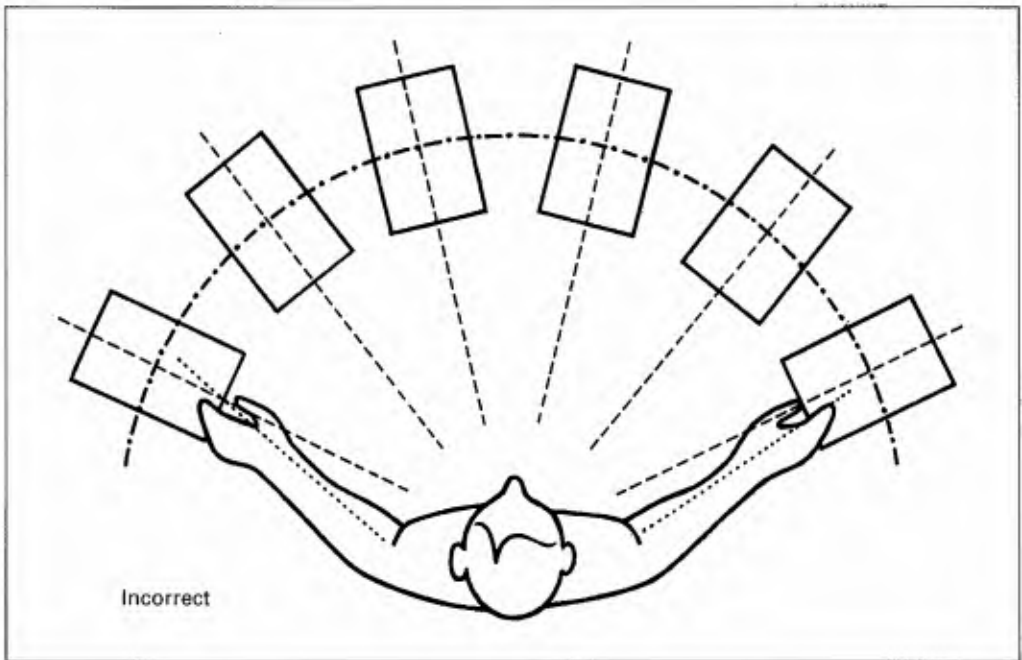
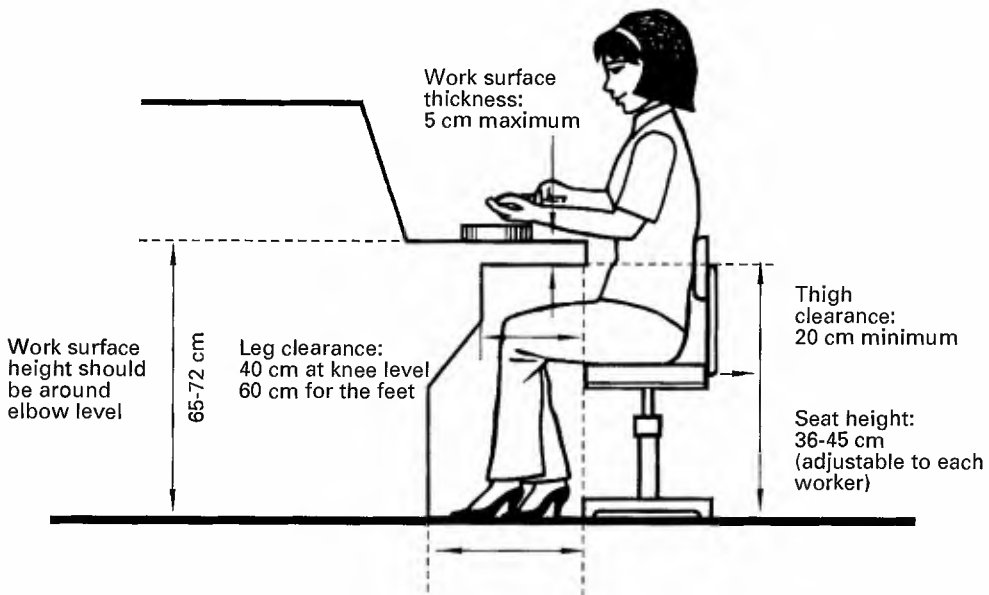


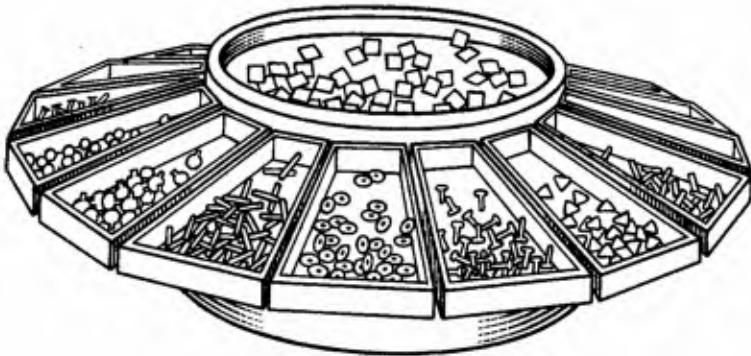
Figure 51. Recommended dimensions for seated tasks



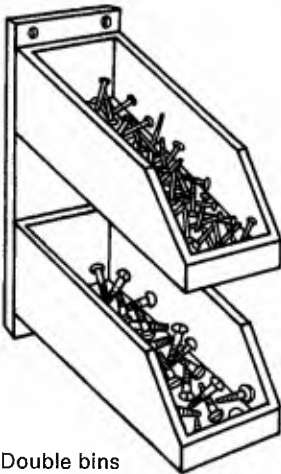
Source: Thurman et al., op. cit., figure 54.

- (6) Hand tools should be picked up with the least possible disturbance to the rhythm and symmetry of movements. As far as possible the operator should be able to pick up or put down a tool as the hand moves from one part of the work to the next, without making a special journey. Natural movements are curved, not straight; tools should be placed on the arc of movements, but clear of the path of movement of any material which has to be slid along the surface of the bench.
- (7) Tools should be easy to pick up and replace; as far as possible they should have an automatic return, or the location of the next piece of material to be moved should allow the tool to be returned as the hand travels to pick it up.
- (8) Finished work should be:
 - (a) dropped down a hole or a chute;
 - (b) dropped through a chute when the hand is starting the first motion of the next cycle;
 - (c) put in a container placed so that hand movements are kept to a minimum;
 - (d) if the operation is an intermediate one, placed in a container in such a way that the next operative can pick it up easily.
- (9) Always look into the possibility of using pedals or knee-operated levers for locking or indexing devices on fixtures or devices for disposing of finished work.

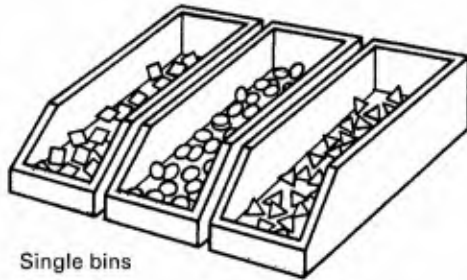
Figure 52. Various bins and motion-economy devices



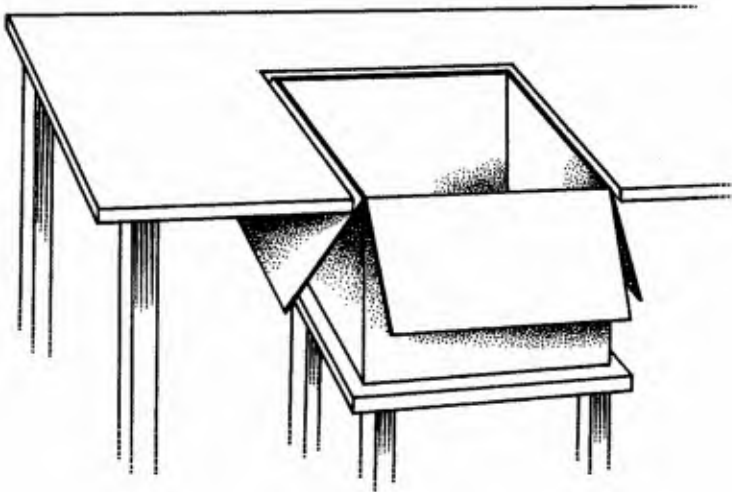
Rotating bin



Double bins



Single bins



Depression in a table to hold flaps of a carton for packaging operation

Figure 53. An example of a workstation layout



Source: Adapted from Thurman et al., op. cit., figure 53.

An example of a workstation layout

Let us now look at a typical workstation with the principles of motion economy and the notes in the previous section in mind.

Figure 53 shows a typical example of the layout of a workstation for the assembly of electrical equipment. Certain points will be noticed at once:

- (1) A fixture has been provided for holding the workpiece, leaving both the operative's hands free for assembly work. The use of one hand purely for holding the part being worked on should **always** be avoided, except for operations so short that a fixture would not be justified.
- (2) The necessary tools are suspended in front of the operative so that he or she has to make only a very short and easy movement to grasp them and bring them to the work. They are, however, clear of the surface of the table and of the work. The hammer and wire-cutter are within easy reach, so that the operative can pick them up without searching. They are placed to one side of the trays of parts, so that they do not get in the way.
- (3) All the small parts are close to the operative, well within the "maximum working area". Each part has a definite location, and the trays are designed with "scoop" fronts for easy withdrawal, parts being drawn forward with the tips of the fingers and grasped as they come over the rounded edge. They are arranged for symmetrical movements of the arms, so that parts which are assembled simultaneously are picked up from trays

in the same relative position to the operative, on either side of him or her. It will be noted that the trays come almost in front of the operative, but this is not very important in this case as the length of reach is not excessive and will not involve much play of the shoulder and back muscles.

5. Notes on the design of jigs, tools and fixtures

A jig holds parts in an exact position and guides the tool that works on them

A fixture is a less accurate device for holding parts which would otherwise have to be held in one hand while the other worked on them

The designer's object in providing jigs and fixtures is primarily accuracy in machining or assembly. Often, opening and closing them or positioning the workpiece calls for more movements on the part of the operative than are strictly necessary. For example, a spanner may have to be used to tighten a nut when a wing nut would be more suitable; or the top of the jig may have to be lifted off when the part might be slid in.

Cooperation between the work study person and the jig and tool designers, in industries where they are employed (principally the engineering industry), should start in the early stages of designing, and tool designers should be among the first people to take appreciation courses in method study. Some points worth noting are:

- (1) Clamps should be as simple to operate as possible and should not have to be screwed unless this is essential for accuracy of positioning. If two clamps are required, they should be designed for use by the right and left hands at the same time.
- (2) The jig should be designed so that both hands can load parts into it with a minimum of obstruction. There should be no obstruction between the point of entry and the point from which the material is obtained.
- (3) The action of unclamping a jig should at the same time eject the part, so that additional movements are not required to take the part out of the jig.
- (4) Where possible on small assembly work, fixtures for a part which does not require both hands to work on it at once should be made to take two parts, with sufficient space between them to allow both hands to work easily.
- (5) In some cases jigs are made to take several small parts. It will save loading time if several parts can be clamped in position as quickly as one.
- (6) The work study person should not ignore machine jigs and fixtures such as milling jigs. A great deal of time and power is often wasted on milling machines owing to the fact that parts are milled one at a time, when it may be quite feasible to mill two or more at once.

- (7) If spring-loaded disappearing pins are used to position components, attention should be paid to their strength of construction. Unless the design is robust, such devices tend to function well for a while but then have to be repaired or redesigned.
- (8) In introducing a component into a jig it is important to ensure that the operative should be able to see what he or she is doing at all stages; this should be checked before any design is accepted.

6. Machine controls and displays of dials

Until recently, machinery and plant of all kinds were designed with very little thought being given to the convenience of the operative. In short cycle work especially, the manipulation of the controls (changing speeds on a capstan lathe, for example) often involved awkward movements. There is not much that the user can do about the controls of a machine after having bought it; but he or she **can** draw the attention of the makers to inconvenient controls so that they can make improvements in later models. There is evidence, however, that machinery makers generally are becoming more conscious of this problem. In the few companies that make their own machinery or plant, the work study department should be called in at the earliest possible stage of the design process, to give assistance and advice.

Physiologists and psychologists have given some thought to the arrangement of dials with a view to minimizing the fatigue to people who have to watch them. The arrangement of the control panels for chemical processes and similar types of process is often made at the works installing them, and the work study person should be consulted when this is done.

The growing awareness of the importance of arranging machine controls and workplaces so that they are convenient for the people who have to do the work has led in recent years to the development of a new field of scientific study which is concerned entirely with such matters. This is **ergonomics**,² the study of the relationship between a worker and the environment in which he or she works, particularly the application of anatomical, physiological and psychological knowledge to the resulting problems. Ergonomists have carried out many experiments to decide on matters such as the best layout for machine controls, the best dimensions for seats and worktops, the most convenient pedal pressures, and so on, and this is often incorporated in the designs of new machines and equipment.

7. The two-handed process chart

The study of the work of an operative at the bench starts, as does method study over the wider field, with a process chart. In this case the chart used is the fifth of the charts indicating process sequence (table 8), the one known as the **two-handed process chart**.

² See Ch. 5.

The two-handed process chart is a process chart in which the activities of a worker's hands (or limbs) are recorded in their relationship to one another

The two-handed process chart is a specialized form of process chart because it shows the two hands (and sometimes the feet) of the operative moving or static in relation to one another, usually in relation to a time scale. One advantage of incorporating a time scale in the chart form is that the symbols for what the two hands are doing at any given moment are brought opposite each other.

The two-handed process chart is generally used for repetitive operations, when one complete cycle of the work is to be recorded. Recording is carried out in more detail than is normal on flow process charts. What may be shown as a single operation on a flow process chart may be broken down into a number of elemental activities which together make up the operation. The two-handed process chart generally employs the same symbols as the other process charts; however, because of the greater detail covered, the symbols are accorded slightly different meanings:

- **OPERATION** Is used for the activities of grasp, position, use, release, etc., of a tool, component or material.
- ⇒ **TRANSPORT** Is used to represent the movement of the hand (or limb) to or from the work, a tool or material.
- D **DELAY** Is used to denote time during which the hand or limb being charted is idle (although the others may be in use).
- ▽ **HOLD** The term **storage** is not used in connection with the two-handed process chart. Instead, the symbol is redesignated as **hold** and is used to represent the activity of holding the work, a tool or material — that is, when the hand being charted is holding something.

The symbol for **inspection** is not much used because the hand movements when an operative is inspecting an article (holding it and examining it visually or gauging it) may be classified as “operations” on the two-handed chart. It may, however, sometimes be useful to employ the “inspection” symbol to draw attention to the examination of a piece.³

The very act of making the chart enables the work study specialist to gain an intimate knowledge of the details of the job, and the chart itself enables him or her to study each element of the job by itself and in relation to other elements. From this study ideas for improvements are developed. These ideas should be written down in chart form when they occur, just as in all other process charting. It may be that different ways of simplifying the work can be

³ Some authorities feel that the standard process-chart symbols are not entirely suitable for recording hand and body movements and have adopted variants, such as:

O: Operation; TL: Transport loaded; TE: Transport empty; H: Hold; R: Rest.

found; if they are all charted, they can be compared easily. The best method is generally that which requires the fewest movements.

The two-handed process chart can be applied to a great variety of assembly, machining and clerical jobs. In assembly operations, tight fits and awkward positioning present certain problems. In the assembly of small parts with close fits, "positioning" should be shown as a separate movement ("Operation") apart from the actual movement of assembly (e.g. fitting a screwdriver in the head of a small screw). Attention can thus be focused on it and, if it is shown against a time scale, its relative importance can be assessed. Major savings can be made if the number of such positionings can be reduced.

Notes on compiling two-handed process charts

The chart form should include:

- spaces at the top for the usual information;
- adequate space for a sketch of the layout of the workplace (corresponding to the flow diagram used in association with the flow process chart), or a sketch of jigs, etc.;
- spaces for the movements of right and left hands;
- space for a summary of movements and analysis of idle time;

Examples are given in the following pages.

Some points on compiling charts are worth mentioning:

- (1) Study the operation cycle a few times before starting to record.
- (2) Chart **one** hand at a time.
- (3) Do not record more than a few symbols at a time.
- (4) The action of picking up or grasping a fresh part at the beginning of a cycle of work is a good point at which to start the record. Start with the hand that handles the part first or the hand that does the most work. The exact point of starting is not really important, as the complete cycle will eventually come round to it again, but the point chosen must be definite. Add in the second column the kinds of work done by the other hand.
- (5) Only record actions on the same level **when they occur at the same moment**.
- (6) Actions which occur **in sequence** must be recorded on the chart at different horizontal levels. Check the chart for the time relation of the hands.
- (7) Care must be taken to list **everything** the operative does and to avoid combining operations and transports or positionings, unless they actually occur at the same time.

Example of a two-handed process chart: Cutting glass tubes

This very simple example describes how a two-handed process chart was constructed for cutting off short lengths of glass tube with the aid of a jig. This is illustrated on the form; the operations involved are self-explanatory (figure 54).

Figure 54. Two-handed process chart: Cutting glass tubes (original method)

Two-handed process chart									
Chart No. 1		Sheet No. 1		of 1					
Drawing and part: <i>Glass tube 3 mm dia., 1 metre original length</i>			Workplace layout						
Operation: <i>Cut to lengths of 1.5 cm</i>			Original method						
Location: <i>General shop</i>									
Operative:									
Charted by		Date:							
Left-hand description	○	▷	◻	▽	○	▷	◻	▽	Right-hand description
<i>Holds tube</i>									<i>Picks up file</i>
<i>To jig</i>									<i>Holds file</i>
<i>Inserts tube to jig</i>									<i>File to tube</i>
<i>Presses to end</i>									<i>Holds file</i>
<i>Holds tube</i>									<i>Notches tube with file</i>
<i>Withdraws tube slightly</i>									<i>Holds file</i>
<i>Rotates tube 120°/180°</i>									<i>Holds file</i>
<i>Pushes to end jig</i>									<i>Moves file to tube</i>
<i>Holds tube</i>									<i>Notches tube</i>
<i>Withdraws tube</i>									<i>Places file on table</i>
<i>Moves tube to R. H.</i>									<i>Moves to tube</i>
<i>Bends tube to break</i>									<i>Bends tube</i>
<i>Holds tube</i>									<i>Releases cut piece</i>
<i>Changes grasp on tube</i>									<i>To file</i>
Summary									
Method	Present		Proposed						
	L. H.	R. H.	L. H.	R. H.					
<i>Operations</i>	8	5							
<i>Transports</i>	2	5							
<i>Delays</i>	-	-							
<i>Holds</i>	4	4							
<i>Inspections</i>	-	-							
<i>Totals</i>	14	14							

RECORD

In the original method the tube was pressed to the stop at the end of the jig, marked with the file and then eased back for notching. It was then taken out of the jig for breaking. The chart goes into great detail in recording the movements of the hands, because in short cycle work of this kind fractions of seconds, when added together, may represent a large proportion of the total time needed for the job.

EXAMINE critically

An examination of the details of the original method, using the questioning technique, at once raises certain points. (It is not considered necessary to go through the questions in sequence at this stage in the book: it is assumed that the reader will always do so.)

- (1) Why is it necessary to hold the tube in the jig?
- (2) Why cannot the tube be notched while it is being rotated instead of the right hand having to wait?
- (3) Why does the tube have to be taken out of the jig to break it?
- (4) Why pick up and put down the file at the end of each cycle? Can it not be held?

A study of the sketch will make the answers to the first three questions plain.

- (1) The tube will always have to be held because the length supported by the jig is short compared with the total length of the tube.
- (2) There is no reason why the tube cannot be rotated and notched at the same time.
- (3) The tube has to be taken out of the jig to be broken because, if the tube were broken by bending against the face of the jig, the short end would then have to be picked out — an awkward operation if very little were sticking out. If a jig were so designed that the short end would fall out when broken, it would not then be necessary to withdraw the tube.

The answer to the fourth question is also obvious.

- (4) Both hands are needed to break the tube using the old method. This might not be necessary if a new jig could be devised.

DEVELOP the new method

Once these questions have been asked and answered, it is fairly easy to find a satisfactory solution to the problem. Figure 55 shows one possible solution. It will be seen that, in redesigning the jig, the study person has arranged it in such a way that the notch is cut on the right-hand side of the supporting pieces, so that the short end will break away when given a sharp tap and it will no longer be necessary to withdraw the tube and use both hands to break off the end. The number of operations and movements has been reduced from 28 to six, as a result of which an increase in productivity of 133 per cent was expected. In fact this was exceeded, because the job is now more satisfactory following the elimination of irritating work such as "position tube in jig". The new method can be carried out without looking closely at the work, so that workers can be trained more easily and become less fatigued.

8. Micromotion study

In certain types of operation, and particularly those with very short cycles which are repeated many times over, it may be worth while going into much greater detail to determine where movements and efforts can be saved and to develop the best possible pattern of movement, thus enabling the operative to perform the operation repeatedly with a minimum of effort and fatigue. The techniques used for this purpose are known collectively as **micromotion study**.

In the earlier periods of work study special types of chart such as the simo chart, as well as special micromotion symbols known as therbligs, were used for micromotion study. These have now been replaced by the use of Predetermined Time Standards charts (PTS charts), which will be explained in Part Four of this book, as well as by the use of film and video.

Both film and video cameras can be used to record activities at the workplace. Although film provides greater flexibility in terms of filming and playback speeds, video is generally cheaper and easier to use. With a good-quality video playback unit, it is possible to have high-quality slow motion and still-frame facilities.

The advantages of film and video over direct observation are that they:

- (a) permit greater detailing than eye observation;
- (b) provide greater accuracy than pencil, paper and watch techniques;
- (c) are more convenient;
- (d) provide a positive record;
- (e) help in the development of the work study persons themselves.

The use of films

In micromotion study, films may be used for the following purposes:

- (1) **Memomotion photography** (A form of time-lapse photography which records activity by the use of a cine camera adapted to take pictures at longer intervals than normal. The time intervals usually lie between 0.5 sec. and 4 sec.)

A camera is placed with a view over the whole working area to take pictures at the rate of one or two per second instead of the usual rate of 24 frames per second. The result is that the activities of ten or 20 minutes may be compressed into one minute and a very rapid survey of the general pattern of movements may be obtained, from which the larger movements giving rise to wasted effort can be detected and steps taken to eliminate them. This method of analysis, which is a recent development, has considerable possibilities and is very economical.

- (2) **Retraining of operatives**

Both for this purpose and for analysis it may be necessary to have slow-motion pictures of the process (produced by photographing at high speed); considerable use can be made of loops for this purpose.

The use of video

Video is being used more and more as a vehicle for analysing motions, though it is difficult to obtain equipment with the capacity for time-lapse recording.

Video is also used in a wider sense in method study to record the movements of people and materials in a given workplace, and the type of handling or storage facilities used. A multitude of useful data can then be viewed quickly by the work study specialist in order to assist him or her in drawing up charts, analysing the operation and developing a new method.

In addition, video is becoming a very useful tool for training, for presenting to management, supervisors and workers the existing and the proposed methods of work, and for actively involving those concerned in discussing the nature of the improvements proposed.

9. Other recording techniques

Here we shall describe very briefly one or two other techniques of recording and analysis which have so far only been mentioned, and which will not be dealt with further in this introductory book.

Table 8 in Chapter 7 listed five diagrams indicating movement which are commonly used in method study. Three of these, the flow diagram, the string diagram and the travel chart, have already been described, with examples, in earlier chapters. The other two are the cyclegraph and the chronocyclegraph.

The **cyclegraph** is a record of a path of movement, usually traced by a continuous source of light on a photograph, preferably stereoscopic. The path of movement of a hand, for instance, may be recorded on a photograph in this way if the worker is asked to wear a ring carrying a small light which will make the trace on the photograph. Alternatively, such a light may be attached to a worker's helmet if the purpose is to obtain a record of the path over which he or she moves during the performance of a task.

The **chronocyclegraph** is a special form of cyclegraph in which the light source is suitably interrupted so that the path appears as a series of pear-shaped dots, the pointed end indicating the direction of movement and the spacing indicating the speed of movement.

In comparison with the other recording techniques outlined in this book, the cyclegraph and chronocyclegraph are of limited application, but there are occasions on which photographic traces of this sort can be useful.

10. The development of improved methods

In each of the examples of the different method study techniques given so far, our discussion has covered the three stages of *RECORD*, *EXAMINE* and *DEVELOP*, but has been focused primarily on the first two, the development stage being discussed only as far as was necessary to draw attention to the improvements made in method as a result of using the particular diagram or form being demonstrated.

It will now be appropriate to study a little more closely the manner in which improved methods can be developed.

One of the rewards of method study is the large saving which can often be made from quite small changes and inexpensive devices, such as chutes or suitable bins.

An example of this is a small spring-loaded table, very cheaply made in plywood, for removing the tiles from an automatic tile-making machine. The spring was so calibrated that, each time a tile was pushed on to it by the machine, it was compressed until the top of the tile dropped to the level of the machine platform so that the table was ready to receive the next tile. This enabled the woman operating the machine to concentrate on loading the finished tiles on to a rack ready for firing while the new stack was piling up. When about a dozen tiles were in place, she was able to lift them off the table, which immediately sprang up to the level of the machine platform ready to receive the first tile of the next stack. This very simple device enabled the second operative formerly employed on this operation to be released for other work, an important feature in an area where skilled tile-pressers were difficult to obtain.

In many manufacturing plants the work study person may have to go beyond the study of the movements of materials and workers if he or she is going to make the most effective contribution to increased productivity. For example, he or she must be prepared to discuss with the designers the possibility of using alternative materials which would make the product easier and quicker to manufacture. Even if he or she is not an expert in design — and, indeed, cannot be expected to be — drawing attention to the possibilities of an alternative may put ideas into the minds of the designers themselves which they had previously overlooked. After all, like everyone else, they are human and often hard-worked, and there is a strong temptation to specify a given material for a given product or component simply because it has always been used in the past. Other similar interventions will be outlined in Part Three of this book.

Apart from the elimination of obviously wasteful movements — which can be done from the flow diagram or process chart — the development of improved methods calls for skill and creativity. It is likely to be more successful if work study specialists are also well acquainted with the industry with which they are concerned. In any but the simplest manual operations, they will have to consult the technical or supervisory staff and, even if they do know the right answer, it is better that they should do so, since a method which the staff have taken part in developing is likely to be accepted more readily than one which is introduced as someone else's idea. The same is true of the operatives. Let everyone put forward his or her ideas — two heads are better than one!

The fact that really successful methods improvement is a combined operation is being increasingly recognized. Many organizations, large and small, have set up groups for the improvement of manufacturing and operating methods. These groups may be permanent or set up for some particular job such as the re-laying out of a shop or factory, or the organization of work. Such

groups often decide on the division and allocation of work as well as other related functions such as the control of quality.

Some of these groups are known as “productivity circles” or “quality circles”. Their task is to meet regularly to try to see how they can improve the efficiency of their operation. Prior training by a specialist in elementary approaches to method study can yield high dividends. Apart from that, a work study specialist can always be available as a resource person if the group calls on him or her.

Evaluate, define, install, maintain

1. Evaluating alternative methods

The *DEVELOP* stage of the method study procedure should result in proposed changes to existing ways of carrying out the work under review. Sometimes the changes to be made are clear-cut and a revised method can be clearly defined. In many instances, however, the method study highlights a number of possible changes and therefore a number of potential new methods. Some of these may be capable of immediate introduction, while others — such as the introduction of new equipment, the building of new jigs or fixtures, operator training and so on — may require further actions to be carried out before they can be implemented. The sponsors of the investigation (normally the managers or supervisors in the area in which it is taking place) must make a decision as to the preferred solution. To make this decision, they need appropriate information on the alternative methods, the likely results of the proposed changes and the costs of implementation. Thus the method study person should prepare a cost-benefit analysis for each of the proposed methods. This is normally done in a number of stages.

A “first pass” is carried out in which very broad costs and benefits are associated with each potential change. This can often be done very quickly and gives sufficient information to exclude a number of possible changes and methods from the more detailed evaluation process.

It is important when examining benefits to include not only those that can be easily quantified (such as direct financial savings) but also those that can be expressed only in qualitative terms. Such benefits (for example, improvements in job satisfaction, employee morale or industrial relations) can have significant long-term effects on financial performance and must be included in the evaluation process.

In order to allow the inclusion of qualitative factors alongside quantitative factors as part of the evaluation of alternative methods, use is often made of “pseudo-quantitative” techniques. These express the qualitative benefits in quantitative terms (by translating subjective judgements into numerical scores), allowing the quantitative and qualitative benefits to be combined in an overall evaluation.

A common approach is to use a combination of scoring and weighting. The various factors (normally benefits, but they can include negative benefits or disadvantages) that relate to the potential solutions are listed. This list may

include such entries as direct cost savings, improved safety, greater labour flexibility and so on. A relative weighting is assigned to each factor to indicate its relative importance to the organization. This weighting must be achieved by discussion with the managers or supervisors involved in the work area. (One advantage of this method is that it requires those responsible for the decision-making process to think carefully about their priorities.)

Each potential method is then “scored” against each factor (normally on a simple 1 to 5 or 1 to 10 scale). This scoring can be based on quantitative data, where this is available, or on subjective judgement.

Finally, the score of each factor is multiplied by the weighting for that factor and the resultant sum gives an overall score for that particular potential method, as shown in the example below.

	Weighting	Score	Factor
Cost reduction	4	1	4
Labour flexibility	2	4	8
Increased output	1	4	4
		Total	16

In the above example, a method that will increase output significantly (scoring 4 out of 5 points on that factor) obtains a low overall score because that particular factor carries a low weighting — since the enterprise is not able to sell any increased output.

The main advantage of such a method is not that it produces a numerical result but that it forces those involved in the evaluation process to consider all factors (even those which are not easily measurable) and makes them think carefully about the relative importance of each one. The final figures are guidelines only.

For some kinds of investigation, it may be possible to make use of formal decision-support techniques such as decision matrices and decision trees. As with the simple weighting and scoring method above, such techniques do not make decisions — they provide a framework through which information can be presented and judgemental thinking can be carried out.

When measuring financial costs and benefits which accrue or are expended over time, it may be necessary to use such techniques as discounted cash flow to allow the comparison of incomes and expenditure at present-day monetary values.

The nature of the evaluation outlined above depends on the nature of the situation under review and the scope and scale of the proposed changes. Where the change is minor both in terms of any disruption involved and in terms of the implementation costs, the evaluation can be carried out in a matter of minutes and a decision taken by the supervisor; in other cases it may require a significant investigation in its own right to determine and assess the likely costs and benefits.

The findings of this evaluation phase are included in the project report, perhaps with a recommended course of action, submitted to the management of the area under review. The format of this report may be determined by a “house

style” within the organization. Where this is not the case, the practitioner should simply follow the simple “A-B-C” rule by ensuring that the report is:

ACCURATE

BRIEF

and

CLEAR

Discussions that have taken place during the method study should ensure that the findings contained within this report are no surprise to the readers — the purpose of the report is to summarize the investigation, to present the findings, to produce evaluation data and to make recommendations supported by the material in the report.

Where the recommendation to proceed with a particular new method is very strong and the resulting decision to proceed is clearly anticipated, the report may include a detailed implementation plan for the changes to be adopted. Where this is not the case, the detailed plan may be left until after the decision has been taken — but an outline plan will have been constructed so that implementation costs could be included in the valuation of alternative methods.

If the investigation has been carried out in a structured and systematic manner, and the report has been soundly constructed, the manager is best able to make a rational decision, and the practitioner should ensure that his or her reputation is enhanced.

2. Defining the improved method

Once a decision has been taken on the changes in method to be adopted, it is important that the new method should be strictly defined.

The written standard practice

For all jobs other than those performed on standard machine tools or specialized machines where the process and methods are virtually controlled by the machine, it is desirable to prepare a written standard practice, also known as an “operative instruction sheet”. This serves several purposes:

- (1) It records the improved method for future reference, in as much detail as may be necessary.
- (2) It can be used to explain the new method to management, supervisors and operatives. It also advises all concerned, including the works engineers, of any new equipment required or of changes needed in the layout of machines or workplaces.
- (3) It is an aid to training or retraining operatives and can be used by them for reference until they are fully conversant with the new method.
- (4) It forms the basis on which time studies may be taken for setting standards, although the breakdown by element (see Chapter 20) will not necessarily be the same as the breakdown by motion.

The written standard practice outlines in simple terms the methods to be used by the operative. Three sorts of information will normally be required:

- (1) The tools and equipment to be used and the general operating conditions.
- (2) A description of the method. The amount of detail required will depend on the nature of the job and the probable volume of production. For a job which will occupy several operatives for several months, the written standard practice may have to be very detailed, going into finger movements.
- (3) A diagram of the workplace layout and, possibly, sketches of special tools, jigs or fixtures.

A very simple written standard practice for the operation studied in Chapter 9, section 7 (cutting glass tubes to length), is illustrated in figure 56. The same principle is followed in more complex cases. In some of these the description may run into several pages. The workplace layout and other diagrams may have to be put on a separate sheet. With the more widespread use in recent years of standardized printed sheets for process charts, it is becoming common practice to attach a fair copy of the appropriate process chart to the written standard practice, whenever the simple description entered on it does not constitute a complete definition of the method.

3. Installing the improved method

The final stages in the basic procedure are perhaps the most difficult of all. It is at this point that active support is required from management and trade unions alike. It is here that the personal qualities of the work study person, his ability to explain clearly and simply what he or she is trying to do and a gift for getting along with other people and winning their trust become of the greatest importance.

Installation can be divided into five stages, namely:

- (1) Gaining acceptance of the change by management.
- (2) Gaining acceptance of the change by the departmental supervision.

These two steps are covered in the evaluation and reporting of the alternative methods and have already been discussed. There is no point in trying to go any further if this approval and acceptance have not been obtained.

- (3) Gaining acceptance of the change by the workers and their representatives.
- (4) Preparing to make the changes.
- (5) Controlling the change-over.

If any changes are proposed which affect the number of workers employed in the operation, the workers' representatives must be consulted as early as possible. There may be existing agreements about the displacement of labour and these, naturally, must be adhered to. Plans must be constructed that minimize the hardship or inconvenience caused to workers. This applies not only to job losses but also to changes in work organization, location and so on.

162 Individuals working within a particular section or department establish bonds

Figure 56. Standard practice sheet

Standard practice sheet			
Product: <i>3 mm diam. glass tube, supplied in 1 metre lengths</i>		Equipment <i>Jig No. 231 Half-round 15 cm</i>	
Operation: <i>File and break to lengths of 1.5 cm</i>			
Working conditions: <i>Light good</i>			
Location: <i>Fitting shop</i>		Ref. studies Nos. 12, 13	
Operative:		Clock No. 54	Charted by:
			Date:
		Approved by:	Date:
EL	Left hand	Right hand	EL
1	<i>Take tube between thumb and first two fingers: push forward to stop</i>	<i>Hold file: wait for L.H.</i>	1
2	<i>Rotate tube between thumb and fingers</i>	<i>Notch tube all round with edge of file hard up against face of jig</i>	2
3	<i>Hold tube</i>	<i>Tap notched end of tube sharply with file so that it falls into chute</i>	3

and social relationships which are often very important in determining job satisfaction. Any changes to these established relationships will be resented.

In the case of team or group working, the bonds are far stronger; and breaking up such a team may have serious, adverse effects on productivity, in spite of improved methods. Allegiance of group members to their working group is often stronger than their allegiance to the organization. Failure to take this into account may lead the workers to resist changes which they would otherwise accept.

It is in carrying out the first three steps of installation that the importance of preliminary education and training in work study for all those likely to be concerned with it — management, supervisors and workers' representatives — becomes evident. People are much more likely to be receptive to the idea of change if they know and understand what is happening than if they are merely presented with the results of a sort of conjuring trick. Where work groups are involved in the work under review, it is often advantageous to hold discussions with the group, rather than separately with individual members. This allows group views and fears to be expressed and dealt with.

4. Preparing to make the changes

Where redundancy or a transfer are not likely to be involved, the workers are much more likely to accept new methods if they have been allowed to share in their development. The work study person should confide in the operative from the start, explaining what he or she is trying to do and why, and the means by which he or she expects to do it. If the operative shows an interest, the uses of the various tools of investigation should be explained. The string diagram is one of the most useful of these in gaining interest: most people like to see their activities portrayed, and the idea that he or she walks so far in the course of a morning's work is often a surprise to the worker and makes him or her delighted at the idea of reduced effort. Always ask the workers for their own suggestions or ideas on improvements that can be made, and wherever they can be implemented, do so, **giving the people credit** for them (major suggestions may merit a monetary reward). Let the workers play as full a part as possible in the development of the new method, until they come to feel that this is mainly or partly their own.

It may not always be possible to obtain very active cooperation from unskilled personnel, but they usually have some views on how their jobs can be made easier — or less subject to interruption — which may give important leads to the work study person in reducing wasted time and effort.

Wholehearted cooperation at any level will only come as the result of confidence and trust. Work study practitioners must convince management that they know what they are doing. They should have the respect of the supervisors and technicians, who must realize that they are not there to displace them or show them up, but as specialists at their disposal to help them. Finally, work study people must convince the workers that they are not going to affect their job security.

Where there is deep-rooted resistance to change, it may be necessary to decide whether the savings likely to be made by adopting the new method justify the time and trouble involved in putting the change through and retraining older operatives. It may be cheaper to concentrate on new trainees and let the older workers continue to work in the way they know.

In gaining the trust of the workers, the work study person will find that they will tend to turn to him or her for decisions rather than to the supervisor (a danger already discussed). This situation must not be allowed to arise. The work study person must make certain from the first that everyone understands that he or she cannot give executive decisions and that the instructions concerning the introduction and application of the new methods must come from the supervisor to the worker in the first instance. Only then can he or she proceed.

It is important that the change-over from an existing method to a revised one is properly planned. The first task is to identify the various activities that must be undertaken before the new method can be implemented. The most obvious ones are the purchase or construction of new equipment, tools, fixtures and so on, but the list may include the alteration of layouts or the training of operators. Each of these will have a different "lead time" before it can be completed, and thus an overall implementation schedule must be constructed to ensure that each activity is completed before the final change-over to the new method is made.

Training and retraining operatives

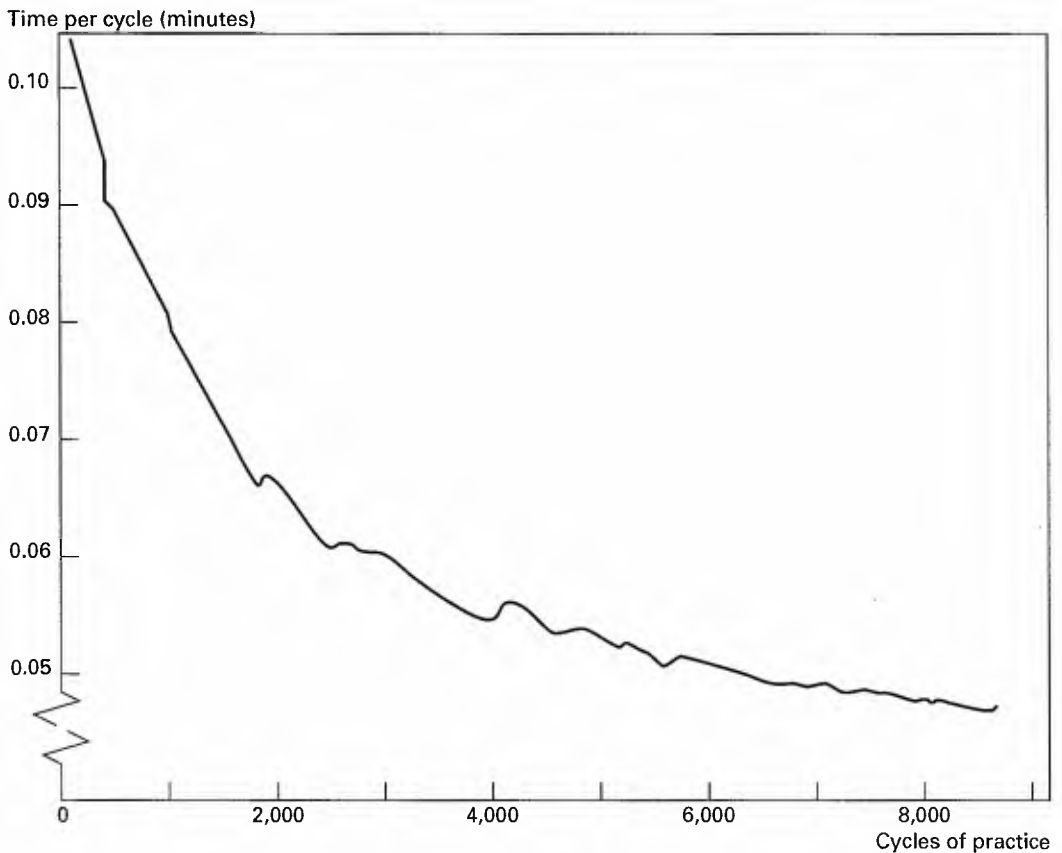
The extent to which the workers require retraining will depend entirely on the nature of the job. It will be greatest in the case of jobs involving a high degree of manual dexterity which have long been done by traditional methods. In such cases it may be necessary to resort to films to demonstrate the old and the new methods and the manner in which movements should be made. Each job will have to be treated on its merits.

In the training or retraining of operatives, the important thing is to develop the **habit** of doing the job in the correct way. Habit is a valuable aid to increased productivity as it reduces the need for conscious thought. Good habits can be formed just as easily as bad ones.

Beginners can be taught to follow a numbered sequence illustrated on a chart or they may be taught on the machine itself. Either way, they must be made to understand the reason for every movement. Still pictures together with instruction sheets have proved very successful. Slides or video can also be used.

Films are particularly valuable when retraining. When old habits have to be broken, it may be found that the workers are quite unaware of what they are doing. A film in slow motion will enable them to see their exact movements and, once these are understood, they can start to learn the new method. It is important that the new method should be really different from the old, otherwise the operatives will tend to slip back into their old ways, especially if they are not young and have spent many years doing the job.

Figure 57. A typical learning curve



In learning a new series of movements, the operative gathers speed and reduces the time required to perform them very quickly at first. The rate of improvement soon begins to slow up, however, and it often requires long practice to achieve really high and consistent speed, although the adoption of modern accelerated training methods will considerably shorten the time needed. A typical “learning curve” is shown in figure 57.

Experiments have shown that in the first stages of learning, to obtain the best results, rests between periods of practice should be longer than the periods of practice themselves. This situation alters rapidly, however, and when the operative has begun to grasp the new method and to pick up speed, rest periods can be very much shorter.

As part of the process of installation it is essential to keep in close touch with the job, once it has been started, to ensure that the operative is developing speed and skill and that there are no unforeseen snags. This activity is often known as “nursing” the new method, and the term is an apt one. Only when the work study person is satisfied that the productivity of the job is at least at the level he or she estimated and that the operative has settled down to it can it be left — for a time.

5. Controlling the change-over

Changing from one method to another must be planned and controlled. Step 4 above has ensured that the work study person has identified, planned and scheduled all the tasks that are prerequisites of the new method. It is now necessary to ensure that these are completed according to schedule and that everyone is ready for the actual change-over.

The first consideration is to decide when the change-over should take place. Even though a new method is more efficient and will ultimately result in greater output, there is often an interim period when output falls, while the workers get up to speed on the new method. Naturally, this should not coincide with a crisis such as the completion of an urgent order, unless additional staff can be used on a temporary basis to keep output levels up. The change-over date should thus be chosen to be as convenient as possible — this is particularly important where radical changes must be made to layout, involving the re-siting of machines and equipment. Management will have to plan for the labour to make such moves, and may want to make such changes over a weekend or other non-working time to cause minimum disruption to normal production.

Having established the date of the change-over, the work study person can work back along the critical path of activities to put a date on each of the other activities. For a simple change-over, the control mechanism for this process may be a simple record of activities in a diary. For complex changes, a formal project planning and control technique, such as network analysis, may be used; this will be explained in Chapter 15.

6. Maintaining the new method

It is important that, when a method is installed, it should be **maintained** in its specified form, and that workers should not be permitted to slip back into old methods, or introduce elements not allowed for, unless there is very good reason for doing so.

To be maintained, a method must first be very clearly defined and specified. This is especially important where it is to be used for setting time standards for incentive or other purposes. Tools, layout and elements of movement must be specified beyond any risk of misinterpretation. The extent to which it is necessary to go into minute details will be determined by the job itself.

Action by the work study department is necessary to maintain the application of the new method because, human nature being what it is, workers and supervisors or chargehands will tend to allow a drift away from the method laid down, if there is no check. Many disputes over time standards arise because the method being followed is not the one for which the time was specified; foreign elements have crept in. If the method is properly maintained, this cannot happen. If it is found that an improvement can be made in the method (and there are very few methods which cannot be improved in time, often by the operative involved), this should be officially incorporated, a new specification drawn up and new time standards set.

The procedure for maintaining a new method may depend on the nature of the relationship between the work study person and the part of the organization in which the method has been implemented. Some work study specialists are permanently assigned to work in a particular part of the organization and will be able to keep methods constantly under review. Where this is not the case and the work study person moves from location to location, it may be necessary to establish a formal method review or method auditing procedure when all methods introduced within a given time span are subjected to a review examination after the lapse of a specified period. The advantage of this formal review process is that it signals to the workers and their supervisors that the review will be carried out according to the predetermined schedule. They are therefore more likely to be motivated to adhere to the specified method.

7. Conclusion

In this and the preceding chapters an attempt has been made to explain and illustrate some of the more common methods of improving productivity through the saving of wasted effort and time, and by reducing the work content of the process. Good method studies will do more than this, because they will draw attention to waste of material and waste of capital invested in equipment. Chapter 11 shows that these methods can be applied not only in production but also in office work.

In Part Three we shall explain briefly some of the important techniques used in production management. These can constitute a valuable set of tools that may be used by the work study person in carrying further the investigation of the methods of work.

Method study in the office

1. The importance of method study in the office

Work study in general is traditionally associated with a manufacturing environment. The purpose of work study is to improve the efficiency of the conversion of resources or inputs into outputs (figure 1), thereby raising the productivity of the organization — this must be applied to every part of the enterprise, and not just to the manufacturing side. Offices use resources, and these resources must be used efficiently. Indeed, the importance of resource utilization within the office becomes ever more important as the percentage of workers in offices continues to increase. Administrative and clerical costs are a significant and growing cost for most organizations and must be controlled. The costs associated with office work are often referred to as “overheads”; in that they do not contribute directly to the final product of the organization. At the same time the introduction of advanced technology and the application of production management techniques, as well as work study on the shop-floor, have raised efficiency to a level where many gains are incremental rather than revolutionary. Office workers, on the other hand, have been subjected to very little systematic study and the potential for improvement is greater. There is thus a need for the application of work study in the office.

One common objection raised against the use of work study in an office is the fact that office work is concerned with mental activity or “brain work” and cannot be easily identified, observed, measured or analysed. However, in most offices, most of the work is routine and any mental activity is at a fairly low level, with decisions being based on firm precedent. Increasingly, also, the office is furnished with technological aids. Such equipment bears a close parallel with shop-floor machinery. Operating a photocopying machine is like operating any other machine. The argument that office work is in some ways fundamentally different from factory work is fallacious.

Another reason that work study is often not practised within offices is the different status of manual and clerical workers. What is perceived as a factory technique is not acceptable to those who think of themselves as having higher status.

This is one of the reasons for the growth of organization & methods (O & M). Properly, O & M is something more than work study in the office, being also concerned with the organization structures in use; but in practice most O & M is concerned with the “methods” part of the technique and is

indistinguishable from work study — if perhaps, because of its different name, more acceptable.

The purposes and principles remain the same, wherever work study is applied. Work study in the office still consists of the basic areas of method study and work measurement, and both of these follow the same pattern as we have seen elsewhere throughout this book. What we shall do in this chapter is to highlight minor changes or additions to techniques that have proved particularly effective within an office environment.

The point about the perception of difference by office workers has also to be applied to managers of administrative and clerical units. They too are probably not used to “experts” coming in and advising them on how to run their departments and sections. They may be suspicious and wary. The practitioner should expect some resistance and be prepared to deal with it. It is important to gain the confidence of those involved and ensure that by the time any investigation is complete, they are committed to the changes that are necessary.

2. The procedure for improving methods of work in the office

The basic procedure of method study:

- SELECT*
- RECORD*
- EXAMINE*
- DEVELOP*
- EVALUATE*
- DEFINE*
- INSTALL*
- MAINTAIN*

remains valid for studies carried out in an office environment. We still have to move systematically from selection of the problem or opportunity to be studied to implementation and maintenance of an improved situation.

Office automation and computerization are often seen as the prime means of improving office efficiency. Yet there is now a growing sense of potential unfulfilled with many computer systems. This is because the computerization or automation often simply speeds up existing inefficiencies. Computers and other information handling aids are useful devices but their use should be determined as part of a systematic analysis of the work involved and not instead of it. Method study provides the means by which that systematic analysis can be undertaken.

Select

Selection of the area or activity to be studied follows the same basic principles as for shop-floor work study. Selection consists of two components: finding those areas which represent significant problems or opportunities, and then

giving priority to them. In the office we shall be looking for areas or activities that:

- account for a significant proportion of office labour costs (Pareto analysis can be used to good effect here);
- are producing large numbers of errors or serious errors;
- are creating high levels of dissatisfaction;
- need to change in response to some external change (e.g. the introduction of new technology such as computerization).

In addition, it may be felt necessary to have some form of regular review of operations. Situations change over time. People also change. Short cuts will be found in working methods, new techniques will be found, new equipment installed. At the same time, less efficient ways of working may be introduced. Even if no alterations take place, there may be changes in levels of dissatisfaction on the part of either management or workers as their expectations change. Changes in procedures may take place for the best of reasons and may in fact increase productivity at a local level. However, it is possible that such unplanned or uncoordinated changes may have repercussions elsewhere in a wider system that are unforeseen by those making the change. Increasing throughput of one section, for example, may create a bottleneck in a procedure at a subsequent stage in the overall system. For all these reasons, some form of structured programme of review is advisable. This may take the form of a procedural audit, a departmental review or a system study, as long as it is a regular review of clerical activity to maintain and improve office efficiency.

Another source of projects to be studied is the employees themselves. Projects could arise out of an employee suggestion scheme or out of such structures as quality circles, implemented as part of an organization-wide attempt to improve the way activities are carried out. Often issues raised by such circles require additional work or study before changes can be suggested and/or evaluated; these investigations may be suitable work study projects where the work study practitioner works on behalf of the quality circle.

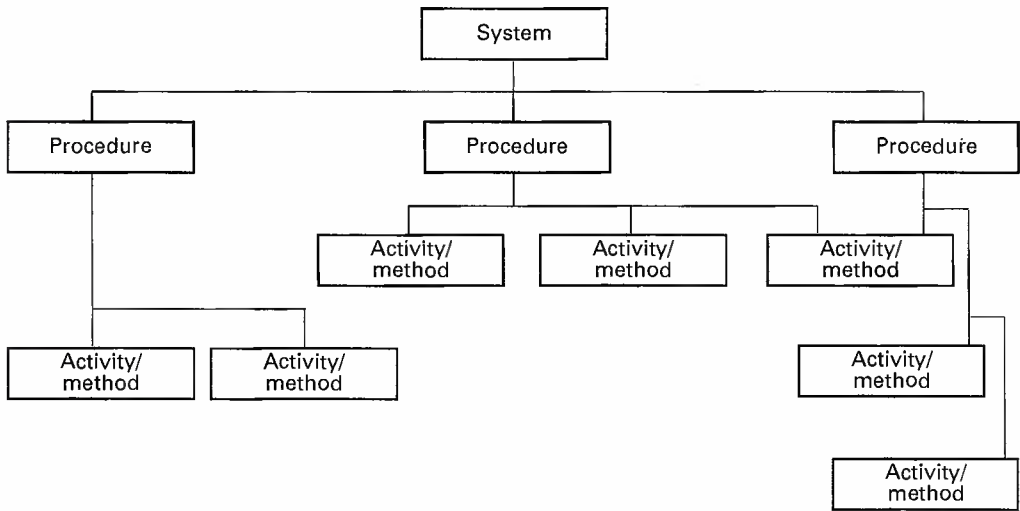
Record

It is the *RECORD* stage that the most obvious changes are seen when comparing shop-floor with office work study. This is because we are usually recording something that is fundamentally different. On the shop-floor, we record the progress or activity of one of three things — workers, materials or equipment. Materials are normally those that make up the final end product of the activity.

In the office, there is no end product. The important material objects in use are normally forms or documents, and thus there are a number of techniques aimed at recording the content of and progress of documents as they move through clerical systems and procedures.

Most office work can be placed on a hierarchy which includes systems, procedures, activities and methods (figure 58). The system is the overall scheme that links different departments and sections together in pursuit of a final aim or objective. Procedures are subunits of the system, often relating to

Figure 58. The hierarchy of office systems, procedures and methods



one particular document, workstation or individual. Each procedure is made up of a number of activities (some of which may be common to a number of procedures), while the methods are the means of carrying out such activities to fulfil the needs of a particular procedure.

Recording often follows this hierarchy, so that first the observer will record information pertaining to the entire system, before moving on to record specific procedures and then particular activities and working methods. This should be the case even where the particular study is concerned only with one procedure or method — knowledge of the fuller system is important in that it provides a context for the investigation. Where an investigation is carried out by an in-house work study person, the knowledge of the overall system within which a procedure takes place may already exist and recording can start at the procedural level.

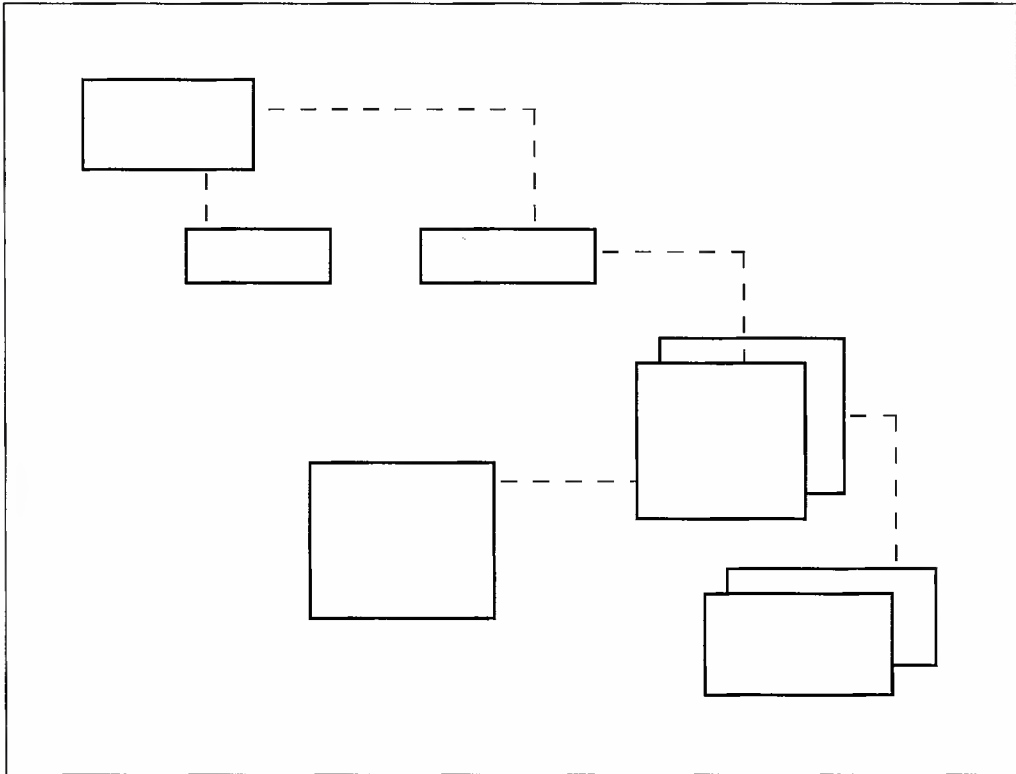
Recording follows the same pattern as with shop-floor work study. Normally, a system or procedure is recorded in outline form to allow consideration of larger issues, and gradually the investigation moves down to a more detailed level, using techniques that allow more detail to be recorded.

One useful recording technique is that of the procedural narrative, which is a “shorthand” means of recording basic textual information about who does what within a procedure. It is a very simple record but serves to identify the main steps in a procedure.

Accounts clerk opens and sorts incoming mail
passes invoices to invoice clerk

Invoice clerk date-stamps incoming invoices
matches invoices with filed orders
checks order for completeness
updates order record
enters invoice details to computer invoicing system

Figure 59. An example of a specimen chart



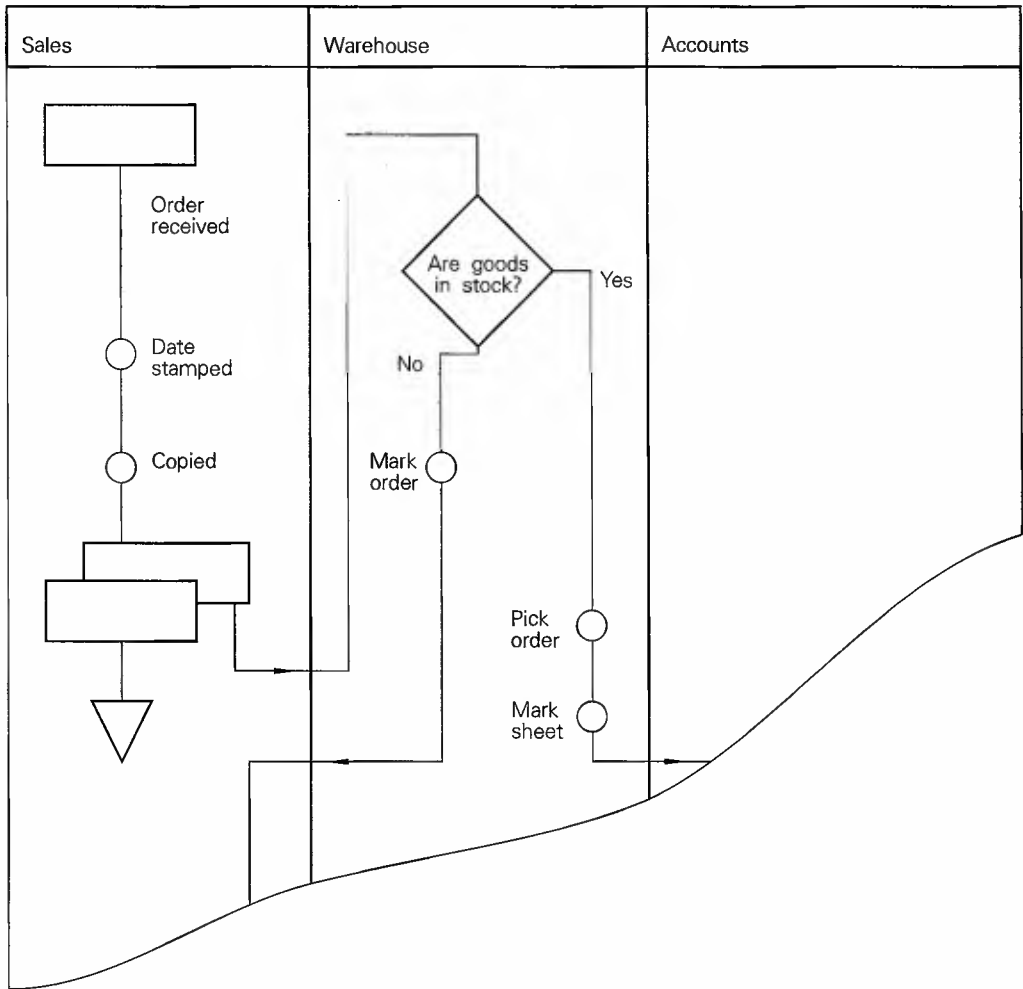
Similarly, at this outline recording stage, it is useful to collect together a copy of each form and document used in a particular procedure. These can be mounted on to a backing sheet which, together with possible annotation, is sometimes referred to as a **specimen chart** (figure 59).

Such recording devices serve the same purpose as an outline process chart: they record the major details and provide the basis for a first-level examination of the procedure. This first-level examination is aimed at eliminating whole areas of activity before the most crucial areas are recorded and examined more closely. At this level a more detailed recording method must be employed.

Process charts can be used in the office but it is more useful to use a variation of the process chart known as a **procedure flowchart** — this is in effect a document-type flow process chart, since it charts the progress of a document or series of documents through a procedure. Since procedures often involve a number of departments, it is common to use the chart in a columnar form in which each column represents one department or section of the organization (figure 60). This allows each department to concentrate on its own part of the procedure and for transfers between departments to be easily recognized.

As with all recording techniques, the important point is to concentrate on recording information to a level of detail and in a form that makes it suitable for subsequent examination.

Figure 60. A procedure flowchart



When recording office work, there is often little that can be directly observed. Much of the information comes from interviews or by asking questions to elicit the detail of what is observed. The practitioner thus needs well-developed interpersonal and communication skills.

Examine, develop, evaluate and define

The examination of the recorded data must be systematic and complete; the critical examination process is useful here in providing the structure. All the points made when discussing critical examination in Chapter 7 are valid here, the purpose of the examination being to eliminate, then simplify or combine activities. As before, one of the difficulties with the *EXAMINE* stage is to stress its importance in spite of the fact that, unlike the *RECORD* stage, there is a limited range of available techniques to support it.

Increasingly, technology is being used in support of office work. Thus, when it comes to developing new and improved methods of working, the work

study practitioner needs an up-to-date knowledge of information systems and computerization. There is often a conflict here between the work study practitioner and the computer specialist. One common distinction is that "computer systems" which are part of the mainstream of business activity (such as payroll, stock control, invoicing, etc.) remain the province of the computer professional, while "computer support" (which tends to be based on a micro or personal computer) is part of office work and workstation design, and is hence the province of the work study practitioner. In reality, if all is working well, the two types of staff should work in tandem and cooperatively.

Similarly, in many organizations, the computer department will lay down the overall computerization strategy and will define the types of equipment to be used with due regard to their compatibility, while others (including work study personnel) will be able to design and provide systems to meet local needs as long as they adhere to these overall standards. The use of personal computers is only an extension of the use of such devices as typewriters and calculators; in fact, the two most common applications are word processing (involving the manipulation of text) and spreadsheets (involving the manipulation of numbers) — both essential parts of office work. Since the personal computer is now in the same category, and is available at a price that brings it within most office budgets, it should be treated in the same way — as an office tool, rather than as part of the computer infrastructure. Where offices make use of centralized databases and local area networks, the setting of hardware and software standards is especially important, but there should still be scope for individual offices to solve for themselves specific office problems within the framework of the overall organizational strategy and policy regarding information technology.

Another factor to be considered in evaluating technology is the conflict between cost and ease or convenience of use. For example, although it may be much more "friendly" to place individual photocopying machines in each department of the organization, this may result in much higher reprographic charges than having a centralized copying department which can use higher-powered, more efficient machinery to produce bulk copies. The same is true of other facilities such as a centralized facsimile (fax) service compared with fax machines around the organization. It may be necessary to establish a company policy with regard to some of these services so that individual departments know the "ground rules".

An important aspect of the development of new methods is to evaluate one potential method and compare it with the existing method or a different potential change. It is important to ensure that any changed method meets the aims of the investigation, but it is also important to identify the secondary benefits of any change. Word processing may be introduced, for example, to increase efficiency but it often has secondary benefits such as improved presentation. Such secondary benefits should be included in any cost-benefit analysis.

Install, maintain

Installation of a revised method is always important. If the installation is handled badly, the new method stands little chance of being a success. However, the principles involved in installing and then maintaining a new method within an office environment are exactly the same as for installing changed methods on the shop-floor.

Training and support of those involved in the change are very important. The first task is to ensure that they know exactly what is expected of them. Some organizations have manuals of formal procedures in which all clerical routines are recorded. When a new system or procedure is first implemented, it may be necessary to supplement the formal description with specific training or instruction sheets and/or with training courses. It is useful to construct some kind of change-over sheet so that workers can look up what they did under the old system or procedure and see immediately what their action should be under the new one.

Where procedures manuals do exist, it is vital that they are kept up to date. There must be some way of ensuring that, whenever a change is made to a system or procedure, all copies of the manuals are updated and all those involved, however remotely or occasionally, are made aware of the change and its implications for them.

Whenever a system or procedure changes there will be some teething troubles. These may be minor in themselves, but if there are a number of them they may accumulate to present a major problem or to lower confidence in the changes. It is therefore important that the implementation is carefully monitored and that minor modifications, if necessary, can be made before any problems become severe.

3. Design and control of forms

As we have stated above under *RECORD*, documents and forms are common features of all offices, often being the only physical evidence of a procedure. Documents are used as the carriers of information, and the effectiveness of this process is determined by the effectiveness of the document itself — the way in which it holds and transfers information, and the way in which it interrelates with other documents and with the people who use it.

Perhaps we might by now have expected to see the paperless office, but this appears to be a long way off. Information is harder to read from a screen than it is from paper and people therefore tend to take paper copies of information even though it may originate on screen. The electronic form makes transfer of information much faster and the rise of such technologies as electronic data interchange is having some impact on the volume of paper forms being transferred between organizations. The proper design of forms, however, remains an important part of office-based work study. In addition, there tends to be a proliferation of forms in many organizations — ad hoc forms are designed for a specific, perhaps temporary, function but then get absorbed into the mainstream of office life. Over a period of time, many new

forms arrive on the scene but very few forms are ever deliberately discontinued. There is thus an equal need for the control of forms.

The objectives of form design are the same as that of method study itself — to eliminate activity, and where this is not possible to combine or simplify. In terms of forms, this can mean eliminating (and then combining or simplifying) whole forms, or eliminating (and then combining or simplifying) particular entries on forms. The design and control of forms is therefore a specialized form of method study rather than an alternative activity.

Design of forms

Naturally, a document or form should be examined together with the procedure in which it is used. Changing a system or procedure may have automatic implications for forms used. Forms themselves should be examined when the procedure itself has been examined and improved or validated. Examination of a form follows the basic critical examination process, asking:

Why is the form necessary?

What information does it convey?

Who uses it?

When do they use it?

Where is it used?

How is it used? (Is the form produced by a computer, are entries typed on to the form, is it filled in manually, etc.?)

and then examining and evaluating alternatives.

In addition, we need to gather information about the frequency and volume of use, the methods of filing, the length of time that the form is to be kept, and the relation to other forms in this or other procedures.

Once we are clear that a particular form (which may be a combination of two or more existing forms) is necessary, we can start to (re-)design it.

When designing forms we are trying to make the form:

- compatible with its intended use:** For example, a form that has a long expected length of use or that has to be used in an outdoor environment, and perhaps in adverse weather conditions, needs different quality paper from a form which is used internally or has a short lifespan.
- easy to complete:** This means that the form should be clear and unambiguous. Entries should be compatible with the source of the data — if data are copied from another form, they should be in the same sequence — or in some logical sequence. (Transcription errors are very common. They are minimized when the data have a structure and a context which enables errors to be easily identified.) There should be sufficient space for each entry, allowing for the method of entry (printing, typing, etc.). Multiple-choice and abbreviated-entry formats should be used where possible both to save time and to minimize the number of errors.
- easy to use:** This refers to the part the form plays in a procedure after it has been completed. Generally the information it carries must be read and acted upon by another person, and the design must therefore depend on

what this action is. It may be that the only action is for the form to be filed, and occasionally retrieved for the information to be accessed. In such a case, the prime requirement is that the reference identity (form number or identifying entry — employee number, department name, or whatever) is clear and positioned as appropriate to the filing method. If the form is to be posted, it should be designed to fit into a standard-sized envelope with the minimum of folding. Further considerations are discussed under “Detail design”, below.

These criteria may conflict with one another. For example, when considering ease of use, it may be necessary to place the information on a given form in a particular sequence since some of it will later be copied on to another form which already contains the data in a given sequence. This may, however, be different from the sequence of data on the source document. In such a case, it may be necessary to extend the scope of the exercise to take in **all** the forms that are affected, even at one or two stages removed. If this is not possible, some form of compromise design must be reached.

If it is necessary to examine a number of forms involved in the same procedure, the **X-chart** provides a useful means of summarizing the entries on the different forms and highlights overlap between the forms. An X-chart is simply a matrix which shows all the forms against all the entries on each form. An X in a matrix cell indicates that a particular form has a given entry (figure 61). This chart is useful in helping to identify overlap and duplicate entries so that forms can be combined with one another.

The design of the detail of the form should be based on practical rather than aesthetic considerations, although often the most practical forms are the most aesthetically pleasing.

Consideration must be given to:

- paper size;
- paper weight;
- shape;
- colour;
- maintaining any house style or corporate identity;

and balancing these with the cost involved.

Figure 61. An X-chart

Data item Document	Customer name	Address	Contact name	Sales record	Sale terms
Order	X	X	X		
Delivery note	X	X			
Invoice	X	X			X
Customer card	X	X	X	X	X

Detail design

We have also referred to the fact that detail design is dependent on the way in which the form will be used. Details that affect design are:

- the filing/retrieval process;
- the routing of the form throughout the organization (and the degree to which additional entries are made on the form at subsequent stages);
- the nature of data entered on the form and the degree to which they can be grouped.

Grouping of data is one of the first considerations when designing a form. Often data can be split into two or more basic categories. A personnel record form, for example, may contain personal data about the member of staff, departmental data about the job to which the person is appointed and its place in the organization, and salary data about rates of pay and conditions of work.

A simple example of such a form is shown in figure 62. In this form, the name and address have been placed as they would be on an envelope (since they will almost certainly be copied from this form on to envelopes in the future). The employee number is placed at the top right-hand side to fit in with the filing method. The entries for employee number, department, section, salary scale and point on scale are pre-fixed since codes are used for department and section, and boxes have been provided to guide the user to fill in the correct number of characters.

Similarly, the start-date box has been included to ensure that the date is entered in the correct format. The form reference number is included at the bottom so that the form can be easily reordered and the name of the form is included clearly at the top so that it can be easily verified that the right form is being used.

Multi-part form sets can be useful in certain circumstances, but this must be balanced by the additional costs of production. When such forms are not used but multiple copies are required, people often revert to photocopying

Figure 62. A personnel record form

Personnel record form		Employee No.	<input type="text"/>
Title:	<input type="text"/>	Job title:	<input type="text"/>
Last name:	<input type="text"/>	Department	<input type="text"/>
First name:	<input type="text"/>	Section	<input type="text"/>
Address:	<input type="text"/>	Salary scale	<input type="text"/>
<input type="text"/>		Point on scale	<input type="text"/>
<input type="text"/>		Start date	<input type="text"/>
Telephone:	<input type="text"/>		
Next of kin:	<input type="text"/>		
			Form AZ/124

forms. This is expensive, not so much in terms of photocopying costs but in the cost of the staff time involved.

It is always worth producing a “mock-up” of the form and talking through the design with those who are going to have to use it.

Many forms, these days, are produced in-house using special-purpose packages or desktop publishing software for the design of forms. There is a danger, with the proliferation of such software, that forms design will be carried out by many people within the organization, many of whom will not have appropriate training, expertise or experience. The danger with desktop publishing is the range of facilities and design options it provides — there is a tendency among the untrained user to make use of too many in any one publication. This is one of the reasons why the control of forms is important.

Control of forms

The most important part of controlling forms is to undertake regular audits to discover if each form is still necessary to serve a particular business function (in effect, the *MAINTAIN* stage of method study applied to the design and control of forms). This is best served by having a central register of all forms in use, together with a review schedule for each form in the register. Where the purpose of the form is still valid, questions must be asked about the environment in which the form operates and whether changes here — for example, in technology or filing methods — require changes to be made to the form.

Other items to be considered are:

- the production method:

How is the form produced and are there now better or cheaper ways?

- stocks:

How much stock of each form is held, and where is it held?

Is this appropriate to the use of the form?

(Is the minimum stock dictated by use or by the economics of production?

If the latter, is there an alternative production method?)

How are supplies to users reordered?

How is stock issued to users?

How is issued stock tracked? (For example, if a form is discontinued, how do we trace all copies of it so that they can be destroyed?)

- the nature of disposal:

What is the useful life of information on the form?

Are there any legal constraints on disposal?

How do we ensure that forms are disposed of, after their useful life is ended (to release valuable space)?

Are there security restrictions on disposal (should forms be shredded or burnt)?

4. Office layout

Office layout is another specialized form of method study in the office — in effect, it is an extension of plant layout, the principles and the approach remaining the same. All types of layout except layout by fixed position, which will be referred to in Chapter 14, are valid in an office environment. In addition, there is often a debate about the relative merits of open-plan or cellular offices (see below). In reality, most offices combine the two, the choice often depending as much on such factors as the constraints of existing buildings and the organizational culture as on practical design considerations. Planning office layout should follow the hierarchy of the system. The overall system will dictate the broad layout, the procedural breakdown will determine the detailed layout and the nature of working methods will dictate the workstation design.

The differences then relate to the overall type of layout selected. A layout built around particular procedures will obviously be different from one built around specific office functions.

As with all method study investigations, we need information on which to base any decisions as to type of layout. The *RECORD* stage of the investigation must provide details of equipment in use, volumes and flows of documents, numbers of staff, communication flows and so on. Such devices as travel charts may be used to supplement the data from procedure flowcharts and provide information on communication and contact between workstations.

The increasing use of office technology means that office layout must pay strict attention to power and service requirements, to proper lighting and to the avoidance or reduction of noise. Additionally, there is a strong need for the appropriate arrangement of cables — a workstation may have a computer, a printer, an answering machine, a facsimile machine, a telephone and perhaps other devices, all with power and connecting cables. If not handled correctly, these are unsightly and constitute a safety hazard.

Open-plan office layout

The main drive towards open-plan offices is the cost of space. Open-plan offices almost always result in space saving compared to a suite of small, cellular offices. However, in open-plan offices great care must be taken to ensure privacy for those activities which require it and to minimize the effects of noise. The advantages of open-plan working are:

- the saving of space devoted to walls and partitions;
- improved communication and contact between different workstations — this should lead to a reduction in the number of internal telephone calls and of internal memoranda;
- greater flexibility, if the layout needs to be changed in the future to cope with a change in working methods;
- easier supervision of staff;
- easier and cheaper cleaning of office space;
- easier power and service distribution.

There is often a reluctance of staff to move from a traditional, cellular office layout to an open-plan one. However, this resistance is often minimized if the change is accompanied by a significant improvement in the quality of office furniture and decor, and if careful landscaping is used to split up a large, open-plan space into smaller, screened areas.

Office layout studies

Taking account of the above points, an office layout study should consist of the following steps. This assumes that, as a result of the *SELECT* and *DEFINE* stages of the project, the practitioner is aware of the constraints on the investigation — especially those dictated by existing buildings and by limitations of finance.

- (1) Record details of the major systems in use within the office.
- (2) Record details of the clerical procedures that support those systems.
- (3) Examine the working methods of those procedures and carry out a basic method study of each one. (For most of them this may be a very simple exercise, but some may demand a fuller study before the method is confirmed as the most appropriate.) This stage is important as it is pointless to build a layout around working methods that may change in the near future. In particular, it is important to identify the range of equipment that is currently in use, or is proposed to be in use in the short term.
- (4) Carry out a capacity assessment of each part of the procedure — possibly down to each workstation within the procedure. (This is a work measurement exercise; where there is no formal work measurement system, it may be necessary to obtain the information from estimating, with help from managers and supervisors.)
- (5) Analyse volumes of output and question the senior managers to discover likely future trends.
- (6) Identify communication and contact paths and frequencies.
- (7) Design individual workstations. Make use of ergonomic principles as described in Chapter 5. Some of the workstations may be simple desks, while others may be computer workstations or photocopiers. The workstation should be designed as a complete entity, including working surfaces, seating and equipment. Where appropriate it should also include space for “personal” filing. At this stage, the design should remain conceptual, consisting only of the details of what is needed and not how they are going to be provided.
- (8) From volume and capacity data, calculate total workstation requirements.
- (9) Decide on basic type of layout.
- (10) Identify any “external” constraints. For example, a department that has a high number of external visitors may need to be located close to the reception area. A department that makes use of heavy machinery may need to be on the ground floor of a multi-level building.

- (11) Use communication and contact data to draw up a schematic layout showing the location of different work areas or work functions relative to one another.
- (12) Investigate available hardware solutions (choice and arrangement of furniture, filing, screening, document transfer technologies, etc.). Consider packaged solutions in which different components are designed to fit with and match each other. Generally, modular solutions are to be preferred since these allow greater flexibility through the interchangeability of units.
- (13) Design a provisional layout, fitting proposed solutions to a scale plan of the work area. This layout should take account of existing doors, lifts, etc., and should include the provision of power and services.
- (14) Discuss the provisional layout with both the users and the services or building department (where one exists) to discover operational and financial feasibility.
- (15) Modify the layout in accordance with the results of discussions and prepare the proposed layout.

The layout should also include an analysis of lighting, heating and ventilation needs, and the provision of toilet facilities and rest rooms. It should be detailed enough to include such things as waste bins, coat stands or cupboards, filing cabinets, bookshelves and so on (since it is often the small items that have a major effect on overall efficiency). The layout may, in some circumstances, have to take account of additional factors such as security, for example by grouping together sections or departments which have to be within a particularly secure space envelope.

Items such as heating, lighting, ventilation and noise control (see Chapter 5) require specialist knowledge, and advice may be required before such matters can be properly included in a layout. It is important to remember that modern office equipment generates considerable amounts of heat and that air conditioning may be required to maintain a suitable working temperature. Similarly, although noise control is a specialist area, much of it is common sense and many basic preventive measures (such as using sound-deadening material under typewriters and printers, acoustic hoods and screens, furnishings and fittings which are sound absorbent, etc.) can be specified at the office layout design stage.

Since documents are the main "product" of offices, careful thought should be given to filing and retrieval systems. It may be possible at the filing stage to replace the paper document by microfilm or magnetic media to reduce the space consumed by filing. The nature of the medium used for filing will depend on the nature and frequency of subsequent retrieval and on any legal requirements for documents to be maintained. Where large quantities of documents have to be stored (as for example in many financial services organizations), it may be necessary to investigate automated storage systems.

Document transport is another area in which technology is developing. There are now systems by which documents can be routed around buildings, including changes of floor level, on a pre-programmed basis using tubes and/or

rails. The document transport system should be designed alongside the storage and retrieval system as part of the materials handling study. It is normally much easier to design and develop automated document handling systems when the office is being located in a new building, but it is often possible to fit a system into an existing building with all the inherent constraints.

5. Quality control in the office

The biggest single “quality question” is always: Are we doing the right thing? Only if this is answered satisfactorily should any attention be given to the way in which something is being done.

Quality control is not generally applied to office work. There seems to be an implicit assumption that office workers do not make mistakes. This is simply not true — office workers are no different from any other category of workers, in that they too lose concentration and produce errors and defective work. These errors can be costly: if they are spotted, they cost money to put right; if they are not spotted, they can be much more costly in supplying incorrect information to others in the organization or to customers or clients. However, errors introduced by the workers are often a small proportion of total errors. Most errors are system errors where the system fails to work adequately, with the result that delays, misunderstandings and misrouteings occur. It is therefore important to ensure that the systems, procedures and methods of working used in offices are designed to minimize errors and that some form of control of errors is instituted, especially where the results of any error may be significantly costly or damaging. Good systems and procedures prevent errors, leaving quality control techniques to pick up the small number that do occur.

It is possible to implement specific quality control techniques such as spot checking and random sampling and, for some activities, this may be deemed necessary. However, it is just as important to pay attention to the “human factor” involved in determining quality. This factor also leads to system errors since the workers are an integral part of, and probably the most important part of, the system in operation.

One important source of error is a lack of — or inadequate — training of the personnel involved. People generally work without error, but only if they know exactly what is expected of them, they are given the appropriate tools, equipment and support, and they are properly trained in the techniques and skills required. If all of these are true, the “system” has done its job. The workers should also have confidence in their ability to deliver and will carry out their work with the minimum of error — confidence breeds competence.

Recent initiatives such as total quality management and customer service programmes have highlighted the importance of each stage of a procedure in the determination of overall quality of the end product or service. It is important that the culture of the organization makes people want to provide a high-quality service in their own sphere of activity and lets them feel that their own activity is important to the organization and its overall quality delivery.

PART THREE

**Selected production
management
techniques**



Product design and materials utilization

1. Product design

Before discussing the various aspects of production management that could benefit from work study techniques, in this chapter we first consider the characteristics of the products to be manufactured.

The way a product is designed greatly affects production costs. For example, in investigating production costs the Japanese company Hitachi estimated that 75 per cent of these costs were already determined in the design and development phase, while further costs such as handling or layout and other operations combined determined the remaining 25 per cent of the cost of a product.¹ This is because product design determines the number of component parts, the sequence of production and whether the various stages of making a product can be accomplished by existing machinery and equipment or require new capital investment.

The relation between work study and product design is evident. It is not uncommon that a method study specialist, while investigating a lengthy operational sequence, would do better to think in terms of simplifying product design rather than simplifying the existing process. However, modifying product design is a shared responsibility between various partners. The work study person cannot alone take initiatives on product design, but he or she can certainly call attention to his or her findings and act as a resource person for production engineers during the development of the prototype or the pilot run of a product.

A product has aesthetic requirements which are usually highly emphasized by the marketing personnel, and production requirements in terms of the material, equipment and skills needed to make it, as viewed by the production manager; it also generates a certain return on investment given the various costs involved in its production, and this is how it is seen by the financial manager. In addition, new products and services are the driving force for the survival and growth of an enterprise in an increasingly competitive business environment. The continuous development of new products has become an essential function of an enterprise. As existing products continue to sell, new products are being prepared to replace them before their life-cycle decays; and modern-day product development is in fact a shared responsibility

¹ Johnson A. Edosomwan (ed.): *People and product management in manufacturing* (Amsterdam, Elsevier Science Publishers, 1990), p. 26.

if not a compromise between the views of the marketing, production and financial services. Figure 63 shows a simplified sequence for developing a new product. In fact, many weeks or months may elapse between each stage and the next.

From figure 63 one can see that good opportunities exist to influence manufacturing costs when producing a *prototype*, and later at the pilot production stage. By a prototype we do not mean just one prototype — there could be many, each tested for functional performance, dependability and materials used, as well as market acceptability as assessed by the marketing specialists. This development of prototypes has been greatly facilitated through the use of **computer-aided design (CAD)**.

CAD enables a designer to project on to a video screen drawings of various parts or the product itself. These can be rotated on the screen to be viewed in a three-dimensional fashion from various angles. Design changes can be introduced using various devices such as a “mouse” or a pencil-like device, by touching the screen or by punching instructions to the computer (figure 64). Thus such possibilities as increasing the diameter of a part or the position of a hole may be tested, to see to what extent this will influence the fit and final shape of the product.

The pilot production phase also offers a second chance to examine the way in which production costs can be reduced without detracting from the marketability of a product. But what can be done in this respect? Here are a series of pointers.

- (1) **Reducing component parts:** This is a big cost saver. When several parts are eliminated (figure 65), there is a marked reduction in the cost of acquiring parts, assembly time, and the cost of equipment, inventory and floor space. Many examples can be quoted of how enterprises embarked on this road with excellent results. For example, the Hewlett-Packard Touch Screen II personal computer was finally introduced into the market with 150 component parts as against 450 parts in the original design. The Asuag-SSIH Swiss consortium came up with the Swatch watch which had only 51 parts.
- (2) **Standardization or modularization of parts:** This aims at creating certain standard parts that can meet the requirements of several products. Let us take an example of a furniture factory making sideboards. Originally these were made according to customers' specifications. An examination of a simple sideboard shows that it has three dimensions — length, depth and height. By introducing two standard specifications for each dimension, the final product can be assembled in eight different models of varying length, depth and height. These could then be offered to the customer. Such a modularization allows the mass production of component parts. Standardization also means fewer varieties held in stock, facilitates production planning and enables better utilization of space.
- (3) **Use of existing machinery and equipment:** The possibility of using existing production facilities, tools or fixtures to manufacture the new product can cut down considerably on manufacturing costs.

Figure 63. From idea to final product

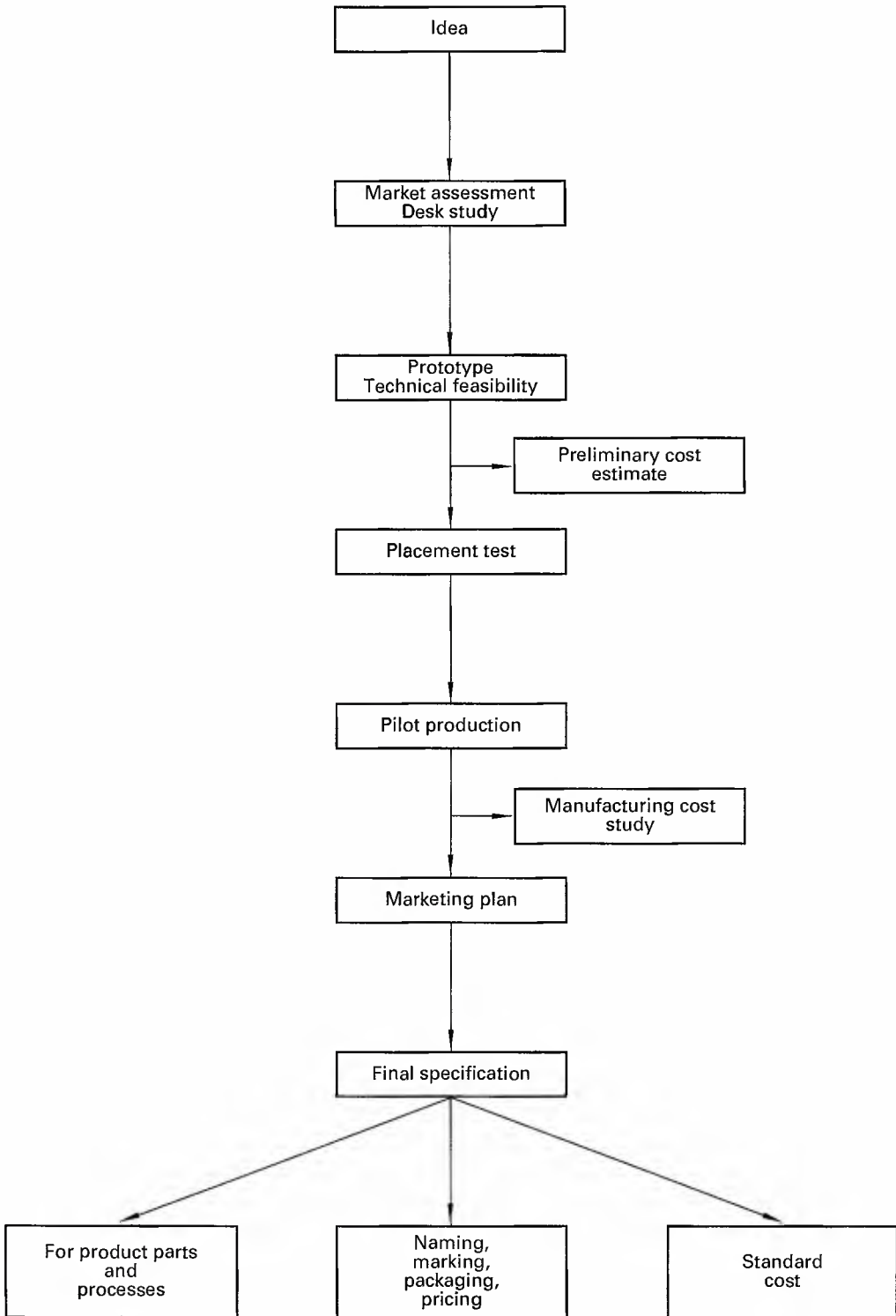


Figure 64. Computer-aided design (CAD)



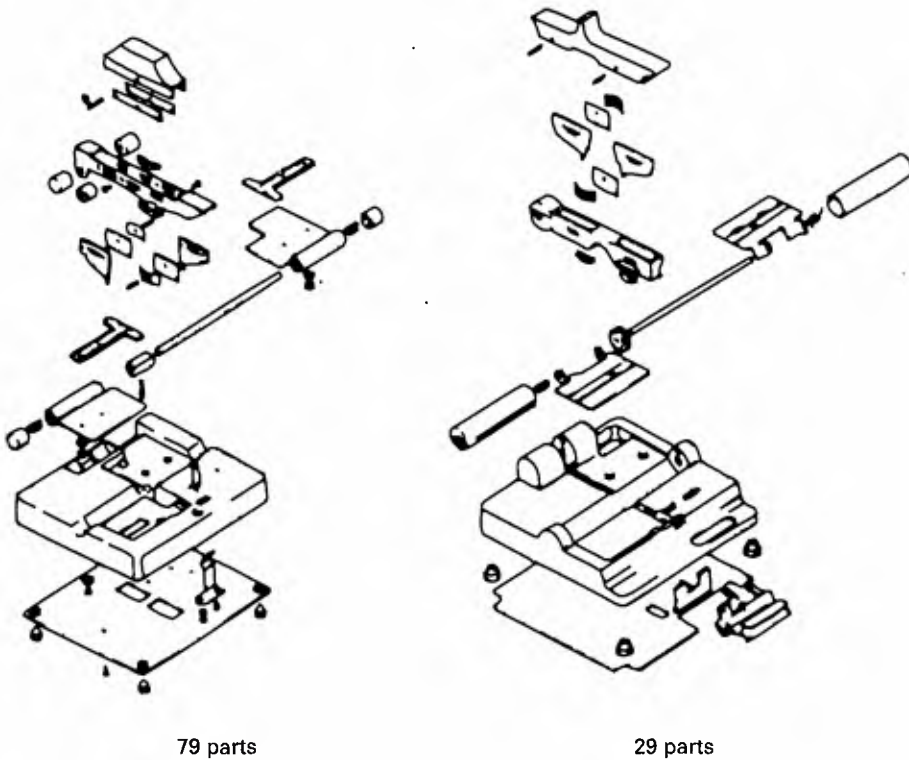
Source: Reproduced by courtesy of Hewlett Packard.

- (4) **Redesigning to simplify methods of work:** In manual bench assembly operations, for example, the relocation of holes to create symmetry can facilitate assembly or enable a better combination of certain assembly operations.
- (5) **Facilitating handling:** Products or parts may also be designed with handling in mind. Packages that could transform the dimensions of a product into squares or rectangular shapes allow several possibilities of handling.
- (6) **The use of substitutes:** The use of plastic or aluminium alloys on certain products instead of metal can cut down on costs. In the chemical industries certain fillers and additives are cheaper than others.

Value engineering

All these points can be systematically taken into account by applying value engineering (also known as **value analysis**) techniques for increasing product value by improving the relationship between the function of a product and its cost. As up to two-thirds of production costs are often determined at the design stage of a product, the contribution of value engineering to productivity

Figure 65. Reducing component parts in product design



improvement cannot be overestimated. Productivity improvement programmes frequently concentrate on the production process rather than on the product, thus neglecting the potential for an important productivity improvement.

Not only does value engineering consist of an analysis of product value, but it also comprises the whole process of “brainstorming” and developing improved products. It is characterized by three main features:

- it analyses the **functions** of a system and its elements;
- it consists of **teamwork** by representatives of different departments with different interests, backgrounds and skills;
- creativity techniques** are applied systematically.

Value engineering was probably the earliest small-group activity, long before quality circles (QC) were established and such activities became fashionable. Although value engineering was originally developed to improve the value of products, it is now also applied to processes. For office work an **information value analysis** has been created. The result of a value engineering project is usually a simplified and often more intelligently designed product.

2. Utilization of materials

A great variety of materials normally enter into the “making” of a product. These may be direct materials such as component parts, or indirect materials such as energy, lubricants, catalysts, solvents, packaging materials and so on.

Manufacturing costs can be reduced through a more efficient utilization of these materials. Proper materials utilization seeks two goals: improving the yield (or reducing waste) and the salvage of waste.

Improving the yield

The maximization of yield and the reduction of waste are of major concern to the work study person. Often, however, he or she would be concerned merely with the waste that is generated from primary material during processing. It is rare that a work study person gives sufficient attention to the economies that can be achieved from proper utilization of indirect material or to other issues involved with the salvage of waste. Economies — which are sometimes substantial — in production costs can also be achieved through proper utilization of various materials in a production operation.

Waste can be classified into unavoidable and avoidable waste. The second type of waste is the one that concerns us here. Avoidable causes normally arise from using excessive or inappropriate forms of raw material or poor methods of work. Several techniques can be used to improve the yield:

- (1) Change the original size of the raw material so that it can give the maximum yield. This is particularly useful in cutting operations of, say, fabric or metal sheets, or paper. In a process of printing labels, for example, changing the size of the original paper used could yield more labels per sheet. Similarly, the proper positioning of these labels on a sheet could also reduce waste.
- (2) Proper methods of work can also reduce waste during processing. In Chapter 7 several examples were given where method study resulted in waste reduction.
- (3) Quality control, which will be dealt with in Chapter 13, when properly applied controls the generation of waste.
- (4) Improving the utilization of indirect material can be equally important. Energy-saving measures, recycling of certain solvents and choice of appropriate packaging can also help to cut down costs.

It should be noted that as the semi-finished product passes through the various stages of production its value increases progressively as it reaches the final stage. As a result, waste reduction towards the end of the operation needs to be addressed even more closely.

Salvage of waste

Irrespective of the time and effort expended in reducing waste, it will still result and a good part of it will be unavoidable. There are two options here:

- Use the waste to manufacture other products. For example, waste from a saw-mill can be used to make compressed wood. Similarly, in producing

certain products in the chemical industry, by-products usually result which in turn can be processed to make new products.

- Find the most appropriate way of selling the waste. If an enterprise produces various types of scrap, a higher price will be paid if the scrap is sorted, as certain scraps, such as copper, are more valuable than others.



Quality control

Quality has become a strong competitive weapon on account of several factors. First, producing a quality standard commensurate with consumers' expectations creates loyal customers and improves the enterprise's image. Second, properly applied quality control can in many cases reduce rather than increase manufacturing costs. Third, when applied as a managerial tool, it can help breed a culture within the enterprise which is constantly striving for improved quality in products, processes, information and other enterprise functions. The first factor mentioned above is obvious and needs no particular elaboration. The last two will become clear as we proceed with our discussion in this chapter.

1. Meaning and scope

In the preceding paragraph we saw quality as conformity with customers' expectations. Quality control therefore means measures undertaken to ensure such conformity. It **does not** necessarily mean measures undertaken to attain the highest possible quality. As a result of the application of quality control, products or services would have consistent and uniform specifications.

Quality control has also come to be identified with two approaches:

- a technical and statistical tool to keep variations from the norm under control. Here various techniques can be used for this purpose. They will be briefly explained in the next section;
- a management tool intended to influence attitudes so that various persons and groups in the organization become committed to pursuing and maintaining quality improvement. This latter concept is referred to as "total quality control". This approach will be discussed later in this chapter.

The approach to quality control was in the past based mainly on the use of statistical analysis to measure the deviation from certain defined specifications. It is for this reason that quality control is sometimes referred to as "statistical quality control". While this approach continues to be used as a basis for measuring quality standards, over the past 15 years a new approach to quality control has been developed by Taguchi which carries quality control a step further, namely towards quality improvement rather than merely statistical measurement and taking corrective action. A still broader concept is that of

total quality control, extended to all the activities of the enterprise. We explain these approaches briefly below.

2. Statistical quality control

In traditional statistical quality control certain steps are followed:

- (1) Identify the quality characteristic we want to measure. This can be weight, length, diameter, density, humidity, etc.
- (2) Decide on the desired quality standards for that characteristic. This should be determined in line with consumers' or users' acceptance level. As we increase the level of quality standards, consumers' satisfaction may increase but up to a point after which increased quality standards will not make much difference to the average consumer. Cost, however, will continue to increase in an accelerated manner as we pursue higher specifications. For example, in refining olive oil it will not make much difference to the average consumer if the percentage of remaining impurities (fatty acids) is 0.01 or 0.005, but the cost of refining to attain the last figure can become exorbitant.
- (3) Decide on the accepted tolerance level. For various reasons, products rarely conform 100 per cent to the desired specifications. There can be specific reasons relating to the manufacturing process, variations in the raw material used, sensitivity of the product to the outside or manufacturing environment, and so on. These various factors combine to give variations from the specifications we desire. We should accept or "tolerate" the deviation from our specification up to a point and then reject the product if its characteristic falls beyond our tolerance level. Setting tolerance levels is one of the most crucial issues in any quality control operation. Setting tolerance levels that are too tight can increase the number of rejects considerably, thereby increasing the costs. On the other hand, setting them too loosely could mean that products with a wide variation in quality standards would find their way on to the market, with an adverse effect on consumer satisfaction. In the final analysis, in setting tolerance levels management will be guided by its assessment of consumers' tolerance of quality variations and by cost.
- (4) Decide on the method of sampling to test for quality. Inspecting every product may not be possible in all cases (e.g. if we are testing a car against shock or accident impact, testing all cars produced means virtually destroying them all). Neither is there any guarantee that 100 per cent testing is an effective method. When sampling is decided upon, there are three issues to be addressed. First, are there operations that require more control than others? Here we can use a Pareto analysis (see Chapter 6) to indicate those operations or products-in-progress that have the highest value or suffer the largest number of defects. Second, we can decide on where to place our inspection points. A third decision to be made would be on sample size and the frequency of sampling. On this last point, we would use some of the statistical tools available to assist us in this

respect¹ These tools, which will not be elaborated on here, indicate to us the sample size we need if we want to be, say, 95 per cent confident that the observed deviation from the standard we require is merely due to chance. If we want to be 99 per cent confident, then the sample size will increase.

- (5) Establish control charts to measure deviation from tolerance levels. There are two basic dimensions used in most charts: (a) the mean or average \bar{X} , indicating the central tendency for various observations to occur; and (b) the range R, or the range of variation between the lowest and highest quality characteristic. Let us assume for simplicity's sake that we have taken ten samples of a certain product (a rod) and measured its length in millimetres (mm). As a result, we obtained the following:

Sample No.	1	2	3	4	5	6	7	8	9	10
Length (mm)	7	10	9	10	8	9	12	7	9	9

In this case the average is equal to = $\frac{\text{sum of total reading}}{\text{number of samples}}$

that is $\bar{X} = \frac{90}{10} = 9 \text{ mm}$

and the range = difference between the highest and lowest reading or
 $R = 12 - 7 = 5 \text{ mm}$.

We can speak here of an operation that produces rods of 9 mm average length, but the products can vary between 7 and 12 mm. If we had decided on a specification of 9 mm and a tolerance level of ± 2 mm, this would mean that we would accept all those products ranging between 7 and 11 mm. In this case we would reject sample No. 7, which is 12 mm.

There are many types of chart that can be used in quality control, some relating to standard deviation from the standard specification, and others to the range. Histograms, scatter diagrams, and so on, are used in one way or another. However, the most commonly used chart is the \bar{X} chart. Figure 66 shows an \bar{X} chart drawn in accordance with our example. It shows an average 9 mm, an upper control limit of 11 mm and a lower control limit of 7 mm. Figure 67 shows another hypothetical example where \bar{X} tends to exceed the upper control limit. This is an indication that the process is getting out of control, in which case it is stopped to detect and correct the reason for this variance.

Useful as these charts are, the basic approach here is to control variation from a predetermined tolerance level. The Taguchi method of quality control follows a different approach.

¹ Several references dealing with quality control or with production management can be consulted. See, for example, Elwood S. Buffa and Rakesh K. Sarin: *Modern production operations management* (New York, John Wiley, 8th ed., 1987), Ch. 13. See also Ch. 19 of this book on determination of sample size for various levels of confidence.

Figure 66. An \bar{X} -chart: Process within control limits

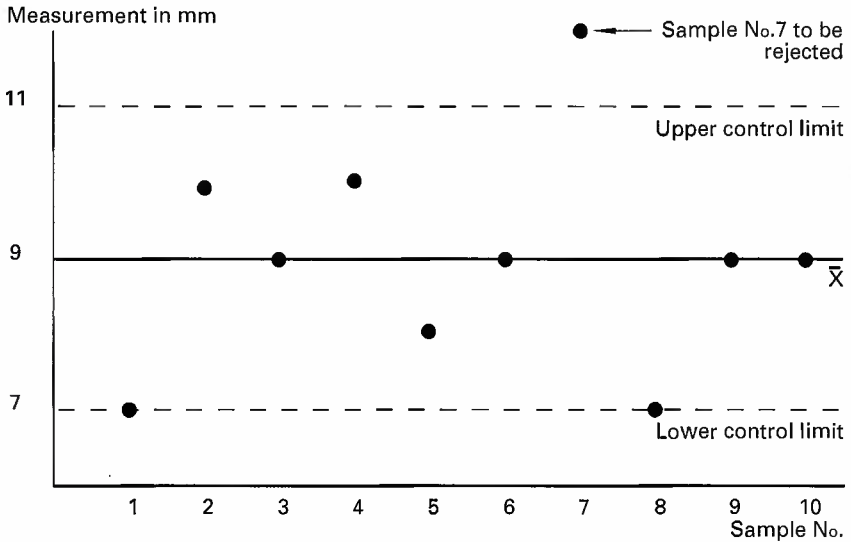
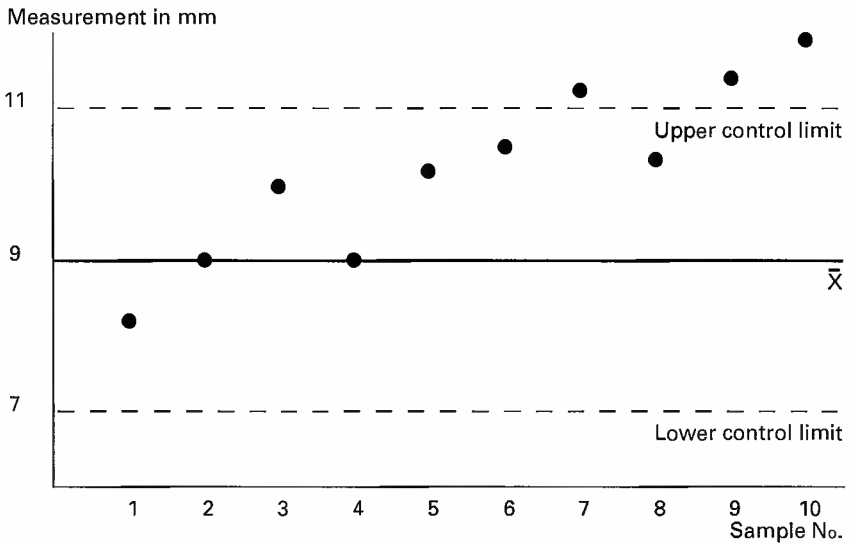


Figure 67. An \bar{X} -chart: Process drifting



3. The Taguchi approach

The Taguchi approach to quality control in its simplest form may be compared to the approach of an agronomist. Agronomists have for years experimented with seeds that were immune to climatic conditions or attacks by insects. The central theme of Taguchi's approach to quality is to have a second look at the product and process design, and change these in such a way as to render them

immune to variations. Let us take a simple example of a factory producing tiles. Under traditional statistical quality control approaches, the composition of the tiles is given and quality control aims at assessing the variations in product specification. These variations can arise out of many factors such as uneven temperature distribution during the baking operation, the mixing operation, and so on. Under the Taguchi approach, one would try to change the mixture of the ingredients that make up a tile, with a view to creating one that is immune to temperature variations. For example, in this particular case an increase in the lime content reduces variations a great deal. This is a proactive approach that invites the search for a better product and process design, so as to reduce the chances of quality variations.

In addition, every product has several quality characteristics (shape, colour, strength, etc.), but it is not economical to try to improve all of them. Under the Taguchi method only those that are of primary importance need to be investigated. Some of these characteristics may be produced in accordance with a certain specification but suffer deterioration on use, say, the colour of a fabric which may fade. Here again, using more fast colours can alleviate the problem of fading. Thus, apart from controlling the manufacturing operation to reduce variations from the desired standard, it is better to go back to the product design stage and create a so-called "robust" design which can resist both deterioration and variations in the environment during manufacturing.

4. Total quality control

As mentioned earlier in this chapter, quality can also be embraced by management as an effective competitive tool. As a result, managers may organize the running of the enterprise in such a way that pursuing quality objectives becomes inherent in employees' activities. Since customer satisfaction is the determining yardstick for quality specifications, then total quality control implies the continuous identification of customers' preferences and, as in the Taguchi approach, a continuous probing of product design to minimize variations from specifications, as well as a concerted effort by all concerned to minimize variations during processing and to improve customer services. Instead of relegating quality to a specific department such as the quality control department, total quality control becomes everybody's business. Customer satisfaction is obtained not only through the acquisition of a good-quality product but also through courteous telephone service, proper administration of an order, clear and proper billing, and a helpful after-sales service. In implementing total quality control some companies have found it useful to establish quality circles.

Quality circles (QC) started in Japan in the early 1960s. A QC is a small group, normally of six to eight persons, who work in the same area and who meet regularly on a voluntary basis to think of ways to improve the quality of their operational activities. Circle members usually receive suitable training in approaches to problem solving. In the early days of QC development the members were essentially concerned with quality-related problems. However, later on the concern spread also to productivity improvement. As the circle

members develop, they in turn seek to make systematic improvements and not just isolated experiments. As the QC movement began to spread from Japan to various developing and industrialized countries, some variations in the operation of QC were introduced. For example, QC groups in Japan meet after working hours, which is not the case in many industrialized countries. Reward for successful achievements in Japan is given in terms of recognition (say, a trophy), lecturing to other organizations on achievements or attendance at conventions, and for outstanding achievements a visit abroad may also be organized. In other countries the use of direct financial rewards is considered in many cases to be a more appropriate form of compensation.

The advantage of QC is that it involves employees in quality and productivity programmes and as such reinforces the approach to total quality control schemes. Nevertheless, not all QC movements have been successful. Some circles have become inactive almost from their inception or declined in activity after initial enthusiasm; some produced marginal results, while others continued their activities with remarkable success.²

5. Work study and quality control

Part Two of this book outlined the objectives of method study. These included not only quantitative gains or cost reduction but also quality improvement. In this sense, the relation between method study in particular and quality control is straightforward. A work study person evaluates the results of his or her work by looking at quality improvements as well. In addition, we have seen in this chapter that establishing appropriate quality specifications and tolerance levels and signalling the primary characteristic of a product for control can reduce costs, again an issue of concern to the work study person. We have also seen that modern trends look at quality control as a dynamic function that aims at the continuous improvement of product and process design to meet customer expectations.

In this sense the objectives of method study and that of modern quality control coincide. It would indeed be difficult for a work study person to be concerned primarily with quantitative gains while overlooking quality issues. He or she would be ill-advised to look for product simplification in design without taking into consideration the changes that might be needed in the composition of that product to make it more resistant to variations and deterioration. In the same vein, method study cannot pursue improvement in operations without linking them to the resulting quality imperatives. Finally, a total quality control approach creates an enterprise culture which can be more receptive and conducive to a study of the methods of work.

² For an analysis of the reasons for success and failure in the United States and the United Kingdom see, respectively, E. E. Lawler III and S. A. Mohrman: "Quality circles after the fad", in *Harvard Business Review*, Jan.-Feb. 1985, pp. 65-71; B. G. Dale: "The extent of and reasons for quality circle failures", in *Management Research News*, Vol. 7, No. 2, 1984, pp. 4-9.

Layout, handling and process planning

1. Layout

The way in which machinery, equipment and material are arranged in a working area determines the layout in that area. Layout is often determined at the outset of operations, i.e. when a plant or even an office starts operating. Even if the initial layout was well thought out, a re-examination of the utilization of space is often called for because of various factors, among them the following:

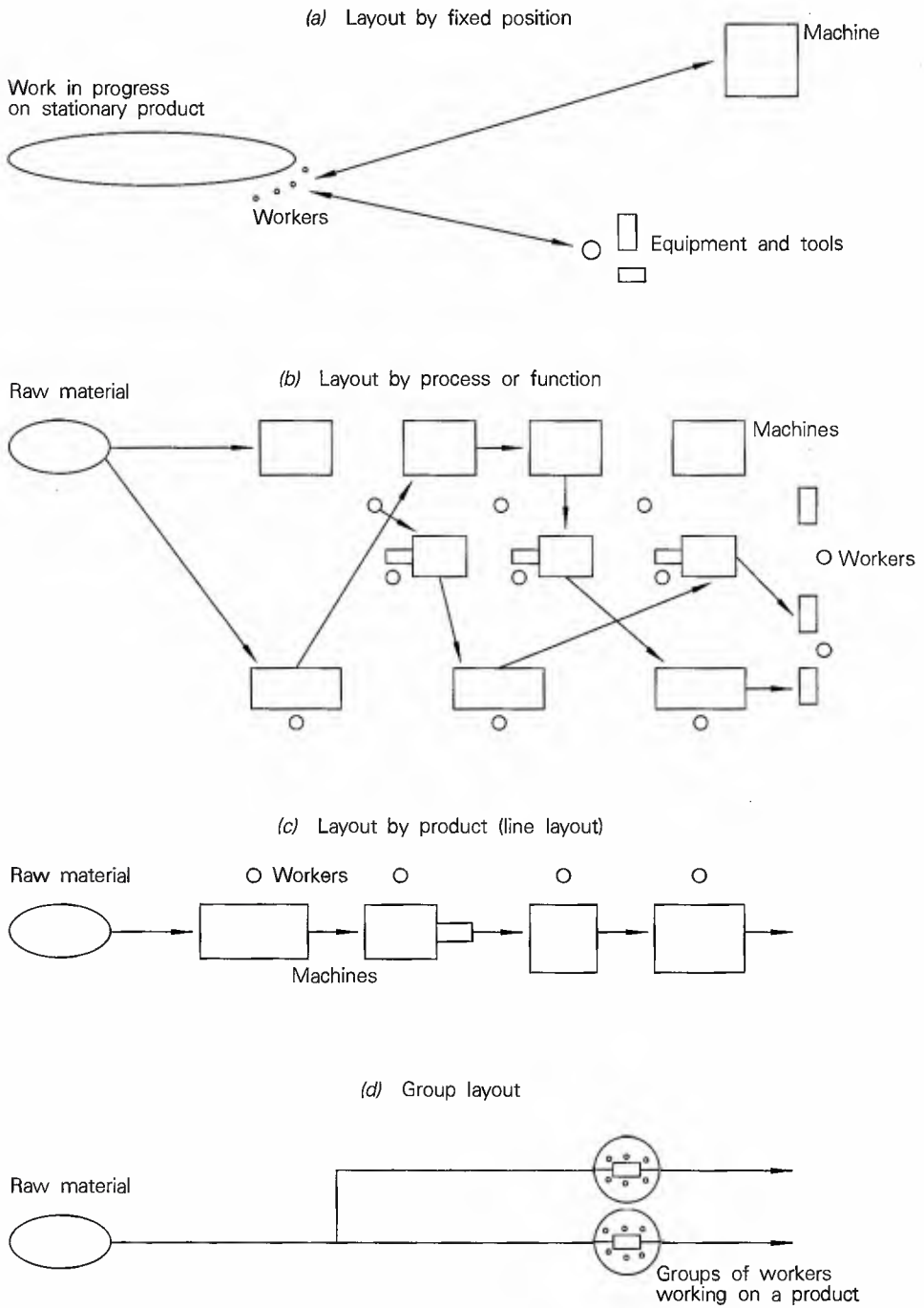
- New products are added or product design changes introduced. Both types of action may necessitate a different sequence of operations.
- New equipment or machinery or a different shape and size of materials are introduced.
- Materials-handling equipment that has different space requirements from the original equipment is acquired.
- Modifications are made to the building to increase space.
- Temporary arrangements may have been made to cope with an upsurge of demand for a certain product, but these then remain semi-permanent.
- Moves are made by management towards advanced technologies such as the use of robotics, automation, computer networking or flexible manufacturing systems.

When situations like these arise, it is said that the plant or a working area has outgrown its present layout. Operations become cumbersome with either congestion or lengthy and unnecessary movements of products-in-progress or operators, often with criss-crossing lines of production resulting in loss of time and energy.

To rethink a layout one has to start by distinguishing among four basic types: (1) layout by fixed position; (2) layout by process or function; (3) layout by product or line layout; and (4) group layout (figure 68). In practice a combination of two types or more of layout may exist in a working area.

- (1) **Layout by fixed position.** This arrangement is used when the material to be processed does not travel around the plant but stays in one place: all the necessary equipment and machinery are brought to it instead. This is the case when the product is bulky and heavy and when only a few units are made at a time. Typical examples are shipbuilding or aircraft construction, and the manufacture of diesel engines or large motors.

Figure 68. Types of layout



- (2) **Layout by process or function.** Here all operations of the same nature are grouped together: for example, in the garment industry all the cutting of material is carried out in one area, all the sewing or stitching in another, all the finishing in a third, and so on. This layout is usually chosen where a great many products which share the same machinery are being made and where any one product has only a relatively low volume of output. Other examples are textile spinning and weaving, and maintenance workshops.
- (3) **Layout by product or line layout,** sometimes popularly referred to as "mass production". In this layout all the necessary machinery and equipment needed to make a given product are set out in the same area and in the sequence of the manufacturing process. This layout is used mainly where there is a high demand for one or several products that are more or less standardized. Typical examples are soft drinks bottling, car assembly and some canning operations.
- (4) **Layout making possible group production methods, or group layout.** Recently, in an effort to increase job satisfaction, several enterprises have arranged their operations in a new way, with a group of workers working together on a given product or on a part of a product and having at hand all the machinery and equipment needed to complete their work. In such cases the workers distribute the work among themselves and usually interchange jobs. Further details of this method of production are given in Chapter 29.

With these various kinds of layout in mind, we may now analyse the flow of materials in a working area. In some situations, rapid changes in output may be realized by switching from one type of layout to another. This is particularly true when a shift is made from a layout by function to a line layout for one or more products whose output has been increased significantly.

In most cases, however, a careful analysis of the flow is called for before any decision is taken to change a given layout, since this is usually a costly process, and management has to be convinced that real savings will result before authorizing the change.

The development of a layout

A. Developing an initial layout

The line of reasoning is as follows:

- (1) From sales forecasts and production planning one can determine the amount of machinery and equipment that will be needed in the present and the future. The space requirement for each item of machinery is then calculated. About 17 per cent of the total space taken up by machinery should be added in a single-storey building and 22 per cent in a multi-storey building to account for passages, aisles and lifts.
- (2) A calculation is then made for the space needed for storing goods-in-progress and various other storage points.

Figure 69. Developing the flow for a number of products, using the cross chart

From \ To	Form	Normalize	Machine	Burr/trim	Paint	Plate	Coat	Polish	Wrap	Pack and ship	Total
Form		 14	 8	 6	 14				 1	 27	70
Normalize					 17	 1					18
Machine				 3	 2	 2				 1	8
Burr/trim		 4						 1	 3	 2	10
Paint				 1	 11	 19		 13	 2		46
Plate							 22				22
Coat								 22			22
Polish					 2				 33	 1	36
Wrap										 39	39
Pack and ship											0
Total	0	18	8	10	46	22	22	36	39	70	

Source: Taken from Richard Muther: "Plant layout", in H. B. Maynard: *Industrial engineering handbook* (New York and London, McGraw-Hill, 3rd ed., 1971), and used by kind permission of the McGraw-Hill Book Company.

- (3) Another calculation is made for auxiliary facilities such as washrooms, offices, pumps, maintenance services, etc. These are all listed and the space for each is determined.
- (4) We are now ready to determine and sketch the flow of work. In the case of layout by fixed position and line layout this is more or less straightforward. By using a flow process chart as explained in Chapter 7, one can visualize the sequence of operations and sketch a diagram to indicate the placement of workstations. It is the functional arrangement that presents us with a problem. This is so because in all probability a multitude of products are produced, each having a different sequence of operations. A helpful way of determining the placement of workstations in this case is to use a **cross chart**.
- As can be seen from figure 69, the cross chart is drawn up by listing the various operations (or machinery) through which the different products pass at the various stages of production, on both the horizontal and vertical dimensions of the chart. The example in figure 69 illustrates the use of the cross chart for a company making decorated metal products. In this case, the company is producing 70 products, each of which passes through some of the operations indicated.
 - To complete this chart, take one product at a time and enter its sequence of manufacturing in the appropriate square on the chart. If a product moves from "Form" to "Normalize", a stroke is made in the square "Form/Normalize". If it subsequently moves from "Normalize" to "Plate", a stroke is entered in the corresponding square, and so on until the whole sequence of operations for that particular product is entered. The same process is then repeated for each of the other 70 products. The completed cross chart appears in figure 69.
 - The next step is to decide which operations should be placed adjacent to each other. From the chart it is clear that 27 products out of 70 (i.e. 39 per cent of the products) pass directly from "Form" to "Pack and ship". These two operations should therefore be adjacent. Similarly, all 22 products that were subjected to plating passed from "Plate" to "Coat" and from "Coat" to "Polish". Hence, these three operations should follow each other in sequence. By following the same line of reasoning it is possible to reach the preferred sequence of operations.
 - A variation on this technique is to complete the cross chart by taking a sample of the most frequently produced items. If the plant is producing over 100 different items, it may become cumbersome to follow the method indicated above. However, investigation may reveal that, say, 15 or 20 items account for possibly 80 per cent of the production volume. The sequence of operations of these items would then be entered on the cross chart, and the flow determined in the same way as that described above.

- (5) Once the dimensions and the relative position of machinery, storage facilities and auxiliary services have been determined, it is advisable to make a visual presentation of the proposed layout before proceeding with the actual rearrangement of the workplace, which may be a costly operation. This can be done by the use of "templates", or pieces of cardboard cut out to scale. Different coloured cards may be used to indicate different items of equipment, such as machines, storage racks, benches or material-handling equipment. When positioning these templates, make sure that gangways are wide enough to allow the free movement of material-handling equipment and goods-in-progress.

Alternatively, scale models may be used to provide a three-dimensional display of the layout. Various types of model for many well-known items of machinery and equipment are readily available on the market and are particularly useful for training purposes.

B. Modifying an existing layout

In modifying an existing layout, a flow process chart may be used to record travel distances and times for various operations. This can be advantageously supplemented by a flow diagram. An example was given in Chapter 7 (figures 27-30). In a study involving the modification of a layout one is better to look at the whole layout of, say, a department or even a plant before moving into the details of one operation. After developing an ideal layout, one has to reconcile it with the constraints that exist. It may be too costly to move certain machinery, or modify the structure of a building to have a smoother layout. The costs may outweigh the resulting benefits. Here one moves from the ideal to the practical. Some of the techniques used in developing an initial layout, such as the use of the cross chart (figure 69) and the various calculations of space requirements, may also be relevant here.

2. The handling of material

A good deal of time and effort is often expended in moving material from one place to another in the course of processing. This handling is costly and adds nothing to the value of the product. In essence, therefore, there should ideally be *no handling* at all. Unfortunately, this is not possible. A more realistic aim would be to move material by the most appropriate methods and equipment at the lowest possible cost and with regard to safety. This aim may be met by:

- eliminating or reducing handling;
- improving the efficiency of handling;
- making the correct choice of material-handling equipment.

Eliminating or reducing handling

There is often ample scope for eliminating or reducing handling. In practice, it becomes obvious that there is a need to improve an existing situation when certain symptoms are observed, e.g. too much loading and unloading, repeated manual handling of heavy weights, material travelling considerable distances,

non-uniform flow of work with congestion in certain areas, frequent damage or breakage resulting from handling, and so on. These are some of the most frequent phenomena that invite the intervention of the work study specialist. The approach to be followed here is similar to the traditional method study approach, using outline and flow process charts and flow diagrams and asking the same questions as to “where, when, by whom, how” and, above all, “why” this handling is done.

However, such a study may frequently have to be preceded by or carried out in conjunction with a study of the layout of the working area, in order to reduce movement to a minimum.

Improving the efficiency of handling

The observance of certain precepts can improve the efficiency of handling. These precepts are:

- (1) Increase the size or number of units being handled at any one time. If necessary, review product design and packaging to see if you can achieve this result more readily.
- (2) Increase the speed of handling if this is possible and economical.
- (3) Let gravity work for you as much as possible.
- (4) Have enough containers, pallets, platforms, boxes, etc., available in order to make transportation easier.
- (5) Give preference in most cases to material-handling equipment that lends itself to a variety of uses and applications.
- (6) Try to ensure that materials move in straight lines as much as possible, and ensure that aisles are kept clear.

Making the correct choice of material-handling equipment

Different kinds and types of material-handling equipment exist. Although there are literally hundreds of various types, these may be classified in five major categories.

Conveyors

Conveyors are useful for moving material between two fixed workstations, either continuously or intermittently. They are mainly used for continuous or mass production operations — indeed, they are suitable for most operations where the flow is more or less steady. Conveyors may be of various types, with either rollers, wheels or belts to help move the material along: these may be power-driven or may roll freely. The decision to provide conveyors must be taken with care, since they are usually costly to install; moreover, they are less flexible and, where two or more converge, it is necessary to coordinate the speeds at which the two conveyors move.

Industrial trucks

Industrial trucks are more flexible in use than conveyors since they can move between various points and are not permanently fixed in one place. They are therefore most suitable for intermittent production and for handling various

sizes and shapes of material. There are many types of truck — petrol-driven, electric, hand-powered, and so on. Their greatest advantage lies in the wide range of attachments available; these increase the trucks' ability to handle various types and shapes of material.

Cranes and hoists

The major advantage of cranes and hoists is that they can move heavy material through overhead space. However, they can usually serve only a limited area. Here again, there are several types of crane and hoist, and within each type there are various loading capacities. Cranes and hoists may be used both for intermittent and for continuous production.

Containers

These are either "dead" containers (e.g. cartons, barrels, skids, pallets) which hold the material to be transported but do not move themselves, or "live" containers (e.g. wagons, wheelbarrows or computer self-driven containers). Handling equipment of this kind can both contain and move the material, and is usually operated manually.

Robots

Many types of robot exist. They vary in size, and in function and manoeuvrability (figure 70). While many robots are used for handling and transporting material, others are used to perform operations such as welding or spray painting. An advantage of robots is that they can perform in a hostile environment such as unhealthy conditions or carry on arduous tasks such as the repetitive movement of heavy materials.¹

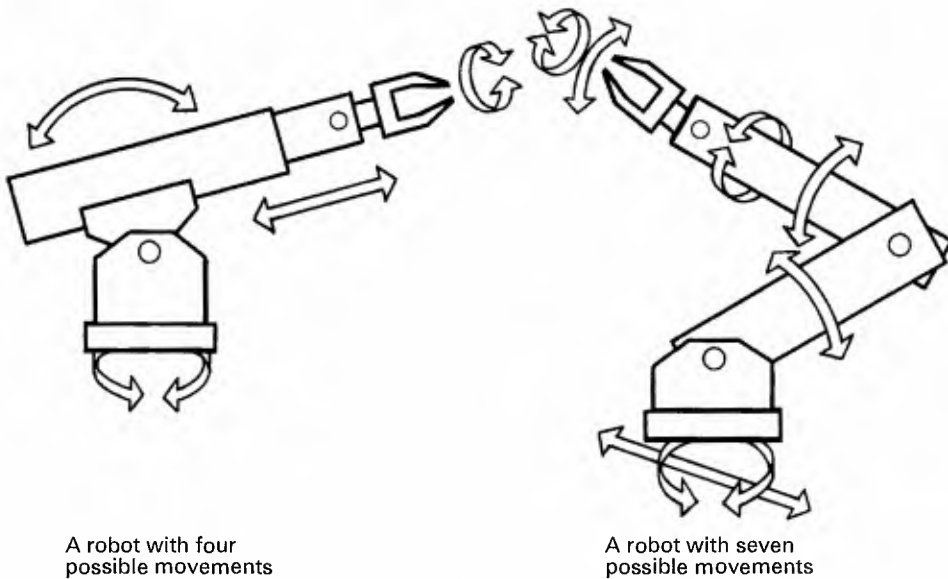
The choice of material-handling equipment among the various possibilities that exist (figure 71) is not easy. In several cases the same material may be handled by various types of equipment, and the great diversity of equipment and attachments available does not make the problem any easier. In several cases, however, the nature of the material to be handled narrows the choice.

Among the most important factors to be taken into consideration when choosing material-handling equipment are the following:

- (1) **Properties of the material.** Whether it is solid, liquid or gas, and in what size, shape and weight it is to be moved, are important considerations and can already lead to a preliminary elimination from the range of available equipment under review. Similarly, if a material is fragile, corrosive or toxic this will imply that certain handling methods and containers will be preferable to others.
- (2) **Layout and characteristics of the building.** Another restricting factor is the availability of space for handling. Low-level ceilings may preclude the use of hoists or cranes, and the presence of supporting columns in awkward places can limit the size of the material-handling equipment. If the building is multi-storeyed, chutes, or ramps for industrial trucks, may be used. Finally, the layout itself will indicate the type of production operation (continuous, intermittent, fixed position or group) and can

¹ Several references deal with robots. Those interested may refer to Sherif D. El Wakil: *Processes and design for manufacturing* (Englewoods Cliffs, New Jersey, Prentice Hall, 1989), pp. 422-445.

Figure 70. Manoeuvrability of robots



already indicate some items of equipment that will be more suitable than others.

- (3) **Production flow.** If the flow is fairly constant between two fixed positions that are not likely to change, fixed equipment such as conveyors or chutes can be successfully used. If, on the other hand, the flow is not constant and the direction changes occasionally from one point to another because several products are being produced simultaneously, moving equipment such as trucks would be preferable.
- (4) **Cost considerations.** This is one of the most important considerations. The above factors can help to narrow the range of suitable equipment, while costing can help in taking a final decision. Several cost elements need to be taken into consideration when comparisons are made between various items of equipment that are all capable of handling the same load. There is the initial cost of the equipment, from which one can derive the investment cost in terms of interest payment (i.e. if the company has to borrow money to buy the equipment) or opportunity costs (i.e. if the company possesses the funds and does not have to borrow, but the purchase of the equipment would deprive it of an opportunity to invest the funds at a certain rate of return). From the cost of the equipment one can also calculate the depreciation charges per year, to which will be added other charges such as insurance, taxes and additional overheads. Apart from these fixed charges, there are also operating costs, such as the cost of operating personnel, power, maintenance and supervision. By calculating and comparing the total cost for each of the items of equipment under consideration, a more rational decision can be reached on the most appropriate choice.

Figure 71. Different possibilities of handling the same object

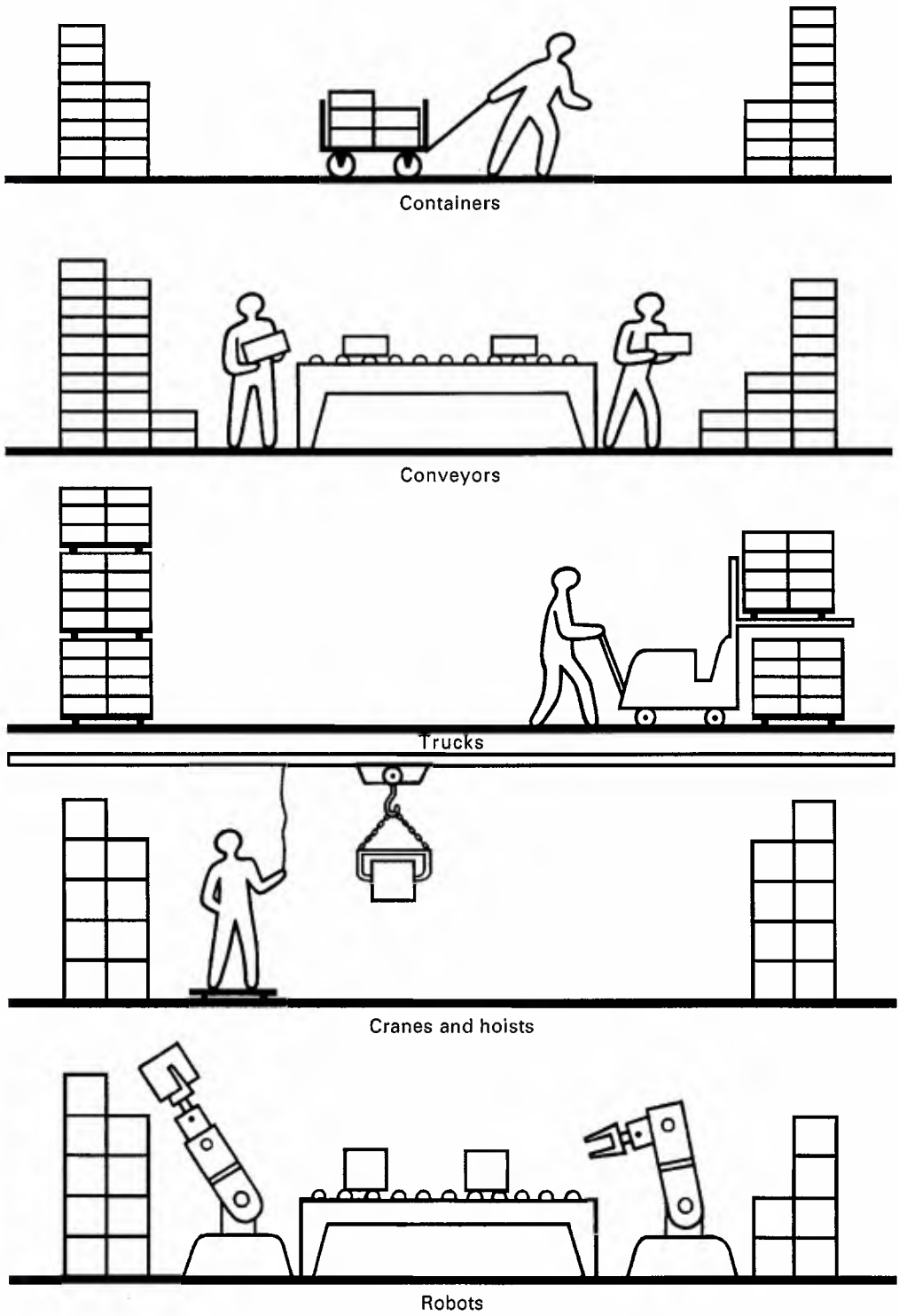
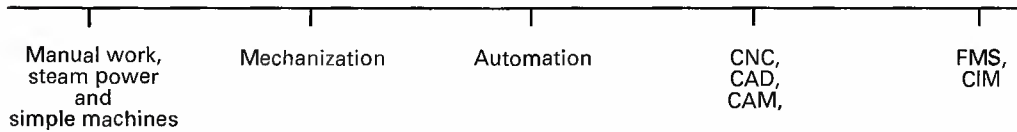


Figure 72. Developments in manufacturing technology



CNC: computerized numerical control; CAD: computer-aided design; CAM: computer-aided manufacturing; FMS: flexible manufacturing systems; CIM: computer-integrated manufacturing.

While proper layout and handling have brought about a considerable improvement in the efficiency of operations, other developments in machinery, information systems and computerization have had an important impact on productivity as well. We shall briefly review some of these developments before dealing with process planning.

3. Developments in manufacturing technology

Ever since the Industrial Revolution, people have been seeking to improve the technology of producing goods, particularly manufactured products. The introduction of the assembly line in 1914 to produce Model T Ford cars was revolutionary at that time; it marked a clear transition from a manual to a mechanized operation. In the 1950s automated processes came into being and, with the rapid developments in computer science and application, we have moved into areas such as computerized numerical control (CNC), computer-aided design (CAD) and computer-aided manufacturing (CAM) and — in the factory of the future — are heading towards flexible manufacturing systems (FMS) and computer-integrated manufacturing (CIM). This is schematically presented in figure 72.

This transition does not mean that each of these phases has been replaced by a successive phase in a chronological order. We still have manual work, assembly line and mechanized processes, sometimes side by side with an automated process in the same plant. However, there is a trend towards more flexible systems of production, and this is gathering pace at an accelerated rate. Thus while the first Industrial Revolution spanned the late eighteenth and early nineteenth centuries, the evolution in electronics and computers over the past 40 years has led many to believe that we have in fact embarked on a second Industrial Revolution.

We shall now review briefly some of the developments in manufacturing technology.

Assembly line: Operations allow a massive increase in production (hence they became synonymous with the term “mass production”). They do so by dividing production operations into elements, each element being performed by an operator while the product moves along the line. Thus the operators are stationary and the product moves. While assembly lines permit a dramatic increase in output, they also breed monotony as each operator repeats the same type of operation over and over again.

Mechanization: Mechanization aims at replacing manual work by machine work when feasible. In this way some monotonous repetitive manual work has been replaced by machinery capable of performing these operations. Still in mechanization, a worker operates a machine and adjusts it to perform the desired quantity of output to the desired level of quality. Quality in this case depends to a large measure on the worker's skill, in addition to the condition of the machine and tools that are being used.

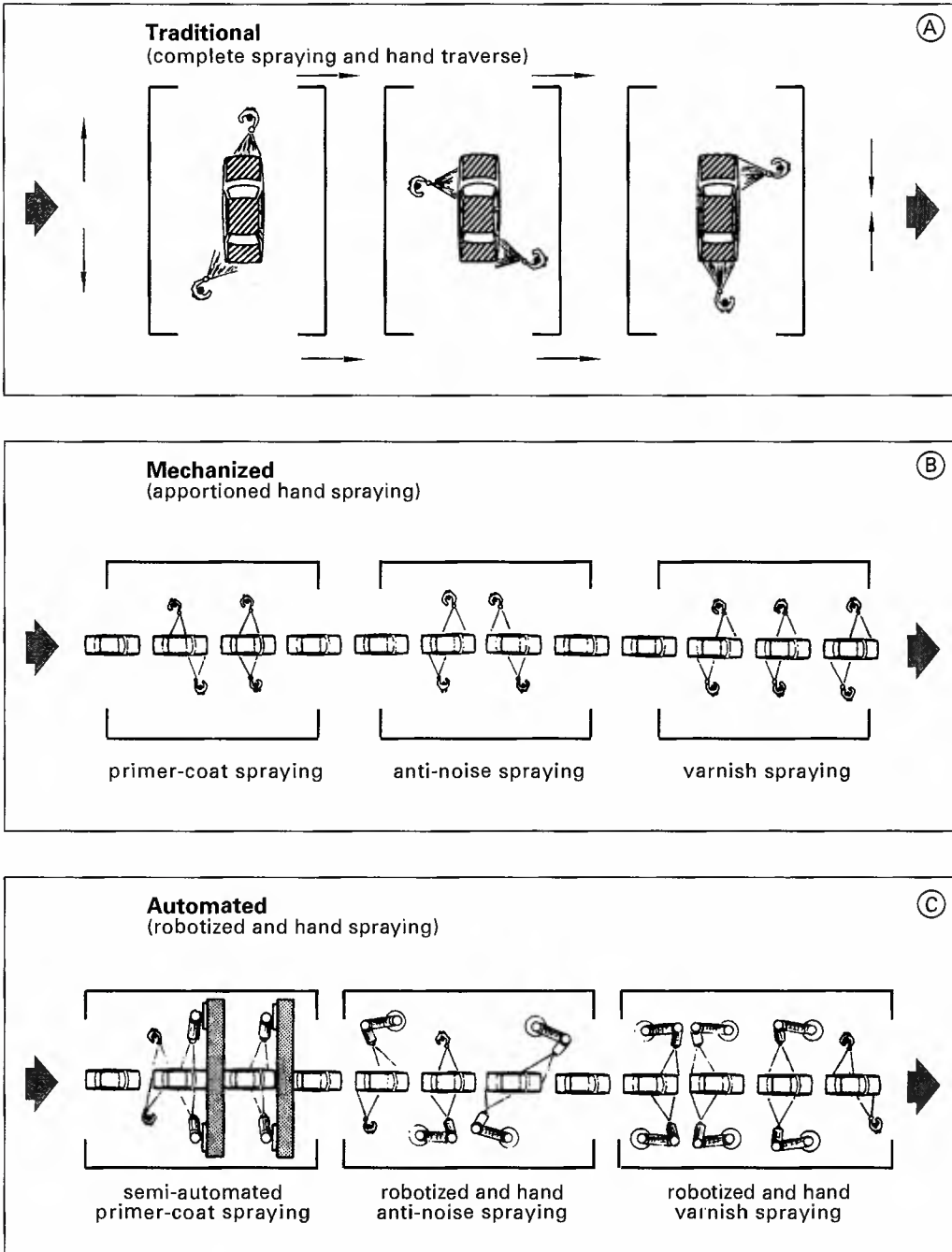
Automation: In automation few workers are involved. The machines receive their instructions from a computer into which all the desired information has been fed, and therefore they continue to operate on their own and with minimum operator interference. The development of robots, CNC and CAM has given a boost to automation. The transition from traditional operations to automation is shown in figure 73.

Numerical control (NC) and computerized numerical control (CNC): The principle of NC technology is that the machine is controlled by preset values, traditionally recorded on a punch tape, each referring to a certain desired physical quantity such as height, length, diameter, etc. The introduction of numerical values for any physical quantity drives the machine to perform the desired operation accordingly. Since then the technology has evolved rapidly towards CNC. NC and CNC machine tools ensure that precise operations are performed repeatedly and rapidly. Modern CNC machines can also store a programme for future use and form the basis for computer-integrated manufacturing (CIM).

Computer-aided manufacturing (CAM): This is a generic name referring to a host of machines and processes that use computers in the management, implementation and control of manufacturing operations. CNC forms part of CAM, but so does computer-aided process planning — which, as the name implies, uses the computer to determine the needed sequence of operations in manufacturing — computer-aided monitoring and control of manufacturing operations.

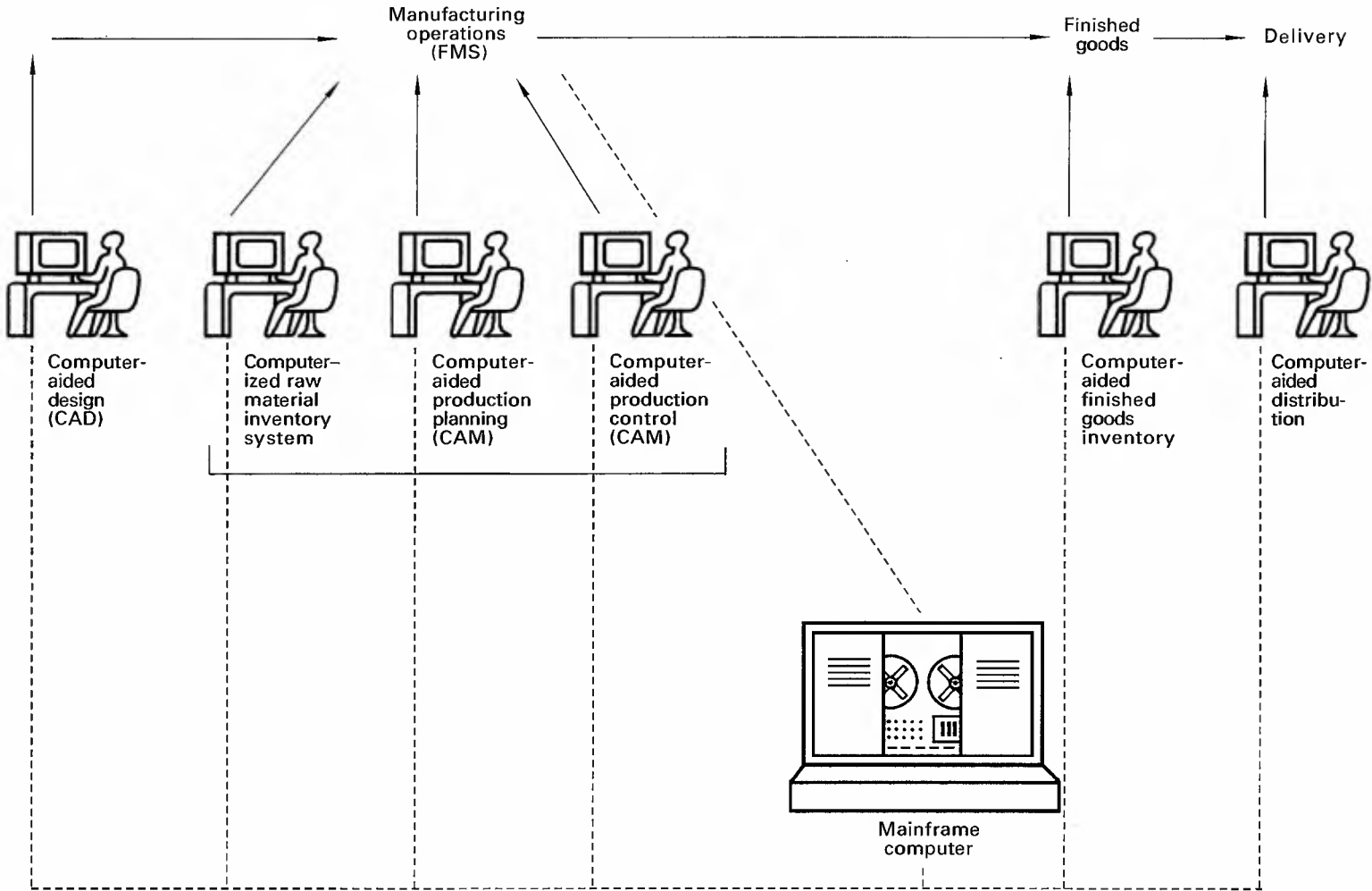
Flexible manufacturing systems (FMS): This is a fairly recent development. FMS allows the construction of a production system that can be responsive to changing production targets. It therefore consists of a series of processes that are needed to make a certain component or a part. These can include operational machinery, an automatic materials-handling system and a computer-control system which coordinates the other two activities. By introducing changes in the programme, the various components of FMS work in tandem to produce a new desired output. While the use of FMS is expanding, these systems are still very expensive to install and operate. More research is needed into the development of software required for their use, and this will no doubt be forthcoming.

Figure 73. The evolution of car painting



Source: Reproduced by courtesy of ENFAPI, Sistemi Formativi Confindustria: *La fabbrica camminando con l'innovazione* [The factory in conjunction with innovation] (Rome, Editore SIPI, 1987), p. 90.

Figure 74. Computer-integrated manufacturing (CIM)



Computer-integrated manufacturing (CIM): By linking all the operations in a given work-setting from the design stage to delivery of goods using a mainframe computer and subsidiary terminals, one can establish a computer-integrated system of manufacturing (figure 74). Such a system would use CAD in design (referred to in Chapter 12) and CAM in all its various forms for subsequent processing. CIM involves the computerization of various processes. More important, this is done in synchronization with information flow so that the whole operational system, from the entry of raw material to the delivery of finished goods, receives various flows of information that allow it to correct anomalies and proceed in an optimal manner. In the early 1990s this was still a sought-after objective that had materialized in a meaningful manner only in a limited number of cases.

4. Process planning

Process planning aims at developing a comprehensive plan for manufacturing a part or a product. The starting-point is the product design, from which one can determine in a chronological order:

- (1) The number of parts needed to make the product.
- (2) Whether to make or buy some of these parts using financial estimations of the costs involved for each alternative, as well as other value judgements; for example, availability of raw material, the skill needed, use of available space for existing production machinery and equipment, and so on.
- (3) Once a decision is made on those parts that will be made, then the sequence of operations may be determined using block or operations charts.
- (4) If new equipment and machinery has to be bought, then a decision needs to be taken as to the type of manufacturing technology that can be used (refer to section 3, above).
- (5) A further decision is then made concerning the by-products of the process of manufacturing; for example, the use of effluent gases, excess heat, waste disposal and treatment.
- (6) A decision is also made on the handling equipment and on the type, skill and number of operators to be assigned to the operation.
- (7) Finally, a decision is taken on the type of information that needs to be designed and generated for the control of the operation, including quality considerations.

While the above seven steps apply essentially to processes that are planned for a new product or part, they can also be applied with some adaptation to the modification of existing processes, to cope with a new product or design change. We shall restrict our discussion to the application of steps 3 and 4 with respect to two types of operations: **functional operations** and **line operations**. As indicated earlier in this chapter, functional operations are those where all similar machinery is arranged together and the products move from one machine to another in a sequence depending on the type of

operation that needs to be performed, whereas line operations are those where the raw material or part moves continuously through a number of sequential operations that end up with the finished product. The remaining steps in process planning referred to above were dealt with earlier, with the exception of step 7 which will be discussed in the next chapter, and step 2, the “make or buy” decision, the explanation of which falls outside the scope of this book.

Process planning in functional manufacturing

Traditional functional manufacturing, which figures prominently in machine-tool industries, garment-making factories and similar types of industry, is based on the premise that all similar machines are put adjacent to each other. Depending on the sequence of operations needed to manufacture a certain product, this product moves from one machine to another. At each machine there may be a need for a setting-up time to adjust it to the machining requirements of that particular product. Process planning aims at defining the sequence of operations for each product and the time it will take to go through each machine, including the set-up time, and then calculating the number of machines and tools and materials that will be needed to manufacture each product.

In comparison with line production this type of arrangement is not effective because of the time lost in setting up various machines as a result of changes from one product to another, and because of the successive handling and backtracking as various products move through differing operations.

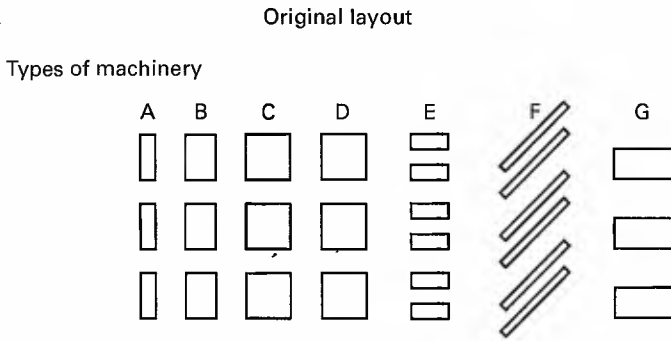
To overcome these difficulties, there have been two major developments. The first consists of performing a Pareto analysis from which the products that account for the largest volume of production are identified. The layout is subsequently changed in such a way that the machinery and equipment needed to manufacture these products are put in sequence and these products are produced in a line fashion (figure 75). Substantial gains in productivity can be obtained in this way. The second approach consists of replacing existing machines by CNC machines where reprogramming is quicker and set-up time is reduced substantially. Again, CNC can be arranged in such a way that all families of certain major products or parts are performed together in the same working area.

Process planning in line manufacturing

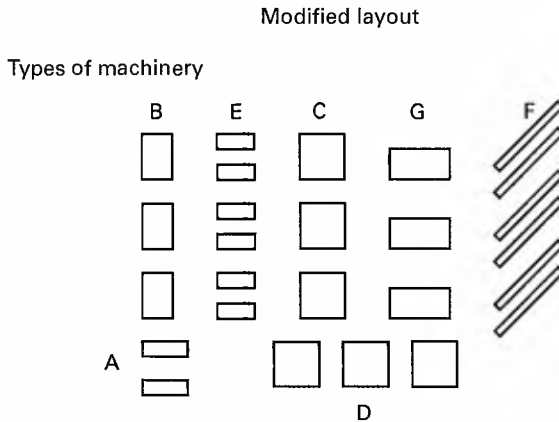
The best examples of line manufacturing are the chemical industry, bottling plants and motor vehicle assembly. In line manufacturing, the process is more or less fixed at the stage of the plant design, but there are usually minimal changes in lead time as the production shifts from one product to another. In a bottling plant, for example, changing the type of soft drink being bottled does not involve too much of a lead time. Because of that line production is considered a highly productive operation.

Process planning in line production consists of making a block diagram (figure 76) followed by a process flow diagram (figure 77). These are then followed by detailed engineering diagrams where the position of various

Figure 75. Changing functional layout to a line or product layout



Here machines are organized by function. However, analysis shows that 80 per cent of the products go through machines B E C G F in that sequence.



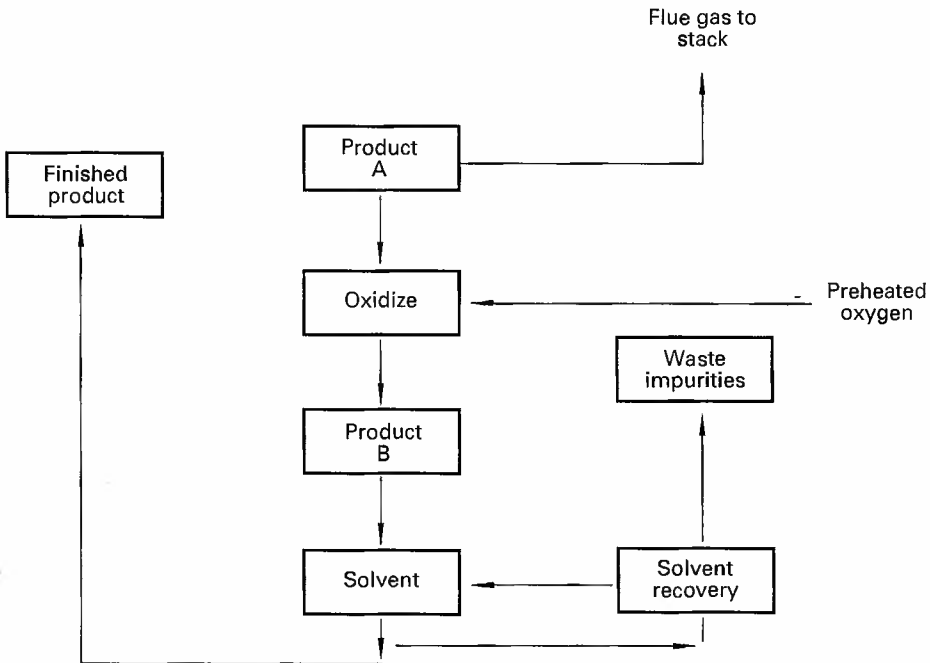
This layout permits 80 per cent of the products to be processed according to a line sequence of manufacturing.

equipment is indicated. These can be pumps, ventilation equipment, vessels, fans, blowers and compressors, vacuum equipment, mixers and agitators. Auxiliary equipment, such as heat exchangers, insulation, air conditioning and sources of power and heat, is then added.

5. Work study, layout, handling and process planning

Layout and the choice of handling methods constitute a major preoccupation in any study of methods of work. In most method study examples mentioned in Chapters 7, 8 and 9, improvements in work methods were obtained through a modification of the layout, shortening distances of travel for materials and operators, and facilitating handling and transport operations whether at the workplace or between workstations.

Figure 76. A block diagram in line manufacturing

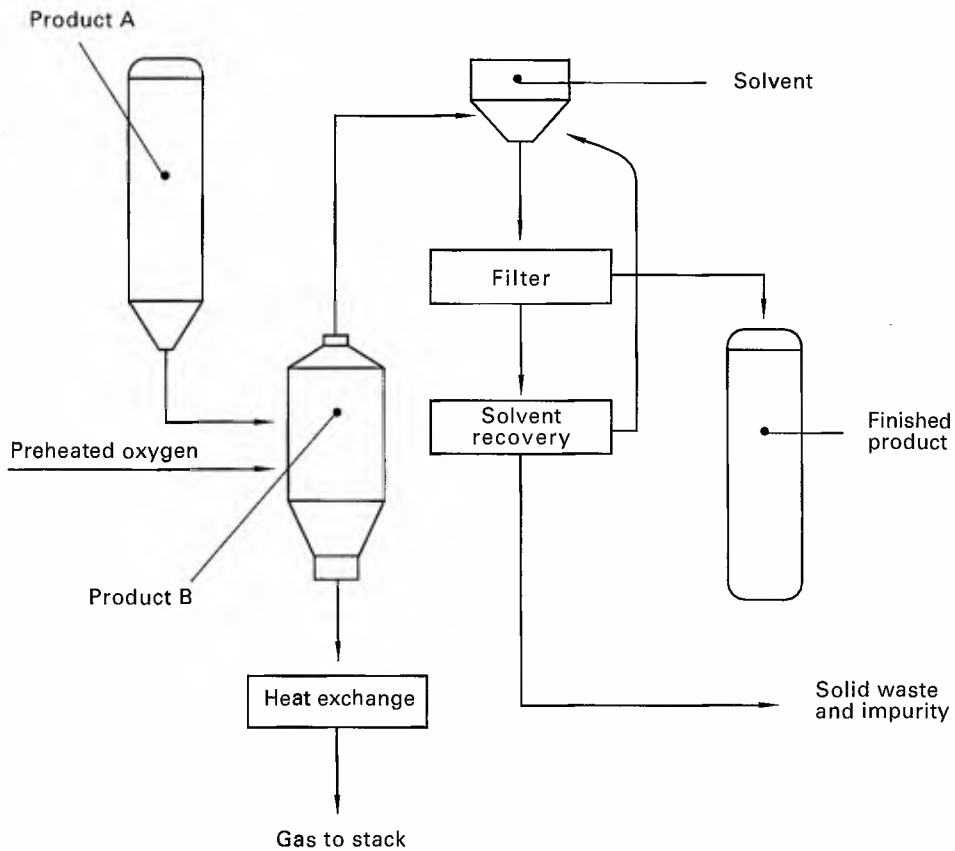


While the basic approach to developing a layout was outlined in this chapter, it is rather rare that a work study practitioner will be called upon to make a complete design of a plant using the basic steps indicated. This is more the task of the industrial engineer or the production management specialist. It is more common for the work study person to be faced with a problem of modifying an existing layout. Here the approach consists of planning an “ideal” layout, taking into consideration some of the constraints such as the cost involved in moving heavy machinery. Before making a decision on the movement from the ideal to the practical, the work study practitioner may then weigh up several possible solutions, each evaluated on its own merits.

We have also seen that in line manufacturing, because process design is inherent in the installation, the freedom of action of a work study person is more limited. It could be restricted to a study of handling operations between lines of production, or of the raw material and packaging of finished products, and in some cases to the balancing of operations among converging lines. By contrast, the work study person can accomplish a great deal by changing a functional operation into an arrangement where the primary products or parts are arranged on a line production basis.

In this respect this chapter has also shown the gradual transition in manufacturing technology, particularly in more industrialized countries, from mechanization to automation and to FMS. This trend, in a sense, is reminiscent of the early days of work study when it assisted in simplifying work, isolating repetitive motions which eventually became mechanized and are now semi- or fully automated. Keeping these trends in perspective permits the work study person to inquire whether the operation under study is likely to go through a

Figure 77. A flow diagram in line manufacturing



technological change fairly soon, before embarking on a lengthy study to achieve gains in efficiency that may pale by comparison with advanced technology gains. Because of his or her intimate knowledge of operations on the shop floor, a work study specialist can be a valuable resource person when it comes to the choice of a new operations technology or advanced handling system.

If need be, he or she can be counted upon to assess the improvements that are likely to arise as a result of introducing advanced technology, or for that matter the problems that could be encountered.



Production planning and control

1. The scope of production planning and control

A crucial issue in production management is how to prepare the plans for manufacturing a product or a range of products in the desired quantity and quality to meet agreed delivery dates. But even then the best-conceived plans are not infallible. Unexpected delays, low inventories or machine breakdowns can undermine production plans. As a result, there is a need to establish a control over the progress of operations which can signal deviations from the plans and thereby trigger off corrective action. Production planning and control are therefore closely related, so much so that some writers have tended to use only one term to encompass them both. Thus “production control” has in some cases been used as a term that includes the planning phase as well.

In addition, there have been two varying interpretations of the scope of production planning and control.

The first approach includes under this discipline the planning of all materials, processes and operations ending with the finished product. Production planning and control are seen to involve inventory control, scheduling of operations, and the planning of tools and equipment that are needed, as well as quality control.

In this chapter we shall not adopt such an embracing definition. Quality control is a sufficiently important subject to be dealt with on its own, and this was done in Chapter 13. Furthermore, new developments in inventory control warrant a separate chapter devoted to that subject (Chapter 16).

The second approach looks at planning as an aggregate overall concept. Here the starting-point is the sales forecast or sales orders depending on the products being produced. A production capacity assessment is then made, and an adjustment introduced to account for the reliability of delivery of raw materials, effective time of operations and the nature of the product mix. Scheduling of operations then begins.

This second approach, if adopted, would take in issues such as estimation of demand for various products, probabilistic assessment of operations breakdowns, labour turnover and absenteeism, all of which fall beyond the scope of this book, where we are more concerned with production operations and their relations to work study. For this reason we intend to take a restrictive view of production planning and control by limiting it to the scheduling, planning and control of operational activities.

In doing so, we have to differentiate between planning and control in continuous or line production, planning and control in intermittent batch production or functional production, and planning for specific projects.

2. Production planning and control in continuous production

As explained in Chapter 14, continuous or line production consists of operations where one or a few products pass through a sequence of operations to produce the desired finished product or products. Examples are chemical industries, paper and pulp plants, and cement factories. In the event that the enterprise is producing one product, production planning and control become a rather simple operation of allocating production targets per week or on a daily basis, the assumption being that all the different machines involved are perfectly synchronized. A control of the output would signal a deviation from the desired norm calling for an intervention to take corrective action.

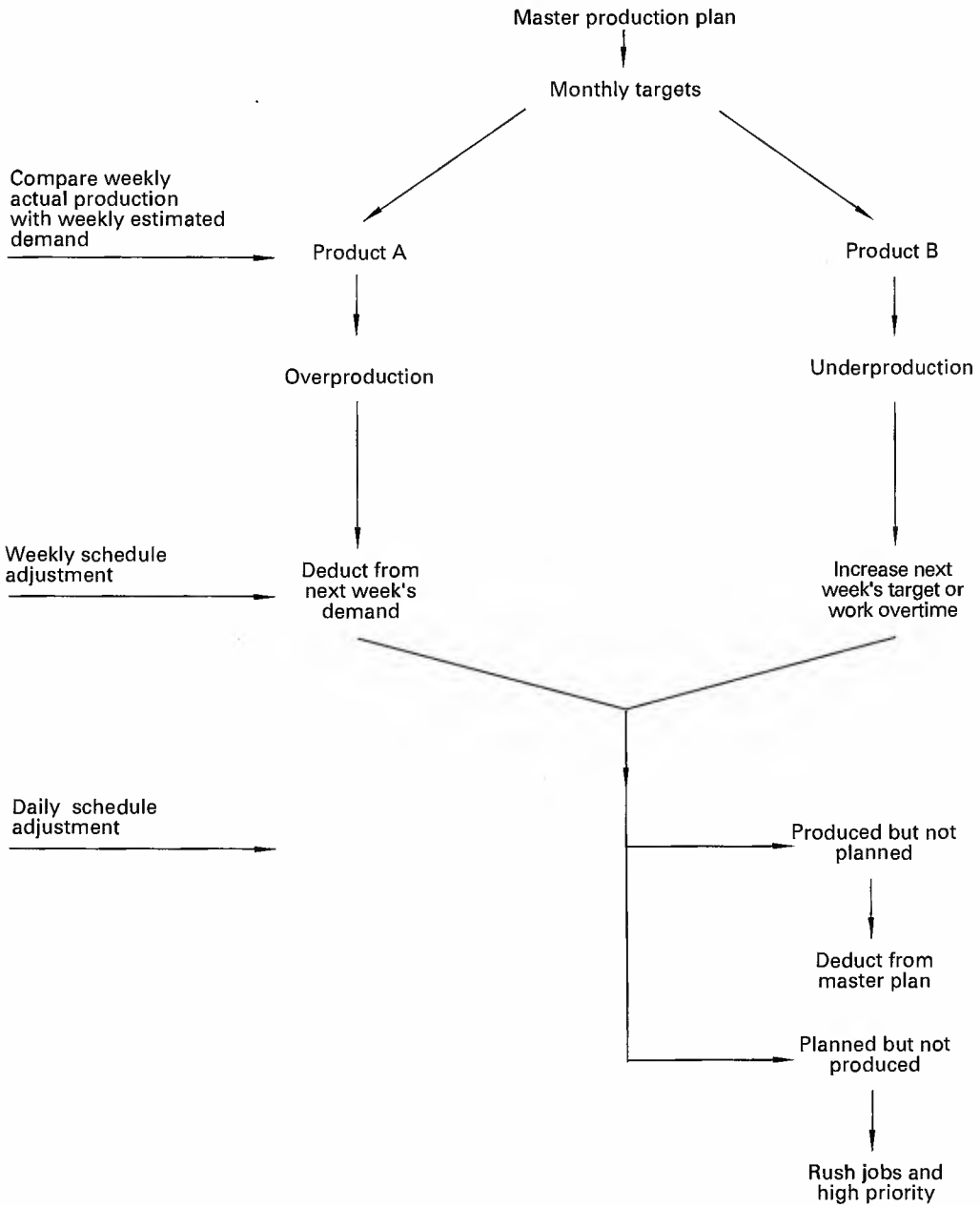
It is rather unusual to have a single product moving through a production line. More likely, a few products may compete for existing capacity. The mix of products involved can render the planning and control operation more complex. In an oil refinery, for example, increasing the planning targets for gasoline means a reduction in the production of other refined products such as diesel oil or kerosene. In several cases in line production operations, as the various products share more or less the same flow, adjustments in the plan are made on a daily basis, depending on variations in demand for each product. A simplified sequence of planning for line production is shown in figure 78. When more than two or three products are involved, more sophisticated tools using suitable computer software are normally used for planning purposes.

3. Production planning and control in intermittent production

Intermittent production is normally a process where a multitude of products or parts are produced, each necessitating a certain sequence of operations. Examples of intermittent production are woodworking and furniture industries, and machine shops. In this type of planning the sequence of operations for each product or part is identified, together with the time needed in each operation, including set-up times. If the number of products is limited, then a suitable chart such as the **Gantt chart** (figure 79) can be used to plan and control the sequence of operations. The same Gantt chart can also be used to show machine loading, thereby identifying idle time. This would enable rescheduling to obtain the optimum utilization of machines and equipment. Finally, the Gantt chart can be used to plan operators' deployment on various machines, or materials procurement and delivery needs.

In constructing a Gantt chart one works backwards, starting with delivery dates of the final product and then scheduling assemblies or subassemblies

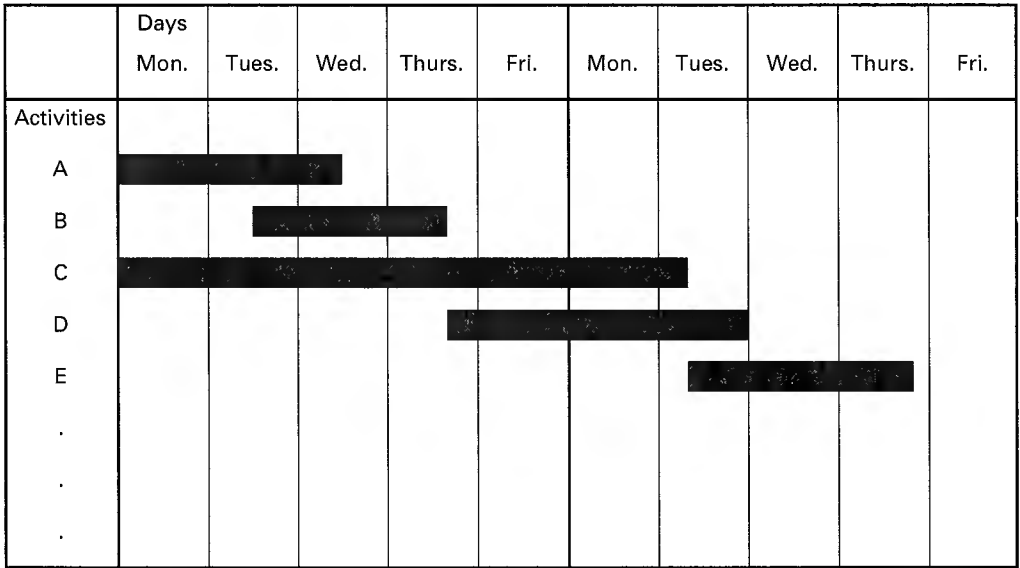
Figure 78. Planning and control for line production: Master production plan



relating them to a time scale (in months, weeks, days or hours as the need may be) until one can determine the starting-point for every operation.

While Gantt charts offer management an easy readable and visual demonstration of a work plan and the position regarding implementation at a certain date, they become cumbersome to use once the products or parts are many and varied and if there are a number of constraints such as capacity utilization, rejection, margins, uncertainty of delivery dates of raw materials or changing priorities for finished products. In such cases more sophisticated tools

Figure 79. Bar diagram or Gantt chart



of probability theory and operations research are used to analyse a planning problem which is decomposed into various scheduling options. Computer software exists to assist with such problems, which involve changing the various constraints to obtain feasible schedules and come up with an optimum solution.

To translate plans into actual operational instructions various forms are issued or instructions given, sometimes using computer terminal facilities. These can include manufacturing orders, including routing of raw material and products-in-progress to final products, operation cards to operators showing distribution of their time on various operations, machine loading and utilization orders, and a feedback monitoring operation. These various types of information, though primarily useful for the optimum allocation of resources for planning and control, are also useful for cost-accounting purposes and enable information to be given on probable delivery dates.

4. Planning and control of special projects

The Gantt chart is unsuitable for planning special projects such as building a ship or a diesel engine, or erecting a building. In these special projects not only are the many activities too cumbersome to be handled by a traditional Gantt chart operation, but also several activities can be, and normally are, performed simultaneously. Such projects are planned and controlled using special planning methods and diagramming techniques called networking. Among the most important planning methods used is PERT (Programme Evaluation and Review Technique) developed by the United States Navy and used to plan and control the activities of some 3,000 different contractors engaged in building the Polaris submarine in 1958. Independently, another planning method called

CPM (Critical Path Method) was developed by DuPont together with the Rand Corporation in 1957. Both systems are similar, and the extended use of both PERT and CPM over the years eliminated some of the differences that originally distinguished one from the other. Because of that we will try to explain briefly the CPM method and the networking planning technique associated with it.

The planning sequence consists of the following steps:

- (1) Identify the activities needed to complete a certain project.
- (2) Determine which activities can run concurrently and which can only be started after another activity is terminated.
- (3) Draw the network diagram, using the principles shown in figure 80.
- (4) Calculate the time required to complete each activity, and indicate this on the diagram.
- (5) Determine the total time for completing the project; this is the longest path on the network and is called the critical path (figure 81).
- (6) Calculate the costs needed for each activity if it were to be carried out at a normal pace, or at a crash or accelerated pace (say by using more people, overtime or more resources).
- (7) Balance the use of resources to even out upsurges in their use.

The example in figure 81 shows a network composed of 11 activities. The figures in bold-faced type indicate the time in days needed to complete each activity. Note that the length of the arrows bears no relation to the time it takes to undertake the particular activity.

To get from starting-point A to finishing-point I there are several paths. Each consists of several activities with time allocations. These are:

A to B to G to F to I or $3 + 2 + 4 + 3 = 12$ days

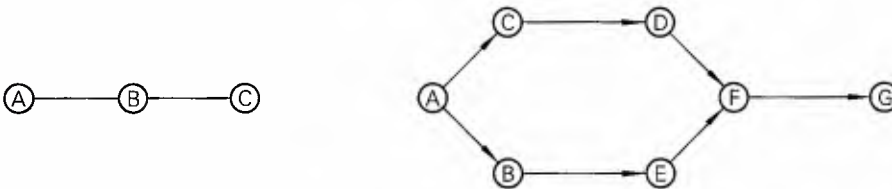
A to B to C to E to F to I or $3 + 5 + 2 + 8 + 3 = 21$ days

A to B to D to E to F to I or $3 + 3 + 8 + 8 + 3 = 25$ days

A to B to H to F to I or $3 + 3 + 3 + 3 = 12$ days

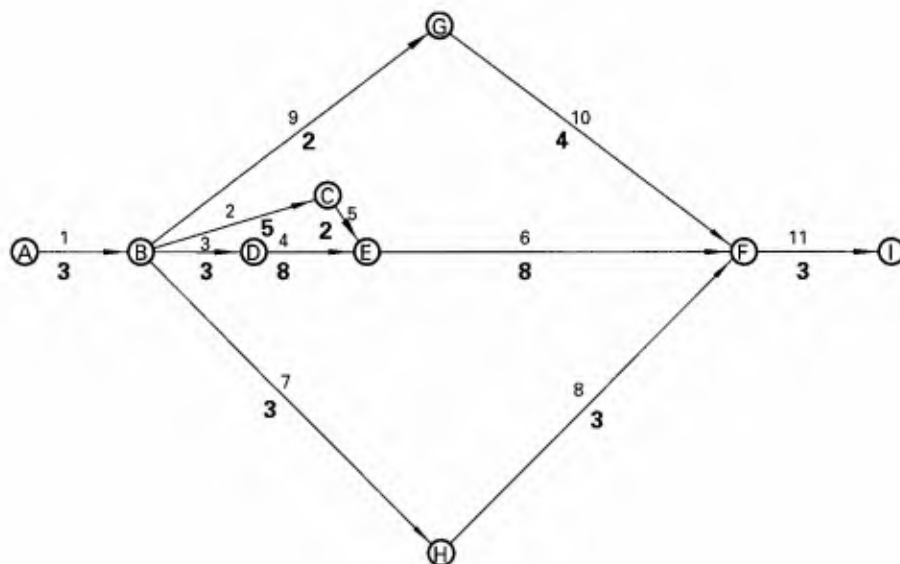
From this analysis one can conclude that the project cannot possibly finish before 25 days have elapsed. This is the longest path, known as the **critical path**, consisting of activities A to B to D to E to F to I.

Figure 80. CPM activities



Sequential activities A to B to C. Activity B to E is independent of activity C to D; however, both must be completed before activity F to G can start.

Figure 81. A network diagram using normal times



There are several uses that can be made of CPM. The line of reasoning goes as follows:

- (1) Activities B to G and G to F require six days to finish. What is important is that they reach point F three days before the end of the project. Therefore they can start at any time before that and need not start immediately after activity A to B is finished. If they do, they will reach point F on the ninth day and will have to wait to day 22. They could start for example, on day 15 or 20 and still would not affect the time needed for completing the project. Since they are not activities on the critical path, they are said to be activities that can **float** forwards and backwards as we wish, with the proviso that they can begin any time after three days from the start of the project and finish three days before the end of the project.

This floating phenomenon of non-critical activities is very useful as it allows the best allocation of resources. For example, the same personnel working on activities B to G and G to F can after they finish be redeployed to perform activities B to H and H to F or vice versa, if the skills needed are the same or similar. Having two teams working simultaneously on activities B-G-F and B-H-F would represent a waste of resources. We can therefore use CPM to reduce project costs.

- (2) If these activities were performed, say, by subcontractors, one could by proper planning of non-critical activities use their float to make the optimum schedule of payment to the contractors. This would also help to solve cash flow problems.
- (3) CPM can also be used to balance project duration with cost, allowing a project manager to make a decision in line with the situation he or she faces. Let us assume that some of the activities mentioned above can be

Table 10. Critical path method: Normal and crash times and costs for performing activities

Activity	Normal time	Crash time ¹	Normal cost	Crash cost
	Days		\$	\$
1. A to B	3	1	500	1200
2. B to C	5	5	10000	10000
3. B to D	3	2	400	600
4. D to E	8	4	8000	16000
5. C to E	2	2	500	500
6. E to F	8	6	2000	2000
7. B to H	3	3	500	500
8. H to F	3	3	1000	1000
9. B to G	2	1	350	600
10. G to F	4	3	2000	2800
11. F to I	3	1	500	1500
Critical path	25 days	15 days	25 750	36 700

¹New critical path given crash time is A to B to C to E to F to I = 15 days.

accelerated, say, by employing more people (or using more trucks or other equipment) but obviously at a higher cost. Others cannot be changed. A new table is then constructed (table 10).

From this table one can now draw a new network using crash times. Figure 82 shows a new critical path of 15 days. Thus the project duration could be reduced from 25 to 15 days at a cost of \$36,700 instead of the original \$25,750. There are obviously options in between.

For example, activities 9 and 10 could start after day 1 and could finish any time before day 14. It would therefore be a waste of funds to accelerate their execution by compressing their times to crash times and spending an extra \$1,050 in the process.

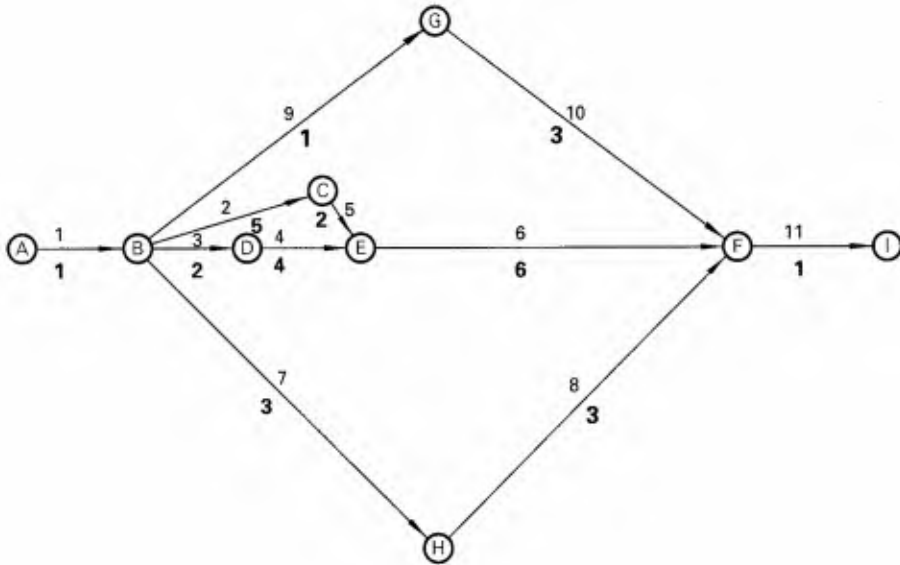
As the number of activities increase and the options for decision-making are taken more and more into consideration, it becomes cumbersome to draw network diagrams for CPM. Instead good project management software exists which allows the processing of all the desired information for planning, as well as for control purposes.

5. Work study and production planning and control

In Chapter 2 we indicated that work study has two basic components, method study and work measurement. In the following chapters we went on to indicate how method study can simplify the methods of work and reduce the time of the operation. Once this is done, work measurement then determines the time it takes to perform the new improved method.

Production planning and control can be carried out only if the times of various activities are known. It follows that the results of work measurement

Figure 82. A network diagram using crash times



should constitute the building blocks of the planning process. It also follows that each time a work study practitioner changes the sequence of operations and its timing, this can play havoc with planning unless the results of his or her work feed into the established system for production planning.

On the other hand, through production control, operations managers are able to detect trouble spots, too lengthy set-up times or lead times, frequent shortages of materials, or uneven utilization of resources resulting in delays. These are all pointers to the work study person, who can usefully be called in to improve the situation.

Inventory control

1. The nature of the inventory problem

Every enterprise carries various quantities and varieties of materials in stock. These are raw materials needed primarily for its operation, as well as other ancillary materials such as lubricants, spare parts, paints, and so on. The materials vary from the expensive, such as tools and spare parts, to the relatively cheap, such as paper and pens needed for clerical work. This inventory of various materials costs the enterprise so-called **carrying costs** which include loss of interest had these funds been invested, the cost of storage space, rent and other expenses such as light, humidity and temperature control, if any, stores operation costs including record keeping, taxes and insurance, and depreciation and deterioration or obsolescence.

Thus an enterprise manager is faced with a dilemma. On the one hand, he or she should not carry unnecessary stocks, otherwise high carrying charges are incurred; on the other hand, if he or she runs out of stock due to very low stock levels, this can cause work stoppage, loss of sales opportunities and reduced orders by impatient customers, in other words so-called **stockout costs**.

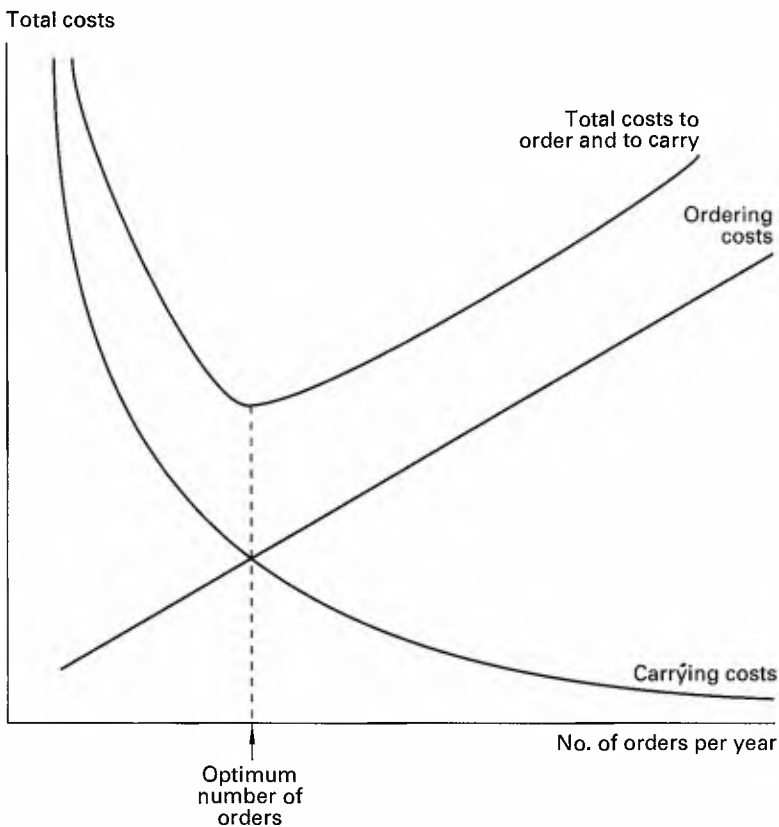
What is needed therefore is to develop a strategy which aims at minimizing carrying costs without losing opportunities for sales or incurring stockout costs.

Apart from the various primary and ancillary materials stored, temporary storage of various parts takes place during the production process. These are so-called **goods-in-progress**. Thus parts of a product may undergo one production operation and are then stored temporarily before they go to another operation or to assembly. Again, goods-in-progress represent an inventory cost with carrying charges as well. Minimizing the volume of goods-in-progress can also cut down manufacturing costs considerably.

2. Traditional approaches to inventory control

In the previous section we mentioned that an enterprise carries a large variety of stock of different materials. It would be impractical to investigate the optimum level of stock that needs to be carried for all the materials in stock. This would be a cumbersome and costly operation. Rather, it would be more opportune to concentrate on the relatively few items of inventory that account for the largest monetary value, since it is these items that account for substantial carrying charges.

Figure 83. The relationship between total costs to order and to carry and the number of orders placed



To do this, a Pareto analysis would be carried out (this was discussed in Chapter 6). If the various items in stock are multiplied by their purchasing price, one is able to determine the "A" items, those few that account for the highest value, the "B" items, those that come next and account for less value, and the "C" items, the remaining large number of items that have a far smaller share of the total value of inventory. By concentrating on the "A" items and then the "B" items one can develop a strategy that rests on reducing the quantities of "A" and "B" items held in stock to the optimum level. An important element of this strategy consists of placing several orders of smaller quantities of "A" and "B" items per year instead of placing one order for the whole year and keeping these in stock. The smaller the size of the order, the less are the carrying costs. But at the same time, if more orders are placed then an extra cost is incurred as this may entail hiring more personnel to place and process these orders, and increased paperwork. Therefore the greater number of orders in smaller quantities, the lower will be the carrying costs, but the ordering costs may increase. The optimum solution would be where the two curves intersect (figure 83).

In developing an ordering strategy we need to take two decisions: how much to order of each item in the "A" and "B" categories or **what** is the

economic order quantity (EOQ); and **when** to order this quantity or the **reorder point**.

To determine the EOQ, three figures are needed: the first two are the **average inventory** for the item in monetary terms, and the **ordering costs**, taken as the incremental cost per order or the cost of each additional order. If an enterprise places more orders, there is an increased cost consisting mainly of the salaries of the extra staff that will be required, as well as extra stationery and supplies. The third figure that is needed is the **carrying costs** (the nature of these costs were explained in section 1). The carrying costs are estimated in a similar way to the ordering charge, i.e. at two different inventory levels from which the incremental cost per order is deduced. This is usually expressed as a percentage of average inventory value. By using the following equation one can determine the EOQ for the item in question:

$$EOQ = \sqrt{\frac{2AP}{RC}}$$

where A = the total number of units used per year, P = the ordering cost per order, R = the price of each unit and C = the carrying cost expressed as a percentage of average inventory.

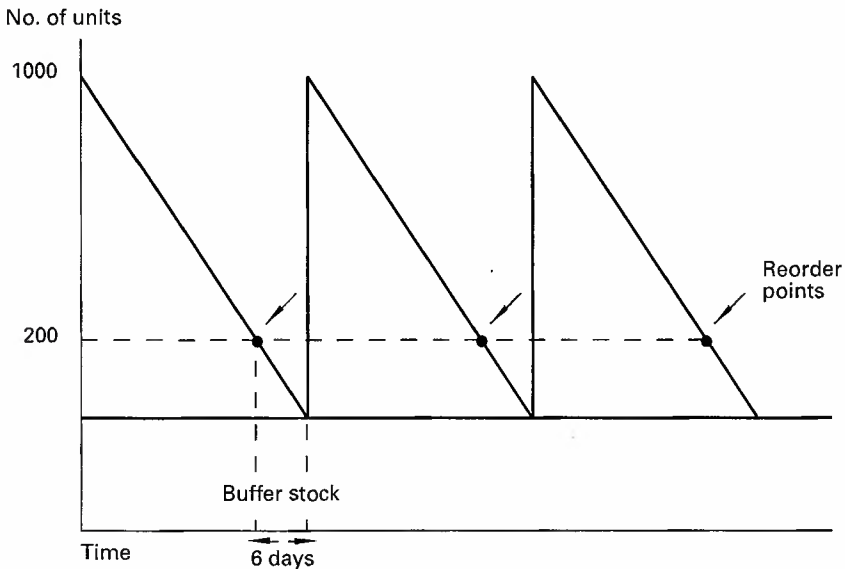
To take a simple example, an enterprise uses \$10,000 worth of a certain item (assuming 10,000 units at \$1 each), the ordering costs are \$5 per order and the carrying costs are 10 per cent of the average inventory:

$$EOQ = \sqrt{\frac{2 \times 10,000 \times 5}{1 \times 0.1}} = \sqrt{1,000,000} = 1,000 \text{ units per order.}$$

We come now to the second issue to be resolved, that is determining the re-order point. If we continue with our example, since the total amount used is 10,000 units and the EOQ is 1,000 units, it follows that in the course of a year we must place an order every 36 days. If it takes six days from the time the order is placed until it is delivered, this means that when the stock drops from 1,000 units to 200 units (the latter figure equivalent to six days' stock) then a second order is placed, and the process is repeated ten times a year. However, one must allow for slight delays in delivery or for an upsurge of demand, which means that the stock could be exhausted at a faster rate. For this purpose a so-called "buffer stock" is constituted to allow for these eventualities (figure 84). To determine the optimum level of buffer stock, one attempts to balance carrying costs with stockout costs.

While this approach remains a valid one, several practical situations arise which necessitate the use of added analytical and mathematical tools to solve inventory problems, for the above approach is based on several assumptions such as a constant demand, a constant purchase price, a constant lead time for delivery and constant carrying and ordering charges. In practice this is seldom the case. Often a manager or a purchasing agent may have to vary the above calculations by introducing variables such as uncertainty in delivery times, how to handle quantity discounts for purchases, expectations of price increases, and so on. It would fall beyond the scope of this book to go into the details of

Figure 84. Re-order point and buffer stock



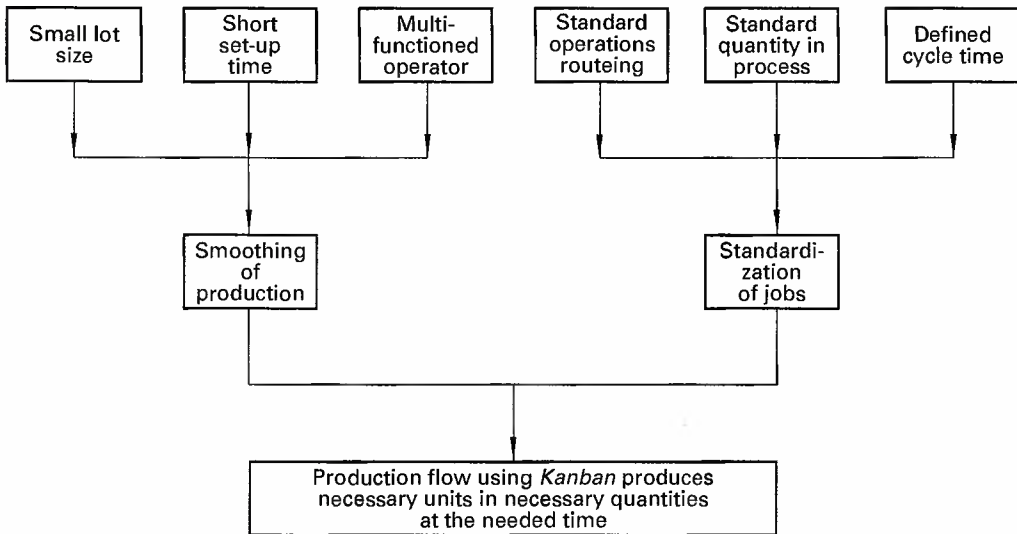
calculations involving multiple decision criteria. Several production management books deal with this issue in more detail.¹

3. Just-in-time inventory method

In their quest to improve productivity and profitability, Japanese management came to look upon inventory as unnecessary and wasteful. Toyota was the first to develop an approach to cut down drastically on stocks, whether for goods-in-progress or for goods in the storeroom: *Kanban*, or “just-in-time inventory management”. The basic idea is that under traditional approaches, the purchasing department buys the raw material and **pushes** it through operations. In just-in-time (JIT), the material is **pulled** in one workstation from the preceding station and ultimately from the raw material stock. In the same vein, it is also pulled from the suppliers **only when** it is needed, and in the desired quantities. Stocks are held down to bare minimum levels, almost totally eliminating buffer stocks.

With experience, JIT developed to be a philosophy of management and a different approach to production planning and control, as well as to inventory control. If we want to reduce carrying charges, then we must order in small lots. It follows that we should attempt to have standard quantities of goods-in-progress to match. It also follows that we must smooth out irregularities in the production flow, otherwise some parts will be produced and wait as an inventory for other parts to be processed so as to be assembled together. This means that we have to measure the cycle time for each operation, train workers to perform various functions and pursue standardization of operation

¹ See, for example, Donald Del Mar: *Operations and industrial management: Designing and managing for productivity* (New York, McGraw Hill, 1985), pp. 261-303.

Figure 85. A simplified JIT (*Kanban*) scheme

processing and standard batches of work processed each at a time. A schematic diagram of JIT is shown in figure 85.

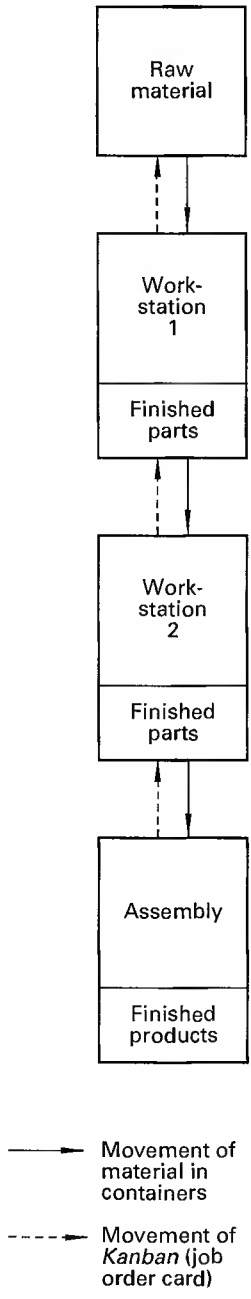
JIT therefore works best with a limited product line in which most of the component parts are repetitively produced by the firm or provided by suppliers.

The mechanics of the operation, simply explained, consists of moving upstream beginning with the last operation (figure 86). Thus, when a final assembly section requires parts from workstation 2 it removes the job card (also called the *Kanban*) from the container which has the parts and passes it on to workstation 2. This *Kanban* in turn becomes a job order for workstation 2, which starts producing replacements for the parts removed and at the same time sends the *Kanban* to workstation 1 to do the same. This finally reaches the raw material inventory where withdrawals are also made in small lots, and hence the orders are supplied equally in small lots and frequently on a daily basis.

The success of JIT in Japan has also been due to the relationship that a producing enterprise develops with its suppliers, which has the following main features:

- The enterprise prefers to deal with one supplier. To qualify to be a supplier, the vendor must offer the lowest price for the highest quality and take responsibility for buffer stock. In return he or she is assured of a high volume of orders.
- Suppliers provide orders in small lots almost daily and are encouraged to locate near the enterprise to reduce the enterprise's transportation cost and lead time.
- Close cooperation exists between the enterprise management and suppliers, which may take the form of technical and financial assistance to suppliers who see themselves as being in "the same boat" as the enterprise and therefore strive for built-in product quality and the lowest price.

Figure 86. A simplified illustration of *Kanban* movement



JIT has been introduced in several enterprises in the United States, Europe and elsewhere, sometimes with excellent results.² As can be seen, however, much depends on the ability to restructure and smooth out production operations and build a strong and different type of relationship with suppliers.

4. Work study and inventory control

The work study person is rarely, if ever, involved in setting up economic order quantities of raw materials from suppliers or in considering how to adjust such orders under uncertainty or to benefit from special opportunities such as quantity discounts. Nevertheless, some of the work done in the area of product design and materials utilization, as indicated in Chapter 12, can influence the range and volume of items that need to be carried in inventory.

Work study becomes more directly related to inventory control when a JIT system is being introduced. This chapter has shown that prerequisites for such a system are standardization of operations routing, establishing reliable cycle times and thereby having standard quantities of small lots flow through the operations line. We have also seen that smoothing of production operations with minimum fluctuations in production targets from one operation to the next is needed, as well as synchronization of converging subassembly if JIT is to be effective. These are all areas where the work study specialist can make a valuable contribution through method study and work measurement.

² See, for example, L. A. Martin-Vega et al.: "Applying just-in-time in a wafer fab: A case study", in Johnson A. Edosomwan (ed.): *People and product management in manufacturing* (Amsterdam, Elsevier Science Publishers, 1990), pp. 121-135.



Maintenance

1. The scope of maintenance

The maintenance function has not always received the importance it deserves. It is sometimes looked upon as an ancillary activity that is performed sporadically and when necessary. Some production managers feel that stopping a machine or a production line to effect inspections or carry out preventive maintenance is an unnecessary nuisance. It is only when such machines break down that the importance of maintenance becomes apparent. Yet, the losses incurred from poor maintenance can be enormous, for apart from stoppages and lost production there is the cost of product defects due to lack of maintenance, and losses due to shorter machine life, which can be substantial in developing countries, since machines are replaced by drawing on scarce foreign exchange.

With advanced technology, the problem of maintenance is becoming more acute. Advanced-technology machines produce a high volume, so that the effect of work stoppages is amplified. Furthermore, the trend towards line operations, automation and FMS has linked machines together either physically or through information systems making the operation of each dependent on the other, so that a whole production line can be stopped because of the failure of one single inexpensive part.

At present, two trends in maintenance can be ascertained. First, the ratio of maintenance workers to direct production workers is growing in industrialized countries, partly in response to the growing sophistication of the machines used and partly because of the decreased amount of direct labour as a result of automation. Second, there is a growing realization of the need to organize maintenance differently, and in a way where it becomes everybody's business to a large or a smaller degree and not solely the concern of maintenance crews.

There are two major types of maintenance:

- **Breakdown maintenance:** This is a responsive approach by the maintenance department to requests for repairs, because of either machine and equipment failure, or inconsistent or unsafe work resulting from the poor condition of machinery. In this case, the maintenance department tries to respond as best it can to the various requests received. If there are several simultaneous requests, as is normally the case, the machine downtime increases. In many cases leaving a machine to run down to breaking-

point can also mean lengthy repairs, and sometimes costly and more lengthy overhauls.

- **Preventive maintenance:** This approach is based on the well-known wisdom that prevention is better than cure. It consists of diagnosing machine maintenance needs ranging from simple lubrication and greasing to more complicated preventive repairs. Factors that are taken into consideration are noise emission, vibration, temperature change and defective production, as well as an analysis of past performance and maintenance records to predict when failure is imminent. A schedule is then drawn up to plan systematic interventions of maintenance and repair to pre-empt breakdowns.

Most enterprise maintenance programmes are based on a combination of both preventive and breakdown maintenance, although it has been shown that an emphasis on preventive maintenance can considerably reduce the need for breakdown maintenance.

2. Organization of maintenance

The organization of maintenance involves two key issues:

- the organization of the maintenance function that is performed by the maintenance specialists; and
- changing attitudes in an enterprise to develop a maintenance-conscious and supportive attitude.

Each of these will be dealt with briefly.

Maintenance as a specialized function

As a specialized function, maintenance requires attention to a number of key aspects:

- **Needs assessment of skills and upgrading** of maintenance crews: Maintenance operations require a relatively large proportion of manual work. Attaining a high degree of skill is especially important because of advanced technology that also requires continuous upgrading of skills. In fact, an important preoccupation of management before acquiring a new piece of equipment is to plan its maintenance and develop the skills needed to do so. Performing maintenance work also requires a multitude of skills. An electric motor detachment, replacement and repair could require both electrical and mechanical skills. If the motor is pumping water or liquid, plumbing skills may also be needed. That is why the multi-skilling of operators in maintenance is becoming more important.
- **Scheduling** of maintenance operations for preventive maintenance should allow a contingency time for breakdown maintenance. The latter is usually based on experience with individual machines' history of breakdowns and is an estimate at best. With time the estimation of the breakdown maintenance period improves. Scheduling is important because it affects production planning. The preparation of such

maintenance schedules needs to be discussed and agreed with the production personnel, who may be able to suggest times that are more suitable than others for maintaining some machines and equipment. In large modern enterprises, preventive maintenance schedules are computerized and involve the various machines as well as ancillary non-productive facilities.

- Division of work:** Not all maintenance operations need to be done by specialists. Periodic lubrication and greasing, for example, can become the responsibility of production operators. There is therefore a need to decide on the division and distribution of work among the various persons who can be involved in maintenance.
- Spare parts inventory control** is an important facet of maintenance organization. A system for spare parts inventory control needs to be established to minimize the risk of running out of spares, particularly for parts which are difficult to obtain readily on the local market, and at the same time to avoid high carrying charges and obsolescence.
- Effectiveness:** The control of maintenance is like any other function — if one cannot measure the results obtained, one cannot control the operation. Furthermore, a recurrent question is whether one is over- or under-spending on maintenance given the results achieved.

An effective index sometimes used relates to total hours worked on maintenance in a given period, say a month or a quarter, compared with total hours of production time lost. Other suitable measures consist of comparing hours of production lost because of breakdowns and preventive maintenance over successive periods of time. Here it is assumed that maintenance costs are more or less constant as they consist mostly of payroll costs and spare parts whose total annual use may be allocated on a monthly or quarterly basis. An important advantage of keeping cost and effectiveness records is that they allow management to take important cost decisions such as whether to replace or overhaul a machine, and when to do so.

Maintenance as an enterprise-wide responsibility

With a realization of the impact of poor maintenance on enterprises' profitability, many managers are mounting campaign drives or revising the view which consisted of relegating maintenance to a specialized crew. The essence of a new approach is to cultivate maintenance consciousness. This requires attitudinal change. Such an approach needs to have the commitment of top management and its willingness to experiment with new approaches.

Training seminars need to be held; some of them will be induction seminars for top managers. Middle management seminars can involve maintenance specialists and other managers who are affected by maintenance problems. The purpose would be to have the participants identify the major problems in their working area, possible causes and how they will be able to assess the results if remedies are found. This would then be coupled with a brief course on maintenance for non-maintenance specialists. The course would assist the groups — which meet regularly — in fact-finding and in discussing

the problems involved in an interactive manner. It would also build strong support within the enterprise for an outside consultant, should this be required. The emphasis here is on solving actual problems with a view to obtaining results rather than a classroom type of training. Additional training is also extended to the operators if need be, where it is coupled with visual guidelines on proper operation and routine maintenance of the machines or equipment with which they are entrusted. The ILO has run several programmes of this nature in various countries.¹

3. Work study and maintenance

A work study person has to take preventive maintenance needs into account when calculating cycle times which in turn affect production planning and scheduling. Furthermore, some of the improvements introduced through method study may lead to reduced maintenance times. Thus the use of more suitable transport and handling equipment or a changed product or process design can affect the time that would be needed for maintenance.

On the other hand, like any other function, the maintenance operation itself can be a subject of study by the work study person. Method study can examine the movements of maintenance workers in a working area and their methods of work. Maintenance operations can be timed, the work involved measured and standard times developed for various maintenance assignments using suitable standard data systems such as the Universal Maintenance Standards System (UMS).² Standard data will be referred to later in Chapter 27.

¹ See, for example, ILO: *Improving maintenance in developing countries: The ILO approach*, Management Development Programme technical paper Man Dev 44 (Geneva, 1987).

² For an explanation of UMS, see H. B. Maynard (ed.): *Industrial engineering handbook* (New York, McGraw Hill, 1971).

PART FOUR

Work measurement



General remarks on work measurement

1. Definition

In Chapter 3 it was said that work study consists of two complementary techniques — method study and work measurement. In that chapter both were defined; before we go on to discuss work measurement it is worthwhile repeating the definition of that technique given there.

Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out a task at a defined rate of working

We shall have occasion to examine several features of this carefully thought-out definition in more detail in later chapters. For instance, the reader will have noted the references to “a qualified worker”, and to “a defined rate of working”. We need not concern ourselves with the exact meaning of these terms for the moment. It is worth noting, however, that the term “work measurement”, which we have referred to hitherto as a technique, is really a term used to describe a family of techniques, any one of which can be used to measure work, rather than a single technique by itself. The principal techniques which are classed as work measurement techniques are listed in section 5 of this chapter.

2. The purpose of work measurement

In Chapter 2 we discussed the way in which the total time of manufacture of an article was increased by undesirable features of the product itself, by a poorly designed process and by ineffective time added in the course of production and by actions due to the human element. All these factors tended to reduce the productivity of the enterprise.

We also discussed the management techniques by which these factors could be eliminated or, at any rate, reduced. Method study has been shown to be one of the principal techniques by which the work involved in the product or

the process could be decreased by the systematic investigation and critical examination of existing methods and processes and the development and installation of improved methods.

Method study is the principal technique for reducing the work involved, primarily by **eliminating unnecessary movement** on the part of material or operatives and by substituting good methods for poor ones. Work measurement is concerned with investigating, reducing and subsequently **eliminating ineffective time**, that is time during which no effective work is being performed, whatever the cause.

Work measurement, as the name suggests, provides management with a means of measuring the time taken in the performance of an operation or series of operations in such a way that ineffective time is shown up and can be separated from effective time. In this way its existence, nature and extent become known where previously they were concealed within the total. One of the surprising things about plants where work measurement has never been employed is the amount of ineffective time whose very existence is unsuspected — or which is accepted as “the usual thing” and something inevitable that no one can do much about — that is built into the process. Once the existence of ineffective time has been revealed and the reasons for it tracked down, steps can usually be taken to reduce it.

Here work measurement has another role to play. Not only can it reveal the existence of ineffective time; it can also be used to set standard times for carrying out the work, so that, if any ineffective time does creep in later, it will immediately be shown up as an excess over the standard time and will thus be brought to the attention of management.

Earlier it was mentioned that method study can reveal shortcomings of design, material and method of manufacture, and, as such, affects mainly technical people. Work measurement is more likely to show up management itself and the behaviour of the workers. Because of this it is apt to meet with far greater resistance than method study. Nevertheless, if the efficient operation of the enterprise as a whole is being sought, the application of work measurement, properly carried out, is one of the best means of achieving it.

It is unfortunate that work measurement — and in particular time study, its principal technique — acquired a bad reputation in the past, especially in trade union circles. This was because in many early applications it was directed almost exclusively to reducing the ineffective time within the control of the operatives by setting standards of performance for them, while the ineffective time within the control of management was virtually ignored. The causes of ineffective time over which management has some control are much more numerous than those which lie within the direct control of the workers. Furthermore, experience has shown that, if causes of ineffective time such as hold-ups due to lack of raw materials or to plant breakdowns are allowed to go on without real efforts being made to eliminate them, operatives tend to get discouraged and slack, and “workers’ ineffective time” increases. This is only to be expected: the attitude taken by the workers is, quite simply: “Well, if we are going to be stopped from doing our jobs by something which we can do nothing about and which it is management’s job to put right, why should we

work harder? Let management put its own house in order first.” It is an argument that can hardly be countered.

Just as method study should precede work measurement in any reorganization that takes place, so must the elimination of ineffective time due to management shortcomings precede any attack on the ineffective time within the control of the workers. Indeed, the mere fact of reducing the hold-ups and stoppages within the control of management will tend to reduce the waste of time by the operatives, because they will find themselves faced with proper supplies of work and of material, and will have the general feeling that the management is “on its toes”. This will in itself have a beneficial effect without the application of incentive schemes or of any form of coercion.

Work measurement may start a chain reaction throughout the organization. How does this come about?

The first thing to realize is that breakdowns and stoppages taking effect at the shop-floor level are generally only the end results of a series of management actions or failures to act.

Let us take an example of excessive idle time of an expensive machine in a batch production type of operation. This excessive idle time was revealed by a study taken over several days. The piece of plant is very productive when operating but takes a long time to set up. It is found that a great deal of the idle time is due to the fact that the batches of work being put on this machine are very small, so that almost as much time is spent in resetting it to do new operations as is spent in actual production. The chain of reactions resulting from this discovery may be something like this:

The work study department

reports that work measurement reveals that the machine is idle for excessively long periods because of small orders coming from the planning department. This is substantially increasing the cost of manufacture. It suggests that the planning department should do some proper planning and either combine several orders for the same product into one large order or make more for stock.

The planning department

complains that it has to work on the instructions of the marketing department, which never seems to sell enough of any one product to make up a decent-sized batch and cannot give any forecast of future orders so that more can be made for stock.

The marketing department

says that it cannot possibly make forecasts or provide large orders of any one product as long as it remains the policy of top management to accept every variation that customers like to ask for. Already the catalogue is becoming too large: almost every job is now a “special”.

The managing director

is surprised when the effect of marketing policy (or lack of it) on the production costs is highlighted and says that the aim was to prevent orders going to competitors by being as obliging to customers as possible.

One of the principal purposes of work study will have been served if the original investigation leads the managing director to think again about marketing policy. Enthusiastic work study persons may, however, find it well to pause a moment and think about the fact that such chains of reaction tend to make someone ask: "Who started this, anyway?" People do not like being "shown up". This is one of the situations in which a good deal of tact may have to be used. It is not the task of a work study specialist to dictate marketing policy, but merely to bring to the attention of management the effect of that policy on the company's costs and hence on its competitive position.

Thus it can be seen that the purposes of work measurement are to reveal the nature and extent of ineffective time, from whatever cause, so that action can be taken to eliminate it; and then to set standards of performance of such a kind that they will be attainable only if all avoidable ineffective time is eliminated and the work is performed by the best available method and by appropriately trained and capable personnel.

We can now go on to discuss in greater detail the uses and techniques of work measurement.

3. The uses of work measurement

Revealing existing causes of ineffective time through study, important though it is, is perhaps less important in the long term than the setting of sound time standards, since these will continue to apply as long as the work to which they refer continues to be done and will show up any ineffective time or additional work which may occur once they have been established.

In the process of setting standards it may be necessary to use work measurement:

- (1) To compare the efficiency of alternative methods. Other conditions being equal, the method which takes the least time will be the best method.
- (2) To balance the work of members of teams, in association with multiple activity charts, so that, as nearly as possible, each member has a task taking an equal time to perform (see Chapter 8, section 4).
- (3) To determine, in association with worker and machine multiple activity charts, the number of machines an operative can run (see Chapter 8, section 4).

The time standards, once set, may then be used:

- (4) To provide the basis for production planning and control for the choice of a better layout and for process planning, and for establishing just-in-time inventory control systems (see Chapter 16, section 3).
- (5) To provide information that can enable estimates to be made for tenders, selling prices and delivery dates.
- (6) To set standards of machine utilization and labour performance which can be used for any of the above purposes and as a basis for incentive schemes.
- (7) To provide information for labour-cost control and to enable standard costs to be fixed and maintained.

It is thus clear that work measurement provides the basic information necessary for all the activities of organizing and controlling the work of an enterprise in which the time element plays a part. Its uses in connection with these activities will be more clearly seen when we have shown how the standard time is obtained.

4. The basic procedure

In section 3 of Chapter 3 we described the basic steps of work study, embracing both method study and work measurement. We shall now isolate those steps which are necessary for the systematic carrying out of work measurement. These steps are:

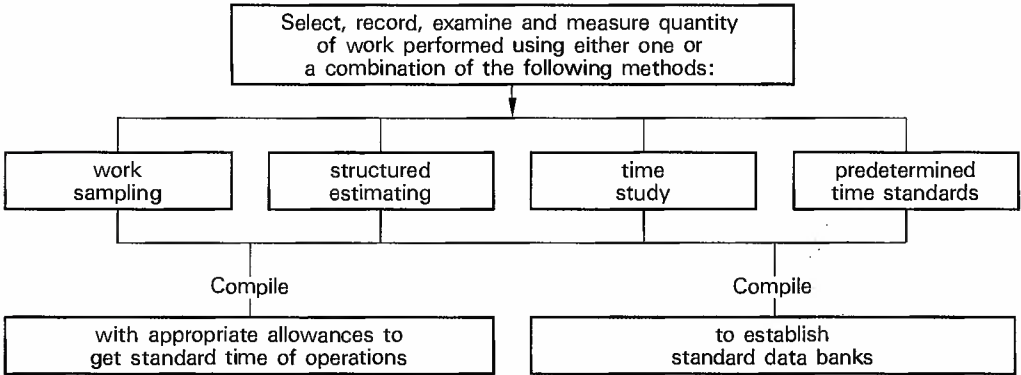
- SELECT* the work to be studied.
- RECORD* all the relevant data relating to the circumstances in which the work is being done, the methods and the elements of activity in them.
- EXAMINE* the recorded data and the detailed breakdown critically to ensure that the most effective method and motions are being used and that unproductive and foreign elements are separated from productive elements.
- MEASURE* the quantity of work involved in each element, in terms of time, using the appropriate work measurement technique.
- COMPILE* the standard time for the operation, which in the case of stop-watch time study will include time allowances to cover relaxation, personal needs, etc.
- DEFINE* precisely the series of activities and method of operation for which the time has been compiled and issue the time as standard for the activities and methods specified.

It will be necessary to take the full range of steps listed above only if a time is to be published as a standard. When work measurement is being used only as a tool of investigation of ineffective time before or during a method study, or to compare the effectiveness of alternative methods, only the first four steps are likely to be needed.

5. The techniques of work measurement

The following are the principal techniques by which work measurement is carried out (figure 87):

Figure 87. Work measurement



- work sampling;
- structured estimating;
- time study;
- predetermined time standards (PTS);
- standard data.

In the next few chapters we shall describe each of these techniques in some detail.

Work sampling and structured estimating

Work sampling is a method of finding the percentage occurrence of a certain activity by statistical sampling and random observations

1. The need for work sampling

Work sampling (also known as “activity sampling”, “ratio-delay study”, “random observation method”, “snap-reading method” and “observation ratio study”) is, as the name implies, a sampling technique. Let us first see why such a technique is needed.

In order to obtain a complete and accurate picture of the productive time and idle time of the machines in a specific production area, it would be necessary to observe continuously all the machines in that area and to record when and why any of the machines were stopped. It would of course be quite impossible to do this unless a large number of workers spent the whole of their time on this task alone — an unrealistic proposition.

If it were possible to note at a glance the state of every machine in a factory at a given moment, however, it might be found that, say, 80 per cent of the machines were working and 20 per cent were stopped. If this action was repeated 20 or more times at different times of the day and if each time the proportion of machines working was always 80 per cent, it would be possible to say with some confidence that at any one time there were always 80 per cent of the machines working.

As it is not generally possible to do this either, the next best method has to be adopted; that of making tours of the factory at random intervals, noting which machines are working and which are stopped, and noting the cause of each stoppage. This is the basis of the **work sampling** technique. When the sample size is large enough and the observations made are indeed at random, there is quite a high probability that these observations will reflect the real situation, plus or minus a certain margin of error.

2. A few words about sampling

Unlike the costly and impractical method of continuous observation, sampling is mainly based on **probability**. Probability has been defined as “the extent to which an event is likely to occur”. A simple and often-mentioned example that illustrates the point is that of tossing a coin. When we toss a coin there are two possibilities: that it will come down “heads”, or that it will come down “tails”. The law of probability says that we are likely to have 50 heads and 50 tails in every 100 tosses of the coin. Note that we use the term “likely to have”. In fact, we might have a score of 55-45, say, or 48-52, or some other ratio. But it has been proved that the law becomes increasingly accurate as the number of tosses increase. In other words, the greater the number of tosses, the more chance we have of arriving at a ratio of 50 heads to 50 tails. This suggests that the larger the size of the sample, the more accurate or representative it becomes with respect to the original “population”, or group of items under consideration.

We can therefore visualize a scale where, at one end, we can have the complete accuracy achieved by continuous observation and, at the other end, very doubtful results derived from a few observations only. The size of the sample is therefore important, and we can express our confidence in whether or not the sample is representative by using a certain **confidence level**.

3. Establishing confidence levels

Let us go back to our previous example and toss five coins at a time, and then record the number of times we have heads and the number of times we have tails for each toss of these five coins. Let us then repeat this operation 100 times. The results could be presented as in table 11, or graphically as in figure 88.

If we considerably increase the number of tosses and in each case toss a large number of coins at a time, we can obtain a smoother curve, such as that shown in figure 89.

Figure 88. Proportional distribution of “heads” and “tails” (100 tosses of five coins at a time)

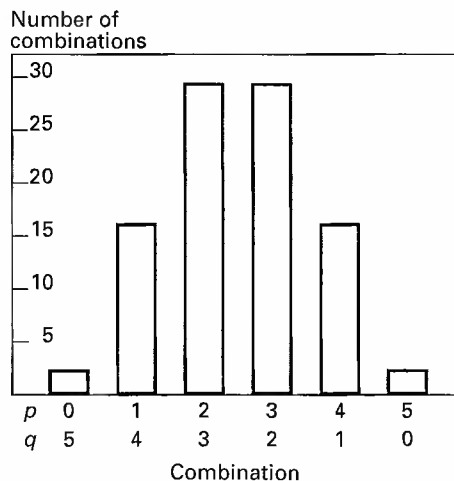
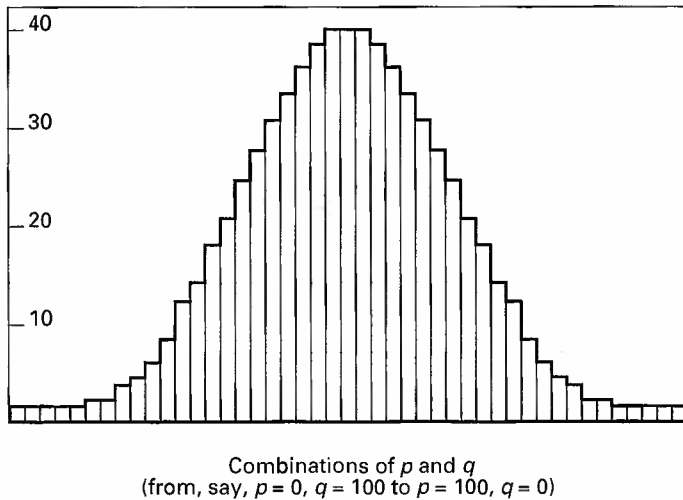


Table 11. Proportional distribution of "heads" and "tails" (100 tosses of five coins at a time)

Combination		No. of combinations
Heads (p)	Tails (q)	
5	0	3
4	1	17
3	2	30
2	3	30
1	4	17
0	5	3
		100

Figure 89. Distribution curve showing probabilities of combinations when large samples are used

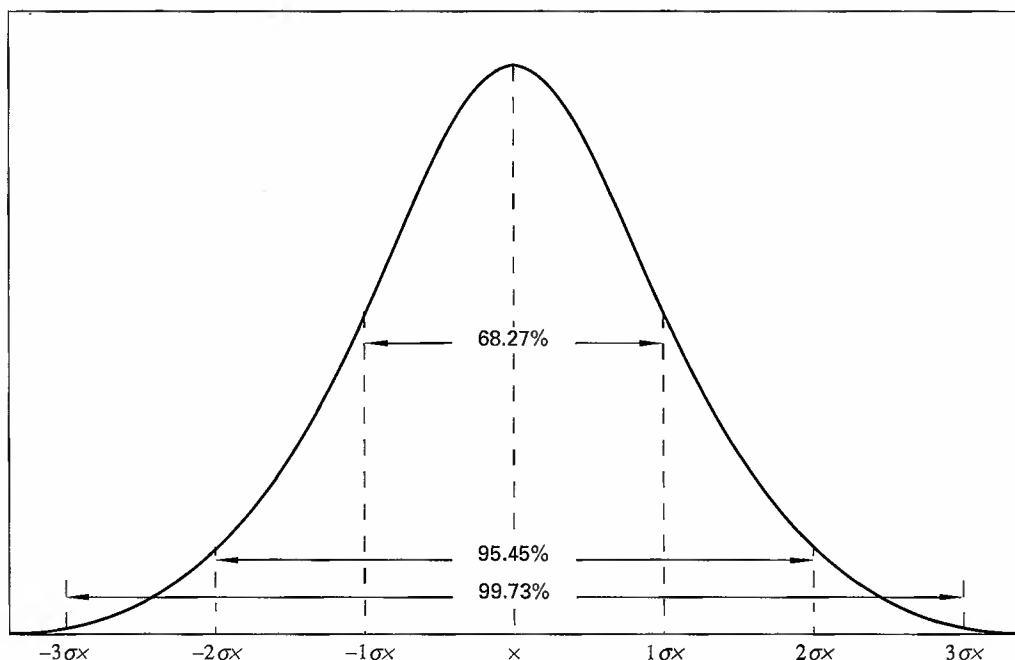


This curve, called the **curve of normal distribution**, may also be depicted as in figure 90. Basically, this curve tells us that, in the majority of cases, the tendency is for the number of heads to equal the number of tails in any one series of tosses (when $p = q$ the number of tosses is a maximum). In few cases, however, is p markedly different from q due to mere chance.

Curves of normal distribution may be of many shapes. They may be flatter, or more rounded. To describe these curves we use two attributes: \bar{x} , which is the average or measure of central dispersion; and σ , which is the deviation from the average, referred to as standard deviation. Since in this case we are dealing with a proportion, we use σp to denote the standard error of the proportion.

The area under the curve of normal distribution can be calculated. In figure 90 one σp on both sides of \bar{x} gives an area of 68.27 per cent of the total area; two σp on both sides of \bar{x} gives an area of 95.45 per cent and three σp on both sides of \bar{x} gives an area of 99.73 per cent. We can put this in another way and say that, provided that we are not biased in our random sampling, 95.45 per

Figure 90. Curve of normal distribution



cent of all our observations will fall within $\bar{x} \pm 2 \sigma p$ and 99.73 per cent of all our observations will fall within $\bar{x} \pm 3 \sigma p$.

This is in fact the degree of confidence we have in our observations. To make things easier, however, we try to avoid using decimal percentages; it is more convenient to speak of a 95 per cent confidence level than of a 95.45 per cent confidence level. To achieve this we can change our calculations and obtain:

- 95 per cent confidence level or 95 per cent of the area under the curve = $1.96 \sigma p$;
- 99 per cent confidence level or 99 per cent of the area under the curve = $2.58 \sigma p$;
- 99.9 per cent confidence level or 99.9 per cent of the area under the curve = $3.3 \sigma p$.

In this case we can say that if we take a large sample **at random** we can be confident that in 95 per cent of the cases our observations will fall within $\pm 1.96 \sigma p$.

In work sampling the most commonly used level is the 95 per cent confidence level.

4. Determination of sample size

As well as defining the confidence level for our observations we have to decide on the margin of error that we can allow for these observations. We must be able to say that: "We are confident that for 95 per cent of the time this particular observation is correct within ± 5 per cent, or 10 per cent", or whatever other range of accuracy we may decide on.

Let us now return to our example about the productive time and the idle time of the machines in a factory. There are two methods of determining the sample size that would be appropriate for this example: the statistical method and the nomogram method.

Statistical method

The formula used in this method is:

$$\sigma p = \sqrt{\frac{pq}{n}}$$

where

σp = standard error of proportion

p = percentage of idle time

q = percentage of working time

n = number of observations or sample size we wish to determine.

Before we can use this formula, however, we need to have at least an idea of the values of p and q . The first step is therefore to carry out a number of random observations in the working area. Let us assume that some 100 observations were carried out as a preliminary study and at random, and that these showed the machine to be idle in 25 per cent of the cases ($p = 25$) and to be working 75 per cent of the time ($q = 75$). We thus have approximate values for p and q ; in order now to determine the value of n , we must find out the value of σp .

Let us choose a confidence level of 95 per cent with a 10 per cent margin of error (that is, we are confident that in 95 per cent of the cases our estimates will be ± 10 per cent of the real value).

At the 95 per cent confidence level:

$$1.96 \sigma p = 10$$

$$\therefore \sigma p = 5 \text{ (approx.)}$$

We can now go back to our original equation to derive n :

$$\sigma p = \sqrt{\frac{pq}{n}}$$

$$\therefore 5 = \sqrt{\frac{25 \times 75}{n}}$$

$$\therefore n = 75 \text{ observations.}$$

If we reduce the margin of error to ± 5 per cent, we have

$$1.96 \sigma p = 5$$

$$\therefore \sigma p = 2.5 \text{ (approx.)}$$

$$\therefore 2.5 = \sqrt{\frac{25 \times 75}{n}}$$

$$\therefore n = \frac{25 \times 75}{(2.5)^2}$$

$$= 300 \text{ observations.}$$

In other words, if we reduce the margin of error by half, the sample size will have to be quadrupled.

Nomogram method

An easier way to determine sample size is to read off the number of observations needed directly from a nomogram such as the one reproduced in figure 91. Taking our previous example, we draw a line from the "percentage occurrence" ordinate p (in this case 25-75) to intercept the "error (accuracy required)" ordinate (say, 5 per cent) and extend it until it meets the "number of observations" ordinate n , which it intercepts at 300 for the 95 per cent confidence level. This is a very quick way of determining sample size.

5. Making random observations

Our previous conclusions are valid provided that we can make the number of observations needed to attain the confidence level and accuracy required, and also provided that these observations are made **at random**.

To ensure that our observations are in fact made at random, we can use a random table such as the one in table 12. Various types of random table exist, and these can be used in different ways. In our case let us assume that we shall carry out our observations during a day shift of eight hours, from 7 a.m. to 3 p.m. An eight-hour day has 480 minutes. These may be divided into 48 ten-minute periods.

We can start by choosing any number at random from our table, for example by closing our eyes and placing a pencil point somewhere on the table. Let us assume that in this case we pick, by mere chance, the number 11 which is in the second block, fourth column, fourth row (table 12). We now choose any number between 1 and 10. Assume that we choose the number 2; we now go down the column picking out every second reading and noting it down, as shown below (if we had chosen the number 3, we should pick out every third figure, and so on).

11 38 45 87 68 20 11 26 49 05

Looking at these numbers, we find that we have to discard 87, 68 and 49 because they are too high (since we have only 48 ten-minute periods, any number above 48 has to be discarded). Similarly, the second 11 will also have to be discarded since it is a number that has already been picked out. We therefore have to continue with our readings to replace the four numbers we have discarded. Using the same method, that is choosing every second number after the last one (05), we now have

14 15 47 22

These four numbers are within the desired range and have not appeared before. Our final selection may now be arranged numerically and the times of observation throughout the eight-hour day worked out. Thus our smallest number (05) represents the fifth ten-minute period after the work began at 7 a.m. Thus our first observation will be at 7.50 a.m., and so on (table 13).

Figure 91. Nomogram for determining number of observations

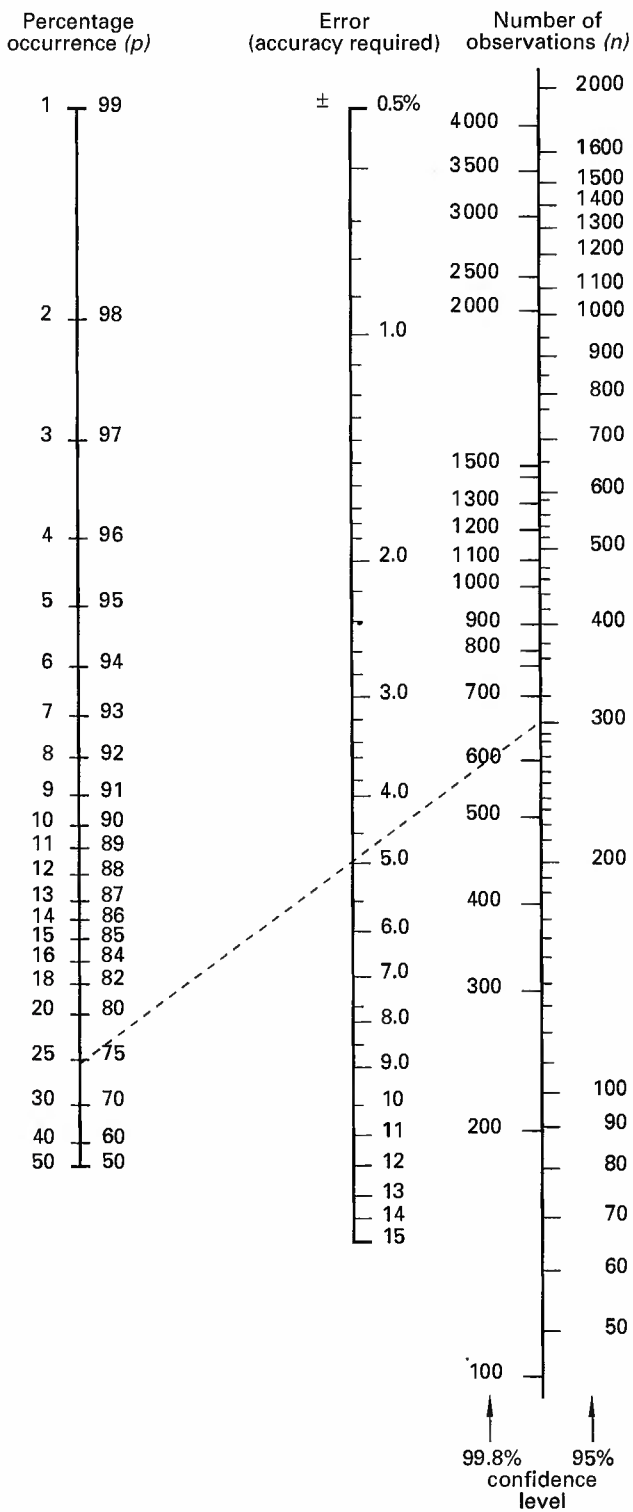


Table 12. Table of random numbers

49 54 43 54 82	17 37 93 23 78	87 35 20 96 43	84 26 34 91 64
57 24 55 06 88	77 04 74 47 67	21 76 33 50 25	83 92 12 06 76
16 95 55 67 19	98 10 50 71 75	12 86 73 58 07	44 39 52 38 79
78 64 56 07 82	52 42 07 44 38	15 51 00 13 42	99 66 02 79 54
09 47 27 96 54	49 17 46 09 62	90 52 84 77 27	08 02 73 43 28
44 17 16 58 09	79 83 86 19 62	06 76 50 03 10	55 23 64 05 05
82 97 77 77 99	83 11 46 32 24	20 14 85 88 45	10 93 72 88 71
82 97 77 77 81	07 45 32 14 08	32 98 94 07 72	93 85 79 10 75
50 92 26(1) 97	00 56 76 31 38	80 22 02 53 53	86 60 42 04 53
83 39 50 08 30	42 34 07 96 88	54 42 06 87 98	35 85 29 48 39
40 33 20 38 26	13 89 51 03 74	17 76 37 13 04	07 74 21 19 30
96 83 50 87 75	97 12 25 93 47	70 33 24 03 54	97 77 46 44 80
88 42 95 45 72	16 64 36 16 00	04 43 18 66 79	94 77 24 21 90
33 27 14 34 09	45 59 34 68 49	12 72 07 34 45	99 27 72 95 14
50 27 89 87 19	20 15 37 00 49	52 85 66 60 44	38 68 88 11 80
55 74 30 77 40	44 22 78 84 26	04 33 46 09 52	68 07 97 06 57
59 29 97 68 60	71 91 38 67 54	13 58 18 24 76	15 54 55 95 52
48 55 90 65 72	96 57 69 36 10	96 46 92 42 45	97 60 49 04 91
66 37 32 20 30	77 84 57 03 29	10 45 65 04 26	11 04 96 67 24
68 49 69 10 82	53 75 91 93 30	34 25 20 57 27	40 48 73 51 92
83 62 64 11 12	67 19 00 71 74	60 47 21 29 68	02 02 37 03 31
06 09 19 74 66	02 94 37 34 02	76 70 90 30 86	38 45 94 30 38
33 32 51 26 38	79 78 45 04 91	16 92 53 56 16	02 75 50 95 98
42 38 97 01 50	87 75 66 81 41	40 01 74 91 62	48 51 84 08 32
96 44 33 49 13	34 86 82 53 91	00 52 43 48 85	27 55 26 89 62
64 05 71 95 86	11 05 65 09 68	76 83 20 37 90	57 16 00 11 66
75 73 88 05 90	52 27 41 14 86	22 98 12 22 08	07 52 74 95 80
33 96 02 75 19	07 60 62 93 55	59 33 82 43 90	49 37 38 44 59
97 51 40 14 02	04 02 33 31 08	39 54 16 49 36	47 95 93 13 30
15 06 15 93 20	01 90 10 75 06	40 78 78 89 62	02 67 74 17 33
22 35 85 15 33	92 03 51 59 77	59 56 78 06 83	52 91 05 70 74
09 98 42 99 64	61 71 62 99 15	06 51 29 16 93	58 05 77 09 51
54 87 66 47 54	73 32 08 11 12	44 95 92 63 16	29 56 24 29 48
58 37 78 80 70	42 10 50 67 42	32 17 55 85 74	94 44 67 16 94
87 59 36 22 41	26 78 63 06 55	13 08 27 01 50	15 29 39 39 43
71 41 61 50 72	12 41 94 96 26	44 95 27 36 99	02 96 74 30 83
23 52 23 33 12	96 93 02 18 39	07 02 18 36 07	25 99 32 70 23
31 04 49 69 96	10 47 48 45 88	13 41 43 89 20	97 17 14 49 17
31 99 73 68 68	35 81 33 03 76	24 30 12 48 60	18 99 10 72 34
94 58 28 41 36	45 37 59 03 09	90 35 57 29 12	82 62 54 65 60

Table 13. Determining the sequence of time for random observations

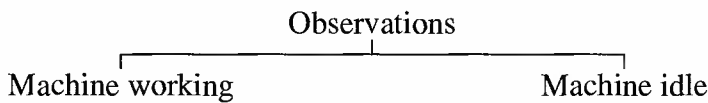
Usable numbers as selected from the random table	Arranged in numerical order	Time of observation ¹
11	05	7.50 a.m.
38	11	8.50 a.m.
45	14	9.20 a.m.
20	15	9.30 a.m.
26	20	10.20 a.m.
05	22	10.40 a.m.
14	26	11.20 a.m.
15	38	1.20 p.m.
47	45	2.30 p.m.
22	47	2.50 p.m.

¹Multiply each number by ten minutes and start from 7 a.m.

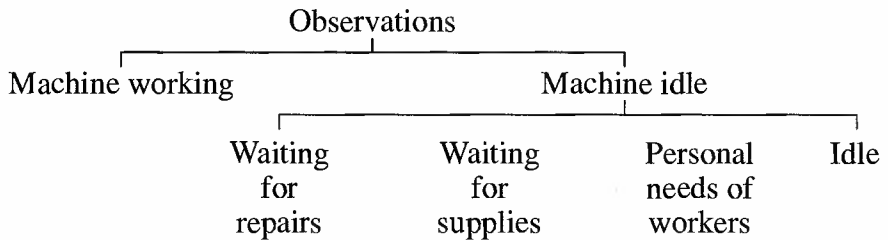
6. Conducting the study

Determining the scope of the study

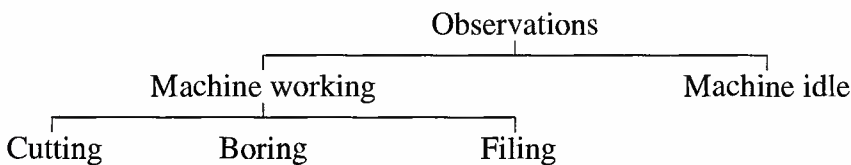
Before making our actual observations, it is important that we decide on the **objective** of our work sampling. The simplest objective is that of determining whether a given machine is idle or working. In such a case, our observations aim at detecting one of two possibilities only:



We can, however, extend this simple model to try to find out the cause of the stoppage of the machine:



Again, we may be interested in determining the percentage of time spent on each activity while the machine is working:



Or perhaps we may wish to get an idea of the percentage distribution of time when the machine is working and when it is idle, in which case we combine the last two models.

We may also be interested in the percentage time spent by a worker or groups of workers on a given element of work. If a certain job consists of ten different elements, by observing a worker at the defined points in time we can record on which element he or she is working and therefore arrive at a percentage distribution of the time he or she has been spending on each element.

The objectives to be reached by the study will therefore determine the design of the recording sheet used in work sampling, as can be seen from figures 92, 93 and 94.

Making the observations

So far we have taken the first five logical steps in conducting a work sampling study. To recapitulate, these consist of:

- selecting the job to be studied and determining the objectives of the study;
- making a preliminary observation to determine the approximate values of p and q ;
- in terms of a chosen confidence level and accuracy range, determining n (the number of observations needed);
- determining the frequency of observations, using random tables;
- designing record sheets to meet the objectives of the study.

There is one more step to take: that of making and recording the observations and analyzing the results. In making the observations, it is essential from the outset that the work study person is clear about what is to be achieved and why. Ambiguity should be avoided when classifying activities. For example, if the engine of a fork-lift truck is running while the truck is waiting to be loaded or unloaded, it should be decided beforehand whether this means that the truck is working or idle. It is also essential for the work study person to contact the persons he or she wishes to observe, explaining to them the purpose of the study, indicating to them that they should work at their normal pace and endeavouring to gain their confidence and cooperation.

The observation itself should be made at the same point relative to each machine. The work study person should not note what is happening at the machines ahead, as this tends to falsify the study. For example, in a weaving department, the observer may notice a loom that is stopped, just ahead of the one he or she is observing. The weaver may have it running again by the time the observer reaches it. The observer would, by noting it as idle, be giving an untrue picture.

The recording itself, as can be seen, consists simply of making a stroke in front of the appropriate activity on the record sheet at the proper and predetermined time. No stop-watches are used.

The analysis of results can be calculated readily on the record sheet. It is possible to find out the percentage of effective time compared with that of

Figure 92. Example of a simple work sampling record sheet

Date:		Observer:		Study No.:	
Number of observations: 75				Total	Percentage
Machine running				62	82.7
Machine idle				13	17.3

Figure 93. Work sampling record sheet showing machine utilization and distribution of idle time

Date:		Observer:		Study No.:	
Number of observations: 75				Total	Percentage
Machine running				62	82.7
Machine idle	Repairs			2	2.7
	Supplies			6	8.0
	Personal			1	1.3
	Idle			4	5.3

Figure 94. Work sampling record sheet showing distribution of time on ten elements of work performed by a group of four workers

Date:		Observer:		Study No.:						
Number of observations: 75										
	Elements of work									
	1	2	3	4	5	6	7	8	9	10
Worker No. 1										
Worker No. 2										
Worker No. 3										
Worker No. 4										

delays, to analyze the reasons for ineffective time and to ascertain the percentage time spent by a worker, groups of workers or a machine on a given work element. These, in themselves, provide useful information in a simple and reasonably quick way.

7. Rated work sampling

In Chapter 22 we shall discuss the problem of rating a worker's performance relative to a conceived standard pace. Thus qualified workers who work according to a specified method and who are motivated to apply themselves to work briskly but naturally without over-exertion are said to be working at 100 per cent standard rating on the performance scale. As will become apparent in that chapter, rating is an important factor in deriving a time for an operation since not all workers work at the same pace. As a result, a work study person has to take the pace of work into consideration when timing a study.

This rating of pace can equally be combined with work sampling to give what is known as **rated work sampling** or **rated activity sampling**.

In this method, observations are taken at fixed intervals rather than at random times. When using fixed interval sampling, care must be taken to ensure that the fixed interval selected does not coincide with a natural cycle in the work. Such a coincidence would distort the results, but generally if the interval is short enough when compared to the overall job cycle time, normal variations in the work will avoid such a problem occurring.

During the sampling study, in addition to the activity being undertaken at the instant of the observation, a recording is also made of the pace of the worker using a performance rating scale. This rating can be used to modify the results of the study through the process of extension (converting observed times to basic times) which is discussed in Chapter 22.

8. Group sampling techniques

As the name suggests, these are designed for the measurement of work carried out by groups of workers. The techniques are sometimes referred to by the term "high-frequency sampling" since, when used for the measurement of short-cycle work, they use fixed short-time intervals with the observer in constant attendance. They are thus very close to time study but have the advantage that the observer can cover the work of the group. Group sampling techniques may make use of rating.

Consider a very simple example of three workers each producing the same parts by a process that involves only hand tools. The sampling is carried out at 0.5 minute intervals and involves the categories of "working" and "not working" only. The sampling observations have been rated and this is thus an example of both rated activity sampling and group sampling.

The sampling sheet would look as shown in table 14.

Table 14. Rated work sampling recording sheet

Time	Operator 1		Operator 2		Operator 3	
	Working	Not working	Working	Not working	Working	Not working
9.00	85		90		80	
9.005	90				85	
9.01	90		90			
9.015						
9.02	95					
9.025						

Total time of observation	= 250 min.
No. of observations on each operator	= 500 min.
Total number of observations — working	= 1,370 min.
— not working	= 130 min.
Average rating for the three workers	= 87% (based on a 100% standard performance)
Total number of parts produced	= 62

Then, total working time = $1,370 \times 0.5 = 685$ min.

Conversion to basic time = $\frac{685 \times 87}{100} = 596$ basic min.

Basic min. per part = $\frac{596}{62} = 9.6$ min.

If rating is not taken into consideration then group sampling results would be = $\frac{685}{62} = 11.04$ min.

9. Using work sampling

Work sampling either individually or by group, with or without rating, is widely used. It is a relatively simple technique that can be used advantageously in a wide variety of situations, such as manufacturing, service and office operations. Apart from providing a quick result, it is a fairly low-cost method and one that is less controversial than time study. The information derived from work sampling can be used to provide for a more equitable distribution of work in a group and, in general, to provide the management with an appreciation of the percentage of and reasons behind ineffective time. As a result it may indicate where method study needs to be applied, materials handling improved or better production planning methods introduced, as may be the case if work sampling shows that a considerable percentage of machine time is spent idle, waiting for supplies to arrive.

10. Structured estimating

Estimating is probably the earliest “measurement” technique. People have always used the basis of past experience to predict future events. Normally, however, simple estimates are too unreliable to be used as the basis of effective planning and control. The accuracy of estimating depends on the experience of the estimator in the field in which he or she is estimating. Structured estimating techniques are an attempt to make use of this fact and at the same time to impose a structure and a discipline on the estimating process so that results derived from it can be treated with confidence.

The advantages of estimating are that:

- it is cheap to apply, and therefore may be the only technique appropriate to one-off jobs;
- it can be used to predict times for work which has not been observed and thus can be used as a basis for price estimating for large, one-off jobs.

Estimating is normally used where the required time values are not required in great detail. Thus such techniques are useful in long-cycle work and in situations where aggregated measurement data are used for planning, control or payment over reasonably lengthy time periods.

Analytical estimating

Analytical estimating is a combination of estimating and synthesis from standard data. The technique is based on the fact that if jobs are broken down into constituent elements and individual elements are measured or estimated, errors in those individual times will be random and will compensate for one another to leave an overall time that will be within acceptable limits. Similarly, when a number of jobs are combined into a larger time accumulation (such as the workload for a given week), individual errors in job times will be random and compensated by one another, leaving an overall time that is acceptable.

The estimating is normally carried out by a worker who is skilled in the area of work being measured and who has been trained in work study techniques. The estimator then:

- breaks a job into elements;
- applies any standard or synthetic data that are available;
- carries out measurement on elements which are considered to warrant such effort and expenditure;
- estimates any remaining elements using his or her experience and knowledge of the working conditions, safety factors, etc.

Element times which are estimated may then be incorporated into the standard data for future use, although such data should be revalidated at intervals.

Comparative estimating

Comparative estimating relies on the identification and measurement of “benchmark” jobs of known work content against which all other jobs to be measured are compared. The benchmark jobs are selected to represent the

whole range of work involved and to represent intermediate points on the overall scale of job. These benchmark jobs are measured with some precision using an established work measurement technique.

The next stage is to identify time bands or slots. These are determined by statistical analysis and may not be of equal width. Commonly, a logarithmic progression is selected with each slot being allocated a basic or standard time equivalent to its mid-point.

Thus:

Slot	1	2	3	4
Range (min.)	0-30	31-60	61-120	121-240
Basic time	15	45	90	180

Each of the benchmark jobs is assigned to the appropriate slot.

When estimating work subsequently, the estimator refers to the benchmark jobs and compares the job being measured. On the basis of experience, he or she makes a comparison of the work content of the job to be estimated with a number of the benchmark jobs. When he or she is satisfied that the correct slot for the job has been identified, he or she assigns the slot basic time to that job. Because this time is to be combined with others to give a total workload over a long period, the fact that this one time is "inaccurate" does not matter. It is dangerous, however, to use such individual times outside the planned period designed to offer the statistically correct error compensation period.

Because of the high set-up cost of this system (in terms of measuring all the benchmark jobs, training estimators, and so on), comparative estimating is most suitable for situations where there is a lot of long-cycle, non-repetitive work. A common area of application is in maintenance work, where the work is similar but no two jobs may be identical. To reduce the set-up time, it is possible to "import" data on benchmark jobs from another organization (such as a consulting firm). If this is done, it is important to validate the data (as with any imported standard data) in its field of operation through carrying out some comparative studies.



Time study: The equipment

1. What is time study?

In Chapter 18 we listed the main techniques of work measurement. We shall now examine, in the next few chapters, one of the most important of these techniques, namely **time study**.

Time study is a work measurement technique for recording the times of performing a certain specific job or its elements carried out under specified conditions, and for analysing the data so as to obtain the time necessary for an operator to carry it out at a defined rate of performance

2. Time study equipment

If time studies are to be made, certain items of equipment are essential. Basic time study equipment consists of:

- a stop-watch;
- a study board;
- time study forms;

although any or all of these may be replaced with electronic equivalents as will be indicated later on.

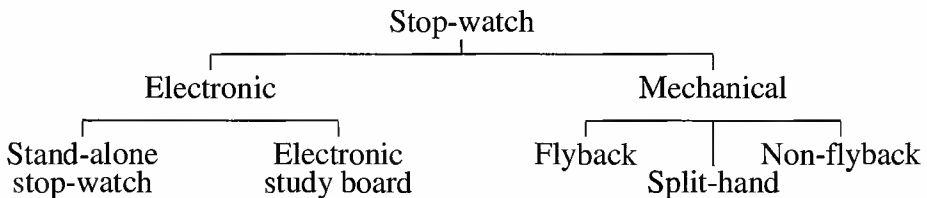
The study person will need to be carrying the timing and recording devices whenever a time study is made. In addition, in the study office, there must be facilities for assisting with the analysis of the time study. These may vary from a small calculator to a personal computer.

Other measuring instruments will be required from time to time to obtain data on the work being measured — most work study offices will have (access to) such devices as tape measures, steel rules, micrometers, spring balances, and so on.

In addition, the office should have a clear, reliable clock with a second hand for recording study start and finish times.

The stop-watch

There are two main types of watch in general use for time study — the mechanical and the electronic. Mechanical watches can again be subdivided into the flyback and non-flyback types, with a third type — the split-hand stop-watch — in less common use. Electronic stop-watches may be part of a specially designed study board or data capture device.



Mechanical-type watches may be obtained with any one of three graduated scales:

- recording one minute per revolution by intervals of one-fifth of a second, with a small hand recording 30 minutes;
- recording one minute per revolution calibrated in 1/100ths of a minute, with a small hand recording 30 minutes (the decimal-minute watch);
- recording 1/100th of an hour per revolution calibrated in 1/10,000ths of an hour; a small hand records up to one hour in 100 divisions (the decimal-hour watch).

It is also possible to obtain watches with the main scale in decimal minutes and an auxiliary scale outside it, usually in red, graduated in seconds and fifths of a second.

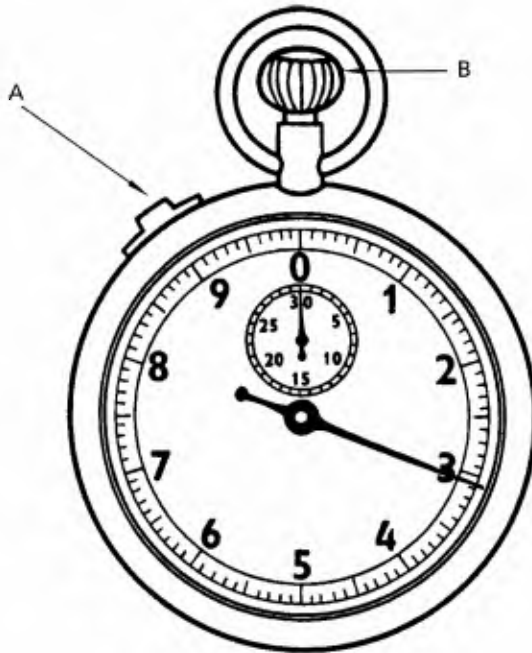
A flyback decimal-minute stop-watch — probably the type in most general use today — is shown in figure 95. The hand of the small dial makes 1/30th of a revolution for each revolution of the main hand, and thus makes a complete turn every 30 minutes.

In this type of watch the movement is started and stopped by a slide (A) at the side of the winding-knob (B). Pressure on the top of the winding-knob causes both the hands to fly back to zero without stopping the mechanism, from which point they immediately move forward again. If the slide is used, the hands can be stopped at any point on the dial and restarted without returning to zero as soon as the slide is released. This type of watch can be used for either “flyback” or “cumulative” timing (see Chapter 21, section 9).

The non-flyback type is controlled by pressure on the top of the winding-knob. The first pressure starts the watch; the second pressure stops it; the third pressure returns the hands to zero. This watch is suitable only for cumulative timing.

In the split-hand type of watch, pressing a secondary knob causes one of the hands to stand still while the other continues to measure time. When the knob is pressed a second time, the stopped hand returns to the moving one and the two go on together. In this way, when a reading is taken, a stopped hand is read instead of a moving one, giving greater accuracy of reading.

Figure 95. A decimal-minute stop-watch



A = Slide for stopping and starting the movement.

B = Winding knob. Pressure on this knob returns both the hands to zero.

The split-hand watch is easier to read, but is heavier, more expensive and, because of its complexity, more troublesome to repair. With properly trained time study persons, equally good results can be obtained with a simpler, lighter and less expensive watch. Unless there are special reasons for preferring one of the other types, the single-pressure, centre-sweep hand, flyback watch with the main dial graduated in 1/100ths of a minute and the smaller dial recording 30 minutes will be found most serviceable for time study. This is the type illustrated in figure 95.

Whatever type of watch is used, it should always be remembered that it is a delicate instrument which must be treated with care. Watches should be wound fully before each study, and should be allowed to run down overnight. At regular intervals they should be sent to a watchmaker for cleaning and routine overhaul.

The study board

The study board is simply a flat board, usually of plywood or of suitable plastic sheet, needed for placing the time study forms. It should be rigid and larger than the largest form likely to be used. It may have a fitting to hold the watch, so that the hands of the work study person are left relatively free and the watch is in a position to be read easily. For right-handed people the watch is normally placed at the top of the board on the right-hand side, so that the board may be rested on the left forearm with the bottom edge against the body and the

forefinger or middle finger of the left hand used to press the winding knob when resetting the watch (figure 96). Some work study persons prefer to attach their watches with strong rubber bands or leather thongs around the two middle fingers of their left hands and to hold them at the top of the board in that way. It is largely a matter of individual preference, provided that the watch is securely held and can be easily read and manipulated. A strong spring clip should also be fitted to the board to hold the forms on which the study is recorded.

A study board which is either too short or too long for the study person's arm soon becomes tiring to use. Most study persons prefer therefore to have their own individual boards made up to fit their own arm lengths, after they have had sufficient practice to know which size will be most comfortable.

Electronic stop-watches and study boards

An electronic stop-watch (figure 97) performs exactly the same role as a mechanical one — the recording of element durations. One of the main advantages is that it allows flyback timing to be performed without any loss of accuracy. (With a mechanical watch the time taken for the hand to return to zero is "lost". With an experienced practitioner, this time is minimal but with a trainee or inexperienced observer, it can be significant and can jeopardize the accuracy of a time study.) With an electronic watch the timing device is running continually and it is only the display that is updated as the "flyback" button is pressed to reset the display to zero. At the end of the time study with most watches it is possible to read off the total elapsed time.

Electronic watches can often be used in a number of calibration modes — they can be set to record in fractions of seconds, minutes or hours.

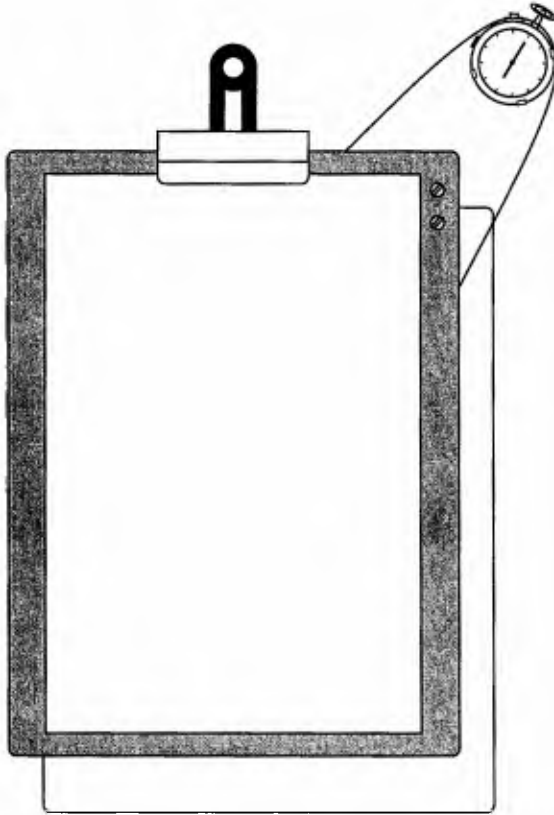
Electronic data capture devices or study boards are units which are used to record activity during a time study and which include an electronic timing device which automatically assigns times to elements.

The most usual procedure is that as work proceeds, the observer keys into the device a code that identifies the element being carried out and then keys in the rating assigned to the element. At the moment of the breakpoint, the observer hits a key to terminate the element. This causes the time to be recorded (but not displayed) and the recording of the next element to begin. The board or data capture unit records all this data (element code, rating and element duration) in its internal memory for later analysis, often via transfer to a personal computer.

There are two types of unit in common use. The first are hand-held computers which have been modified for time study purposes (mainly through the addition of time study software, but the "customization" process may include such things as new legends on the keys) and the second are specially designed electronic time study boards. The first have the advantage that when not being used for time study they may, in addition to other software, be used for other applications. Conversely, hand-held computers may require the use of a study board as well, to take notes, and combining the two may be difficult and cumbersome. The specially designed boards have the advantage that they

Figure 96. Time study boards

(a) Study board for general purpose form



(b) Study board for short cycle form

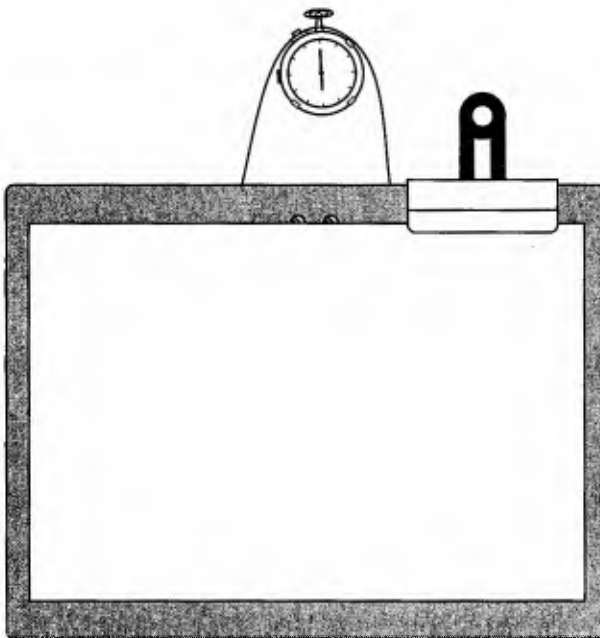


Figure 97. An electronic stop-watch



are generally easier to use for time study recording. For example, they may have keys labelled “OC” for occasional element, “FE” for foreign element, and so on.

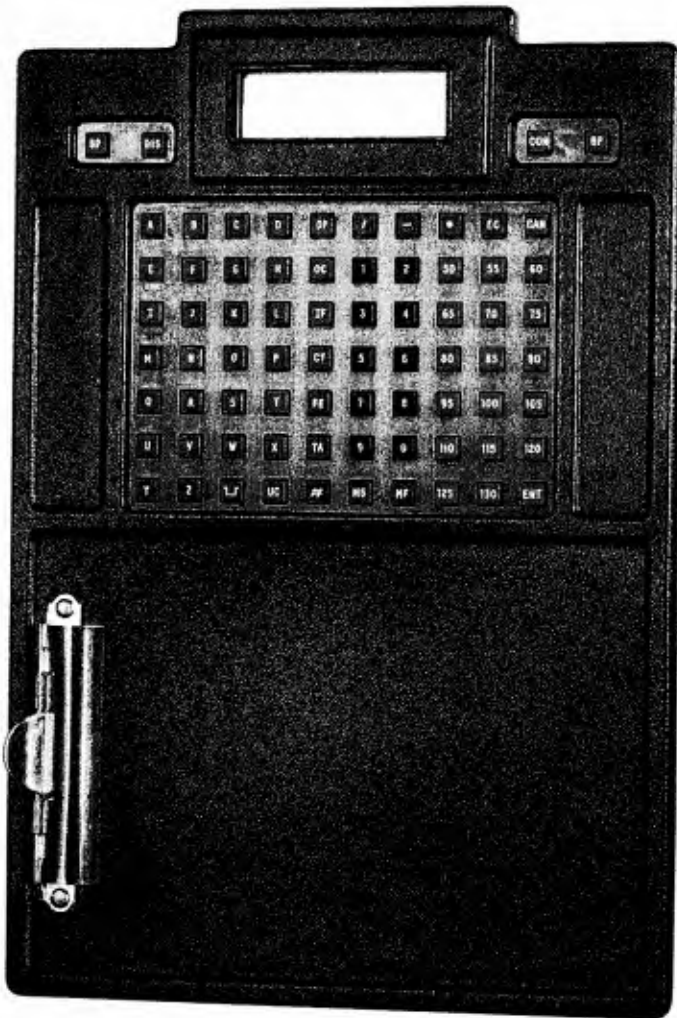
An example of an electronic study board is shown in figure 98.

One of the advantages of electronic data capture is that, because the time is never visible to the observer, it becomes impossible to “clock rate”, in other words to be tempted to adjust the rating as will be referred to later in Chapter 21, section 9. Another important advantage is that the observer is required to carry out less writing (if any at all) and can pay more attention to the work being measured. (Notes may have to be made about foreign elements, frequencies, abnormal occurrences, and so on, and thus the electronic study board normally has space for a writing pad.)

3. Time study forms

Taking a time study requires the recording of substantial amounts of data. These data are in a regular form consisting of element codes or descriptions, ratings and element durations (perhaps with additional explanatory notes). Although the data could be recorded on plain paper, it is more convenient to use pre-printed forms which ensure that each study is of the same consistent format, that all relevant data are recorded and that filing and retrieval of completed studies is more reliable.

Figure 98. An electronic study board



Source: GP-1 Time Study Board supplied by Tectime Data Systems, Newcastle-under-Lyme, Staffordshire, United Kingdom.

There are numerous designs of forms; most work study practitioners have their own ideas on the ideal layout. The examples shown in this book represent designs which have been proved in practice to be satisfactory for general work.

The principal forms used in time study fall into two groups: those used at the point of observation while actually making the study, and which should therefore be designed or selected to fit the study board in use; and those which are used after the study, as part of the analysis process, in the study office.

Electronic study boards and data-capture devices eliminate most of the need for time study forms. However, it is still important to record notes which relate to the work being observed, especially where it is seen to deviate from normal practice or conditions, and a simple form which has as a minimum the recording of the date, time, observer and operator will suffice. Similarly, when it comes to the analysis stage, many of the forms used in the analysis of studies

taken with a conventional stop-watch will not be required since the analysis may be carried out by computer. The forms described here are therefore those which would be used by an observer taking conventional time studies with a mechanical or electronic stop-watch and recording the data by hand.

Forms used on the study board

Time study top sheet: The top and introductory sheet of a study, on which is recorded all the essential information about the study, the elements into which the operation being studied has been broken down, and the breakpoints used. It may also record the first few cycles of the study itself. The example shown in figure 99 has spaces in the heading for all the information normally required about a study except the sketch of the workplace layout, which should be drawn either on the reverse of the sheet, if the layout is very simple, or on a separate sheet (preferably of squared paper) and attached to the study.

Continuation sheet: This form is used for further cycles of the study. An example is shown in figure 100, from which it will be seen that the form consists only of the columns and space for the study and sheet number. It is usual to print this ruling on both sides of the paper; on the reverse side the heading is not necessary.

These two forms are the ones most generally used. Together they are adequate for most general time study work. For the recording of short cycle repetitive operations, however, it is convenient to use a specially ruled form instead.

Short cycle study form: Two examples of a short cycle form are illustrated. That in figure 101 shows a simple type of form which serves very well for most common short cycle work. The other, shown in figure 102 and in figure 103, is a more complicated form, adapted from one in general use in the United States; it may be more suitable if short cycle work is the rule rather than the exception.

Forms used in the study office

Working sheet for analysing the readings obtained during the study and obtaining representative times for each element of the operation. One example of a working sheet is shown in figure 125 in Chapter 25. As will be seen later, there are various ways in which the analysis may be made, each requiring a different ruling on the sheet. For this reason many time study persons prefer to use simple lined sheets, of the same size as the study sheets, for making their analyses, clipping these to the study sheets when complete.

Study summary sheet to which the selected or derived times for all the elements are transferred, with the frequencies of the elements' occurrence. This sheet, as its name suggests, summarizes neatly all the information which has been obtained during the course of the study. The heading includes all the details recorded about the operation at the top of

Figure 102. Short cycle study form (front)

Date of study _____	Time finished _____ Time started _____ Elapsed time _____	Short cycle study sheet				Study No. _____ _____ Sht. ____ of ____ Shts.																																																																																																					
Department _____		Part name _____		Basic cycle time _____ Min.																																																																																																							
Operation _____		DWG No. _____ Part No. _____		or Total ave. element time _____ Min.																																																																																																							
Tools used _____		Speed _____ r.p.m. _____		Rating factor _____																																																																																																							
		Feed _____ Mm/Min. _____		Basic cycle time _____ Min.																																																																																																							
Machine and No. _____		Standard _____ _____ _____		Reason for study Original study <input type="checkbox"/> Method study change <input type="checkbox"/> To check estb. standard <input type="checkbox"/>		Allowances [<table style="display: inline-table; border: none; vertical-align: middle;"> <tr><td style="padding: 0 5px;">Personal</td><td style="padding: 0 5px;">%</td></tr> <tr><td style="padding: 0 5px;">Delay</td><td style="padding: 0 5px;">%</td></tr> <tr><td style="padding: 0 5px;">Fatigue</td><td style="padding: 0 5px;">%</td></tr> <tr><td style="padding: 0 5px;">Others</td><td style="padding: 0 5px;">%</td></tr> </table>] _____ % _____ Min.		Personal	%	Delay	%	Fatigue	%	Others	%																																																																																												
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Figure 103. Short cycle study form (back)

Date of study _____		Time finished _____		Short cycle study sheet						Study No. _____			
		Time started _____								Sht. _____ of _____ Shts.			
Element No.		1	2	3	4	5	6	7	8	9	10	Name of operative _____	
Standing <input type="checkbox"/>		/										Clock No. _____	
Sitting <input type="checkbox"/>												Observed by _____	
Moving about <input type="checkbox"/>												Approved by _____	
												Foreign elements _____	
Cycle No.												Symbol	Description
1												A	
2												B	
3												C	
4												D	
5												E	
6												F	
7												G	
8												H	
9												I	
10												J	
11												K	
12												L	
13												M	
14												N	
15												O	
16												P	
17												Q	
18												R	
19												S	
20												T	
Total													
No. of Obs.													
Average													
Rating %													
Basic time													

TIME STUDY: THE EQUIPMENT

the time study top sheet. The completed study summary sheet is clipped on top of all the other study sheets and is thus filed with them. The summary sheet should therefore be of the same size as that chosen for the study sheets. An example is shown in figure 104, from which it will be seen that the main body of the sheet has space for the ruling of additional columns, should these be needed for the particular study being summarized.

- Analysis of studies sheet** on which are recorded, from the study summary sheets, the results obtained in all the studies made on an operation. The analysis of studies sheet records the results of all the studies made of a particular operation, no matter when they were made or by whom. It is from the analysis of studies sheets that the basic times for the elements of the operation are finally compiled. The sheet is often much larger than the ordinary study forms. See figure 105 and figure 127 in Chapter 25.
- A specially ruled sheet for the compilation of **relaxation allowances** is also often used.

The use of all these forms, both those employed when actually making the study and those used afterwards to analyse and record it, will be described in detail in subsequent chapters.

4. Other equipment

The stop-watch or electronic data capture device provides the necessary accuracy for all general-purpose work. Where this is not so, for example in highly repetitive, very short-cycle work, then some other measurement technique is more appropriate than time study. Time study can be extended into such areas using films or videos of work (see Chapter 9). With film, the number of frames can be counted for a very short sequence of work to give an accurate time duration — as long as it is validated that the projection of the film is at precisely the same speed as that of the camera that took the film. An alternative, for both film and video, is to record the work with an accurate and detailed timing device kept “in shot” while the recording is taking place. Times can then be read off this timing device when the film or video is replayed at slower speeds.

Time study: Selecting and timing the job

1. Selecting the job

As in method study, the first step in time study is to select the job to be studied. Generally speaking, there are few occasions when a work study person can go into a working area or a department and select a job at random. There is nearly always a reason why a particular job requires attention. Some possible reasons are:

- (1) The job in question is a new one, not previously carried out (new product, component, operation or set of activities).
- (2) A change in material or method of working has been made and a new time standard is required.
- (3) A complaint has been received from a worker or workers' representative about the time standard for an operation.
- (4) A particular operation appears to be a "bottleneck" holding up subsequent operations and possibly (through accumulations of work in process behind it) previous operations.
- (5) Standard times are required before an incentive scheme is introduced.
- (6) A piece of equipment appears to be idle for an excessive time or its output is low, and it therefore becomes necessary to investigate the method of its use.
- (7) The job needs studying as a preliminary to making a method study, or to compare the efficiency of two proposed methods.
- (8) The cost of a particular job appears to be excessive, as may be evidenced by a Pareto type of analysis.

If the purpose of the study is the setting of performance standards, it should not normally be undertaken until method study has been used to establish and define the most satisfactory way of doing the job. The reason for this is obvious; if the best method has not been discovered by systematic study, there is always the possibility that a much better way of doing it may be evolved, either by the workers themselves or by technical staff — a way which may need considerably less work to achieve the results required. The amount and nature of the reduction in work may vary at different times, according to which worker happens to be doing the job and the method chosen. The quantity of work involved in the process or operation may actually increase, if an operative less skilled than the one originally timed does the job later on and uses a method more laborious than that on the basis of which the time was set.

Until the best method has been developed, defined and standardized, the amount of work which the job or process involves will not be stable. Planning of programmes will be thrown out and, if the time standard is used for incentive purposes, the payment made to the operative may become uneconomic for the job. The workers may find the time unattainable, or, in the opposite case, may find that the work can be completed in a much shorter time than that set as the standard. If so, they will very probably restrict their output to the maximum which they think the management will tolerate without starting to make inquiries into the validity of the time standard which has been set. Although, in collective agreements introducing work study, it is customary to include a clause permitting the retiming of jobs when the work content is altered in either direction (and the management would, in theory, be justified in invoking this clause where a reduction in work content has been made, whether by worker or management), the retiming of jobs in such circumstances always tends to cause resentment, and if it is done frequently it will quickly shatter the confidence of the workers in both the competence of the work study staff and the honesty of management. Therefore **make sure first that the method is right**. Remember, too, that any one time should refer only to one specified method.

There are problems in the selection of jobs to be studied which have nothing to do with the importance of the jobs to the enterprise or the abilities of the operatives. One difficult problem which may arise in factories where a piece-work system is already in operation is that the existing piece-work times on certain jobs, fixed by bargaining or estimation, may be so liberal that the workers have been earning high bonuses which cannot possibly be maintained if the jobs are properly reassessed. Attempts to alter the methods, which should automatically bring about a reassessment of the times allowed, may meet with such resistance that it is unwise to proceed with the studies. If this is the case, it is better, in an initial application, to tackle a number of jobs where it is evident that the earnings of the workers can be **increased** by the application of time study, even though these jobs may be less important to the performance of the working area as a whole. When the rest of the jobs in the working area have been studied and confidence in the integrity of the work study person has been established, it may be possible to return to the "problem" jobs. It will almost certainly be necessary to negotiate on these problem jobs with the workers' representatives, and it may be necessary to compensate the workers concerned. It is nevertheless possible to carry through such negotiations successfully, if the purpose of the change is fully understood by all concerned.

2. The approach to the worker

The question of relationships between the work study person and the supervisors and workers in the enterprise was dealt with at some length in Chapter 4. The reason for mentioning it here is that what was said about work study in general applies with even more force to time study, especially with respect to the workers.

The purpose of a method study is usually obvious to everyone: it is to improve the method of doing the job, and everyone can see that it is a proper activity for the work study specialist to engage in. The efforts of the work study person may even be welcomed by operatives who may then be relieved of fatiguing or unpleasant work. The purpose of a time study is less obvious and, unless it is very carefully explained to everyone concerned, its object may be completely misunderstood or misrepresented, with consequent unrest and even strikes.

It is assumed that the work study specialist has already become a familiar figure in the enterprise while making method studies and that this person is well known to the supervisor and the workers' representatives. Nevertheless, if no time studies have previously been made there, the workers' representatives and the supervisors should first be brought together and it should be explained to them in simple terms what is going to be done and why, and they should be invited to handle the watch. All questions should be answered frankly. This is where the value of work study courses for workers' representatives and supervisors shows itself.

If a choice of workers is available, it is good policy to ask the supervisor and workers' representatives to suggest the one most suitable to be studied first, emphasizing that this should be a competent, steady person whose rate of working should be average or slightly better than average. Efforts should be made not to select people temperamentally unsuited to being studied and who cannot work normally while being watched.

It is important, where the job is one likely to be done on a large scale (possibly by a large number of workers), to take studies on a number of qualified workers.

A distinction is made in time study practice between what are termed representative workers and qualified workers. A **representative worker** is one whose skill and performance is the average of the group under consideration, and who is not necessarily a **qualified worker**. The concept of the qualified worker is an important one in time study. This person is defined as follows:

A qualified worker is one who has acquired the skill, knowledge and other attributes to carry out the work in hand to satisfactory standards of quantity, quality and safety¹

There is a reason for this insistence on selecting qualified workers. In setting time standards, especially when they are to be used for incentives, the standard to be aimed at is one which can be attained by the qualified worker, and which can be maintained without causing undue fatigue. Because workers work at different speeds, observed times have to be adjusted by factors to give such a standard. These factors are dependent on the judgement of the study person. Experience has shown that accuracy of judgement is attainable only

¹ BSI: *Glossary of terms used in management services*, BSI 3138 (London, 1991).

within a fairly narrow range of speeds close to that which is normal for a qualified worker. The study of slow or unskilled workers or of exceptionally fast workers will tend to result in the setting of time standards that are either unduly large (known as "loose" times), and hence uneconomic, or unduly short (known as "tight" times), in which case they are unfair to the worker and will probably be the subject of complaints later.

When the worker whose work is to be studied first has been selected, he or she should be approached in company with the supervisor and the workers' representative. The purpose of the study and what is required should be carefully explained. The worker should be asked to work at his or her usual pace, taking whatever rest is normally taken, and should be invited to explain any difficulties which may be encountered. (This procedure becomes unnecessary as soon as work study is firmly established and its purpose well understood. It should, however, be carried out with new workers, and new members of the work study staff should be introduced to supervisors and workers when they start studies.) It is important to impress on the supervisor that the worker is then to be **left alone**. Some workers are liable to become apprehensive if one of their direct supervisors is standing over them and watching them.

If a new method has been installed, the worker must be allowed plenty of time to settle down before timing starts. It takes quite a long time for an operative to adapt and to reach a maximum steady speed. Depending on the duration and intricacy of the operation, it may be necessary to allow a job to run for days or even weeks before it is ready to be timed for the purpose of setting standards. In the same way, the work done by new operatives should never be used for timing until they have grown thoroughly accustomed to their jobs.

The observation position, in relation to the operative, is important. The study person should be so placed that everything the operative does can be seen (especially hand movements), without interfering with free movement or distracting his or her attention. The study person should not stand directly in front of the worker, nor in such close proximity that the worker has the feeling of "having someone standing over him or her" — a frequent complaint made against time study. The study person's exact position will be determined by the type of operation being studied, but the position generally recommended is to one side of the operative, slightly to the rear and about 2 metres away. In this position the operative can see the study person by turning his or her head a little, and they can speak if it is necessary to ask a question or explain some point in connection with the operation. The study board and watch should be held well up in line with the job, to make reading the watch and recording easy while maintaining continuous observation.

On no account should any attempt be made to time the operative without his or her knowledge, from a concealed position or with the watch in the pocket. It is dishonest and, in any case, someone is sure to see and the news will spread like wildfire. Work study should have nothing to hide.

It is equally important that the study person should stand up while making a study. There is a tendency on the part of workers to regard themselves as

having to do all the work while the study person simply stands around and watches them. The workers' respect will quickly be lost if the study person looks too comfortably positioned while making the study. It should be remembered though that, during the study, a position should be adopted which can be maintained, if necessary, over a long period. Time study demands intense concentration and alertness, especially when timing very short "elements" or "cycles" (defined later in this chapter), and it is generally agreed that this is better attained when standing.

Most operatives will quickly settle down to their normal working pace, but nervous workers have a tendency to work unnaturally fast, which will cause them to fumble and make errors. If this happens, the study person should stop the study and have a chat with the operative to put him or her at ease, or even leave him or her to settle down for a bit.

On repetitive work it is generally easy to detect operatives who are deliberately working at a pace which is not natural to them because, if they are working naturally, there will be very little variation in the times of the different cycles once they have got going, whereas it is difficult for them to control these times when they are not. When there are wide variations in successive cycle times, and when these are not due to variations in the material being worked on or to the tools or machine (in which case the study person should report the variations to the proper authorities), the differing cycle times must be due to action on the operative's part. If this is the case, the study person should discontinue the study and see the supervisor. As a matter of practical diplomacy it may be wiser not to report the operative for the attempted "leg pulling", but to ask the supervisor to come and look at the job as it does not seem to be running quite right. This is the sort of human situation that must be dealt with according to its merits if the study person is not going to risk unnecessary unpopularity and is one of the reasons why the personal qualities of the study person listed in Chapter 4 are so essential.

When technical considerations have a considerable influence on the job being studied, it may be much less easy to detect attempts to stretch the time of the job, unless the study person is an expert in the process. This is especially so where craft skill is involved (as in some sheet-metal work, or turning and screw-cutting operations to fine tolerances and high finish on centre lathes), even where speeds and feeds have been specified by the process planning department. It is difficult to argue with a skilled craftsman if you are not one yourself! This is one of the reasons why it is so important to establish precisely the method and conditions of an operation before attempting to time it. A really good method study before the job is timed simplifies immensely the task of setting time standards.

In the foregoing paragraphs an effort has been made to suggest some of the practical problems the study person will have to face in obtaining representative times; but there are many others which can be learned only in the hard school of experience, in the atmosphere of the working area, among the men and women who work there. They cannot be translated into print. The human-hearted person will delight in them; the other sort should not take up a career in work study.

3. Steps in making a time study

When the work to be measured has been selected, the making of a time study usually consists of the following eight steps (see also figure 87):

- (1) Obtaining and recording all the information available about the job, the operative and the surrounding conditions, which is likely to affect the carrying out of the work.
- (2) Recording a complete description of the method, breaking down the operation into "elements".
- (3) Examining the detailed breakdown to ensure that the most effective method and motions are being used, and determining the sample size.
- (4) Measuring with a timing device (usually a stop-watch) and recording the time taken by the operative to perform each "element" of the operation.
- (5) At the same time, assessing the effective speed of working of the operative relative to the observer's concept of the rate corresponding to standard rating.
- (6) Extending the observed times to "basic times".
- (7) Determining the allowances to be made over and above the basic time for the operation.
- (8) Determining the "standard time" for the operation.

4. Obtaining and recording information

The following information (or those items which apply to the operation being studied) should be recorded from observation before starting the study proper. It is usual to do so on the time study top sheet. If the various headings are printed, this helps to ensure that no vital piece of information is overlooked. The exact number of the items listed below which may have to be included when a time study form is designed will depend on the type of work carried out in the enterprise in which it is to be used. In non-manufacturing industries such as transport and catering, it should not be necessary to include space for the "product", etc. Working areas where all the work is manual will require space for "tools" but not for "plant or machine".

Details of the workplace can be recorded more quickly and with greater accuracy when they are photographed with a simple instant-print-type camera with flash attachment.

The filling-in of **all** the relevant information **from direct observation** is important in case the time study has to be referred to later; incomplete information may make a study practically useless a few months after it has been made. The forms shown in figures 99 to 103 are designed for manufacturing industry to show the maximum amount of information that is usually necessary.

The information to be obtained may be grouped as follows:

- A. **Information to enable the study to be found and identified quickly when needed**

Study number.

Sheet number and number of sheets.

Name or initials of the study person making the study.

Date of the study.

Name of the person approving the study (head of the work study department, production manager or other appropriate executive).

B. Information to enable the product or part being processed to be accurately identified

Name of product or part.

Drawing or specification number.

Part number (if different from drawing number).

Material.

Quality requirements.²

C. Information to enable the process, method, plant or machine to be accurately identified

Department or location where the operation is taking place.

Description of the operation or activity.

Method study or standard practice sheet numbers (where they exist).

Plant or machine (maker's name, type, size or capacity).

Tools, jigs, fixtures and gauges used.

Sketch of the workplace layout, machine set-up and/or part showing surfaces worked (on the reverse of the time study top sheet, or on a separate sheet attached to the study if necessary).

Machine speeds and feeds or other setting information governing the rate of production of the machine or process (e.g. temperature, pressure, flow, etc.). It is good practice to have the supervisor initial the study form beside the record of information of this sort, as an endorsement of its correctness.

D. Information to enable the operative to be identified

Operative's name.

Clock number.³

E. Duration of the study

The start of the study ("Time on").

The finish of the study ("Time off").

Elapsed time.

² In the case of some engineering products, parts may be modified from time to time and the drawings reissued. It may therefore also be necessary to note the issue number. For "Quality requirements" it may simply be sufficient to put a standard specification number or "Good finish". In engineering practice, tolerances and finish are generally specified on the drawing.

³ In the case of new jobs or new operatives, it may be desirable to note the amount of experience the operative has had on the particular operation at the time of the study, so that the point reached in learning the job can be assessed.

F. Working conditions

Temperature, humidity, adequacy of the lighting, etc., as a supplement to the information recorded on the sketch of the workplace layout.

Where an electronic study board is being used, it is still important to record the same kinds of identifying data. If the software being used for the study does not allow such data to be keyed into the board, the data must be recorded on a separate study top sheet, designed for this purpose. This sheet will be similar to a normal time study top sheet but will include a cross-reference to an identifying code which is part of the data recorded on the board (such as the study reference).

5. Checking the method

Before proceeding with the study, it is important to check the method being used by the operative. If the study is for the purpose of setting a time standard, a method study should already have been made and a written standard practice sheet completed. In this case it is simply a question of comparing what is actually being done with what is specified on the sheet. If the study is being made as the result of a complaint from workers that they are unable to attain the output set by a previous study, their methods must be very carefully compared with that used when the original study was made. It will often be found in such cases that the operatives are not carrying out the work as originally specified: they may be using different tools, a different machine set-up or different speeds and feeds, temperatures, rates of flow or whatever the requirements of the process may be, or additional work may have crept in.

It may be that the cutting tools are worn, or have been sharpened to incorrect profiles. Times obtained when observing work carried out with worn tools or incorrect process conditions should not be used for the compilation of time standards.

In highly repetitive short cycle work, such as work on a conveyor band (light assembly, packing biscuits, sorting tiles), changes in method may be much more difficult to detect, since they may involve changes in the movements of the arms and hands of the operative ("motion patterns") which can be observed only with difficulty by the naked eye and require special apparatus to analyse.

Although it has been emphasized repeatedly in this book that a proper method study should be made before a time study is undertaken for the purpose of setting time standards, there are occasions when time standards may have to be set without a full-scale method study being conducted beforehand. This is most likely to occur with short-run jobs which are only done a few times a year in the working area concerned. In such cases the study person should make a careful record of the method by which the job is being done, after putting right any obvious inefficiencies — in organization, for instance, by providing containers for finished work in the proper positions or by checking machine speeds. This record becomes especially important as it will be the only record

available, and changes in methods will be more likely to occur where operatives have not been instructed in one definite method.

6. Breaking the job into elements

Once the study person has recorded all the information about the operation and the operative needed for proper identification in the future, and is satisfied that the method being used is the correct one or the best possible in the prevailing circumstances, it must be broken down into elements.

An element is a distinct part of a specified job selected for convenience of observation, measurement and analysis

A work cycle is the sequence of elements which are required to perform a job or yield a unit of production. The sequence may sometimes include occasional elements

A work cycle starts at the beginning of the first element of the operation or activity and continues to the same point in a repetition of the operation or activity. That is the start of the second cycle. This is illustrated in the fully worked-out example of a time study in Chapter 25.

A detailed breakdown into elements is necessary:

- (1) To ensure that productive work (or effective time) is separated from unproductive activity (or ineffective time).
- (2) To permit the rate of working to be assessed more accurately than would be possible if the assessment were made over a complete cycle. The operative may not work at the same pace throughout the cycle, and may tend to perform some elements more quickly than others.
- (3) To enable the different types of element (see below) to be identified and distinguished, so that each may be accorded the treatment appropriate to its type.
- (4) To enable elements involving a high degree of fatigue to be isolated and to make the allocation of fatigue allowances more accurate.
- (5) To facilitate checking the method so that the subsequent omission or insertion of elements may be detected quickly. This may become necessary if at a future date the time standard for the job is queried.
- (6) To enable a detailed work specification (see Chapter 28) to be produced.
- (7) To enable time values for frequently recurring elements, such as the operation of machine controls or loading and unloading workpieces from

fixtures, to be extracted and used in the compilation of standard data (see Chapter 27).

Types of element

Eight types of element are distinguished: repetitive, occasional, constant, variable, manual, machine, governing, and foreign elements. The definition of each is listed below, together with examples:

- A **repetitive element** is an element which occurs in every work cycle of an operation.
Examples: the element of picking up a part prior to an assembly operation; the element of locating a workpiece in a holding device; putting aside a finished component or assembly.
- An **occasional element** is an element which does not occur in every work cycle of an operation but which may occur at regular or irregular intervals.
Examples: adjusting the tension, or machine setting; receiving instructions from the supervisor. The occasional element is useful **work** and a part of the job. It will be incorporated in the final standard time for the job.
- A **constant element** is an element for which the basic time remains constant whenever it is performed.
Examples: switch on machine; gauge diameter; screw on and tighten nut; insert a particular cutting tool into machine.
- A **variable element** is an element for which the basic time varies in relation to some characteristics of the product, equipment or process, e.g. dimensions, weight, quality, etc.
Examples: saw logs with handsaw (time varies with hardness and diameter); sweep floor (varies with area); push trolley of parts to next shop (varies with distance).
- A **manual element** is an element performed by a worker.
- A **machine element** is an element performed automatically by any process, physical, chemical or otherwise that, once started, cannot be influenced by a worker except to terminate it prematurely.
Examples: anneal tubes, fire tiles; form glass bottles; press car body shell to shape; most actual cutting elements on machine tools.
- A **governing element** is an element occupying a longer time within a work cycle than that of any other element which is being performed concurrently.
Examples: turn diameter on a lathe, while gauging from time to time; boil kettle of water, while setting out teapot and cups; develop photographic negative, while agitating the solution occasionally.
- A **foreign element** is an element observed which does not form a part of the operation(s) being studied.

Examples: in furniture manufacture, sanding the edge of a board before planing has been completed; degreasing a part that has still to be machined further.

It will be clear from the definitions given above that a repetitive element may also be a constant element, or a variable one. Similarly, a constant element may also be repetitive or occasional; an occasional element may be constant or variable, and so on, for the categories are not mutually exclusive.

7. Deciding on the elements

There are some general rules concerning the way in which a job should be broken down into elements. They include the following:

- Elements should be easily identifiable, with definite beginnings and endings so that, once established, they can be repeatedly recognized. These beginnings and endings can often be recognized by a sound (e.g. the stopping of a machine, unlocking a catch of a jig, putting down a tool) or by a change of direction of hand or arm. They are known as the "break points" and should be clearly described on the study sheet. A break point is thus the instant at which one element in a work cycle ends and another begins.
- Elements should be as short as can be conveniently timed by a trained observer. Opinion differs on the smallest practical unit that can be timed with a stop-watch, but it is generally considered to be about 0.04 min. (2.4 sec.). For less highly trained observers it may be 0.07 to 0.10 min. Very short elements should, if possible, be next to longer elements for accurate timing and recording. Long manual elements should be rated about every 0.33 min. (20 sec.). (Rating is described and discussed in the next chapter.)
- As far as possible, elements — particularly manual ones — should be chosen so that they represent naturally unified and recognizably distinct segments of the operation. For example, consider the action of reaching for a wrench, moving it to the work and positioning it to tighten a nut. It is possible to identify the actions of reaching, grasping, moving to the workpiece, shifting the wrench in the hand to the position giving the best grip for turning it, and positioning. The worker will probably perform all these as one natural set of motions rather than as a series of independent acts. It is better to treat the group as a whole, defining the element as "get wrench" or "get and position wrench" and to time the whole set of motions which make up the group, than to select a break point at, say, the instant the fingers first touch the wrench, which would result in the natural group of motions being divided between two elements.
- Manual elements should be separated from machine elements. This may sometimes be difficult for short cycles. However, although manual and machine time may run concurrently it may be necessary to measure them separately to derive standard data. Machine time with automatic feeds or

fixed speeds can be calculated and used as a check on the stop-watch data. Hand time is normally completely within the control of the operative.

- Constant elements should be separated from variable elements.
- Elements which do not occur in every cycle (i.e. occasional and foreign elements) should be timed separately from those that do.

The necessity for a fine breakdown of elements depends largely on the type of manufacturing, the nature of the operation and the results desired. Assembly operations in the light electrical and radio industries, for example, generally have short cycle operations with very short elements.

The importance of the proper selection, definition and description of elements must again be emphasized. The amount of detail in the description will depend on a number of factors, for instance:

- Small batch jobs which occur infrequently require less detailed element descriptions than long-running, high-output lines.
- Movement from place to place generally requires less description than hand and arm movements.

Elements should be checked through a number of cycles and written down before timing begins.

Examples of element descriptions and of various types of element are shown in figures 120 and 122.

8. Sample size

Much of what was said in Chapter 19 on sampling, confidence levels and the application of random tables applies here also. In this case, however, we are not concerned with a proportion but with finding out the value of the representative average for each element. Our problem, therefore, is to determine the sample size or number of readings that must be made for each element, given a predetermined confidence level and accuracy margin.

Here again, we can apply a statistical method or a conventional method.

For the statistical method, we have first to take a number of preliminary readings (n'). We then apply the following equation⁴ for the 95.45 confidence level and a margin of error of ± 5 per cent:

$$n = \left(\frac{40 \sqrt{n' \sum x^2 - (\sum x)^2}}{\sum x} \right)^2$$

where

- n = sample size we wish to determine
- n' = number of readings taken in the preliminary study
- Σ = sum of values
- x = value of the readings.

⁴ The explanation of the derivation of this formula falls outside the scope of this book. See Raymond Mayer: *Production and operations management* (New York and London, McGraw-Hill, 3rd ed., 1975), pp. 516-517.

An example will make the point clear. Let us suppose that we take five readings for a given element, and find that the value of the elapsed time in 1/100ths of a minute is 7, 6, 7, 7, 6. We can then calculate the squares and the sum of the squares of these numbers:

x	x^2
7	49
6	36
7	49
7	49
6	36
$\Sigma x = 33$	$\Sigma x^2 = 219$

$n' = 5$ readings.

By substituting these values in the above formula, we obtain the value of n :

$$n = \left(\frac{40 \sqrt{5 (219) - (33)^2}}{33} \right)^2 = 8.81 \text{ or } 9 \text{ readings.}$$

Since the number of preliminary readings n' that we took is less than the required sample size of nine, the sample size must be increased. However, we cannot simply say that four more observations are needed. When we add the values obtained from these four additional observations, the values of x and x^2 will change, and this may affect the value of n . Consequently it may be found either that a still larger sample is required, or that the sample taken was in fact adequate or more than adequate.

If we choose a different confidence level and accuracy margin, the formula changes as well. Normally, however, we choose either the 95 or the 95.45 confidence level.

The statistical method of determining the sample size is valid to the extent that the assumptions made in deriving the formula are valid — in other words, that the observed variations in the readings are due to mere chance and are not made intentionally by the operative. The statistical method can be cumbersome, since a given work cycle is composed of several elements. As the sample size will vary with the readings for each element, we can arrive at different sample sizes for each element within a given cycle, unless of course the elements have more or less the same average. As a result, we may have to calculate the sample size, in the case of cumulative timing, by basing it on the element that will call for the largest sample size.

Some authors, and companies such as General Electric, have therefore adopted a conventional guide for the number of cycles to be timed, based on the total number of minutes per cycle (table 15).

It is also important that the readings be continued over a number of cycles in order to ensure that occasional elements (such as handling boxes of finished parts, periodical cleaning of machines or sharpening of tools) can be observed several times.

In conducting the study the table of random numbers (see Chapter 19) may be used to determine the times at which the readings are to be taken.

Table 15. Number of recommended cycles for time study

Minutes per cycle	To 0.10	To 0.25	To 0.50	To 0.75	To 1.0	To 2.0	To 5.0	To 10.0	To 20.0	To 40.0	Over 40
Number of cycles recommended	200	100	60	40	30	20	15	10	8	5	3

Source: A. E. Shaw: "Stop-watch time study", in H. B. Maynard (ed.): *Industrial engineering handbook* (New York and London, McGraw-Hill, 3rd ed., 1971). Reproduced by kind permission of the McGraw-Hill Book Company.

9. Timing each element: Stop-watch procedure

When the elements have been selected and written down, timing can start.

There are two principal methods of timing with the stop-watch:

- Cumulative timing;
- Flyback timing.

In **cumulative timing** the watch runs continuously throughout the study. It is started at the beginning of the first element of the first cycle to be timed and is not stopped until the whole study is completed. At the end of each element the watch reading is recorded. The individual element times are obtained by successive subtractions after the study is completed. The purpose of this procedure is to ensure that all the time during which the job is observed is recorded in the study.

In **flyback timing** the hands of the stopwatch are returned to zero at the end of each element and are allowed to start immediately, the time for each element being obtained directly. The mechanism of the watch is never stopped and the hand immediately starts to record the time of the next element.

In all time studies it is usual to take an independent check of the overall time of the study, using either a wrist-watch or the clock in the study office. This also serves the purpose of noting the time of day at which the study was taken, which may be important if a retiming is asked for. For example, the cycle time of operatives on a repetitive job may be shorter in the first hour or two of the morning, when they are fresh, than late in the afternoon, when they are tired.

In the case of flyback timing, the study person walks to the clock; at an exact minute, preferably at the next major division such as the hour or one of the five-minute points, the stop-watch is set running, and the exact time is noted in the "time on" space on the form. The study person returns to the workplace where the time study is going to be carried out with the watch running, and allows it to do so continuously until ready to start timing. At the beginning of the first element of the first work cycle, the hand is snapped back and, as the first entry on the body of the study sheet, the time that has elapsed is noted. At the end of the study, the hand is snapped back to zero on completion of the last element of the last cycle and thereafter allowed to run continuously until the clock can again be reached and the time of finishing noted, when the watch is finally stopped. The final clock time is entered in the "time off" space on the form. The two times recorded before and after the study

are known as "check times". The clock reading at the beginning of the study is subtracted from the clock reading at the end of the study to give the "elapsed time", which is entered on the form.

The sum of the times of all the elements and other activities noted in the study plus ineffective time plus the check times is known as the "recorded time" and is also noted. It should in theory agree with the elapsed time, but in practice there is usually a small difference owing to the cumulative loss of very small fractions of time at the return of the hand to zero and, possibly, bad reading or missed elements. In certain firms it is the practice to discard any study in which the elapsed time differs from the recorded time by more than ± 2 per cent.

When the same practice is followed using cumulative timing, the elapsed time and recorded time should be identical since the stop-watch is only read and not snapped back.

Cumulative timing has the advantage that, even if an element is missed or some occasional activity not recorded, this will have no effect on the overall time. It is strongly favoured by many trade unions, especially in the United States, since it is regarded by them as more accurate than flyback timing and gives no opportunity for altering times in favour of the management by omitting elements or other activities. Its disadvantage is, of course, the amount of subtraction which has to be done to arrive at individual element times, which greatly increases the time taken in working up the study afterwards.

Flyback timing is still widely used. In competent hands it is almost as accurate as cumulative timing. There is reason to suppose that people being trained in the use of the stop-watch attain a fair degree of accuracy more quickly when using the cumulative method than when using the flyback method.

The experience of ILO missions in training in and applying time study has in fact shown that, generally speaking, cumulative timing should be taught and used, for the following reasons:

- (1) Experience suggests that trainees achieve reasonable accuracy in the use of the stop-watch more quickly if they use the cumulative method.
- (2) It does not matter if element times are occasionally missed by inexperienced observers; the overall time of the study will not be affected. Foreign elements and interruptions are automatically included since the watch is never stopped.
- (3) In assessing the working pace of the operative ("rating"), it is less easy to fall into the temptation to adjust the rating to the time taken by the element than with the flyback method, since only watch readings and not actual times are recorded.
- (4) Workers and their representatives are likely to have greater faith in the fairness of time studies as a basis for incentive plans if they can see that no time could have been omitted. The introduction of time study into an enterprise or an industry may be made easier.

In the flyback method, errors in reading the watch may be added to the slight delay which occurs when the hand is snapped back to zero. The

percentage error becomes greater for short elements. Cumulative timing is therefore likely to be more accurate for short-element short-cycle work, while flyback timing can be more safely used in jobs with long elements and cycles, since the error becomes too small to matter. The question of the confidence of the workers is important as well.

Electronic stop-watches have the benefit of allowing times for individual elements to be recorded on a flyback basis, without any error introduced by the mechanical flyback mechanism of a conventional watch. It thus offers the same levels of accuracy as cumulative timing without the inconvenience of performing the subtractions. It is, however, still possible to misread the watch and a check on the sum of all recorded times against the total elapsed time should still be carried out.

With electronic study boards and data capture devices, the study person does not make readings of element times — these are automatically recorded as the study person identifies the element break points. No errors are therefore introduced by the recording process.

There is a third method of timing which is employed for short-element short-cycle work, and which may indeed be the only way of getting accurate times with a stop-watch, for elements which are so very short that there is not enough time for the study person to read the watch and make a recording on his or her study sheet. In this situation the method used is that known as differential timing. With differential timing, elements are timed in groups, first including and then excluding each small element, the time for each element being obtained subsequently by subtraction. For example, if the job consists of seven short elements, the study person may time numbers 1 to 3, and 4 to 7 for the first few cycles, recording only these two readings per cycle. The timing is then recorded for 1 to 4 and 5 to 7 for a few cycles, and so on. If differential timing is applied in this fashion, either the cumulative or the flyback method of watch manipulation may be used.

We have now discussed all the preliminaries to making a time study, from the selection of the job, through the recording of all relevant data, the breakdown of the job into elements and the examination of the methods employed, to the recording of the actual element times. In the next chapter we shall discuss the means of modifying these observed times to take into account variations in rates of working.

Time study: Rating

In section 3 of the previous chapter the making of a time study was broken down into eight steps or stages, the first four of which were discussed in that chapter. We now come to the fifth step, namely “assessing the effective speed of working of the operative relative to the observer’s concept of the rate corresponding to standard rating”.

The treatment of rating which follows has been selected because experience in the use of this book for training purposes by ILO management and productivity missions suggests that this approach to the subject is best suited to the conditions in most of the countries for which the book is primarily intended.

Rating and “allowances” (dealt with in the next chapter) are the two most controversial aspects of time study. Most time studies in industry are used to determine standard times for setting workloads and as a basis for incentive plans. The procedures employed have a bearing on the earnings of the workers as well as on the productivity and, possibly, the profits of the enterprise. Time study is not an exact science, although much research has been and continues to be undertaken to attempt to establish a scientific basis for it. Rating (the assessment of a worker’s rate of working) and the allowances to be given for recovery from fatigue and other purposes are still, however, largely matters of judgement and therefore of bargaining between management and labour.

Various methods of assessing the rate of working, each of which has its good and bad points, have been developed. The procedures set out in this chapter represent sound current practice and, properly applied, should be acceptable to management and workers alike, particularly when used to determine standards for medium-batch production, which is the most common type in industry all over the world outside the United States and a few large or specialized enterprises elsewhere. They will certainly provide the reader with a sound basic system which will be suitable for most general applications, and one which can later be refined if the particular nature of certain special operations requires a modification of the system, so as to rate something other than effective speed.

1. The qualified worker

It has already been said that time studies should be made, as far as possible, on a number of qualified workers; and that very fast or very slow workers should

be avoided, at least while making the first few studies of an operation. What is a “qualified worker”?

Different jobs require different human abilities. For example, some demand mental alertness, concentration, visual acuity; others, physical strength; most, some acquired skill or special knowledge. Not all workers will have the abilities required to perform a particular job, though if the management makes use of sound selection procedures and job training programmes, it should normally be possible to arrange that most of the workers engaged on it have the attributes needed to fit them for the task. The definition of a qualified worker given in the previous chapter is repeated here:

A qualified worker is one who has acquired the skill, knowledge and other attributes to carry out the work in hand to satisfactory standards of quantity, quality and safety

The acquisition of skill is a complicated process. It has been observed¹ that among the attributes which differentiate the experienced worker from the inexperienced are the following. The experienced worker:

- achieves smooth and consistent movements;
- acquires rhythm;
- responds more rapidly to signals;
- anticipates difficulties and is more ready to overcome them;
- carries out the task without giving the appearance of conscious attention, and is therefore more relaxed.

It may take a good deal of time for a worker to become fully skilled in the performance of a job. In one study it was noted that it was only after some 8,000 cycles of practice that the times taken by workers began to approach a constant figure — which was itself half the time they took when they first tried the operation. Thus time standards set on the basis of the rate of working of inexperienced workers could turn out to be quite badly wrong, if the job is one with a long learning period. Some jobs, of course, can be learned very quickly.

It would be ideal if the time study person could be sure that, whatever job is selected for study, only properly qualified workers would be found performing it. In practice, this is too much to hope for. It may indeed be that none of the workers engaged on the task can really be said to be completely qualified to carry it out, though it may be possible to alter this in time, by training; or that, though some of the workers are qualified, these are so few in number that they cannot be considered to be average or representative of the group. A representative worker is defined as one whose skill and performance is the average of a group under consideration and who is not necessarily a qualified worker.

¹ W. D. Seymour: *Industrial training for manual operations* (London, Pitman, 1966).

If the working group is made up wholly or mainly of qualified workers, there will be one — or perhaps several — of these qualified workers who can be considered as representative workers also. Standard time is the time a job or operation should normally take the average qualified worker, working in an ordinary fashion, provided there is sufficient motivation to want to get on with the job. In theory, therefore, the time study person should be looking for the average qualified worker to study. In practice, this is not as easy as it might seem. It is worth looking more closely into what “average” might mean in this context.

2. The “average” worker

The truly average worker is no more than an idea. A completely average worker does not exist, any more than an “average family” or an “average woman” exists. They are the inventions of statisticians. We are all individuals: no two of us are exactly alike. Nevertheless, among a large number of people from, for instance, the same country or area, variations in measurable characteristics such as height and weight tend to form a pattern which, when represented graphically, is called the “normal distribution curve”. To take one characteristic, height: in many western European countries the average height for a man is about 5 ft. 8 in. (172 cm). In a western European crowd, a large number of the men in it will be between 5 ft. 7 in. and 5 ft. 9 in. tall (170-175 cm). The number of men of heights greater or smaller than this will become fewer and fewer as those heights approach the extremes of tallness and shortness.

The case as regards the performance of operatives is exactly the same. This can be shown very conveniently in a diagram (figure 106). If 500 qualified workers in a given factory were to do the same operation by the same methods and under the same conditions, the whole operation being within the control of the workers themselves, the times taken to perform the operation would be distributed in the manner shown in the figure. To simplify the figure, the times have been divided into groups at intervals of four seconds. It will be seen that the workers fall into the groups shown in table 16.

If the time groups are examined, it will be seen that 32.4 per cent of the times are less than 46 seconds and 34.8 per cent of the times are greater than 50 seconds. The largest single group of times (32.8 per cent) lies between 46 and 50 seconds. We should therefore be justified in saying that for this group of 500 workers the average time taken to perform this operation was between 46 and 50 seconds (say, 48 seconds). We could call 48 seconds the time taken by the average qualified worker to do this job under these conditions. The time might not hold good for any other factory. Factories which are well run, where working conditions and pay are good, tend to attract and keep the best workers, so that in a better-run factory the average worker’s time might be less (say, 44 seconds), while in a poorly run factory with less able workers it might be more (say, 52 seconds).

Figure 106. Distribution of times taken by workers to perform a given job

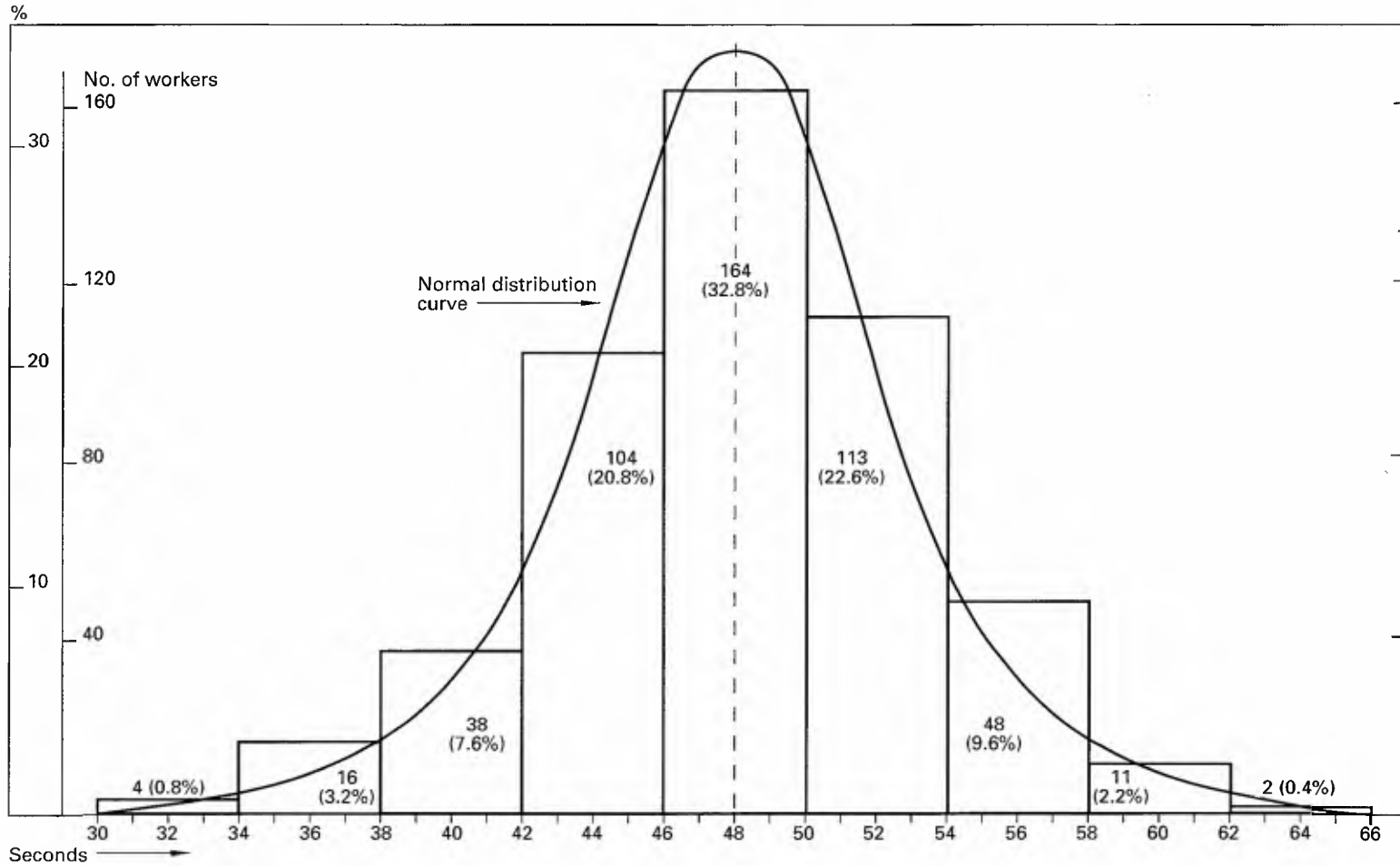


Table 16. Specimen performance distribution

Time group (sec.)	Number of workers (out of 500)	Percentage of total workers		
30-34	4	0.8	}	32.4
34-38	16	3.2		
38-42	38	7.6		
42-46	104	20.8		
46-50	164	32.8		32.8
50-54	113	22.6	}	34.8
54-58	48	9.6		
58-62	11	2.2		
62-66	2	0.4		
	500	100.0		100.0

If a curve is drawn to fit this distribution it will be found to assume the shape of the curve in the figure. This is known as the "normal distribution curve". In general, the larger the sample the more the curve will tend to be symmetrical about the peak value, but this can be altered if special conditions are introduced. For example, if the slower workers were to be transferred to other work, the right-hand side of the curve of performances of the group would probably become foreshortened, for there would be fewer workers returning the very long times.

3. Standard rating and standard performance

In Chapter 18 it was said that the principal use of work measurement (and hence of time study) is to set time standards which can be used for a number of different purposes (including programme planning, estimating and as a basis for incentives) for the various jobs carried out in the enterprise. Obviously, if those time standards are to be of any value at all, their achievement must be within the capacity of the majority of workers in the enterprise. It would be no use setting standards so high that only the best could attain them, since programmes or estimates based on them would never be fulfilled. Equally, to set standards well within the achievement of the slowest workers would not be conducive to efficiency.

How does the work study person obtain such a fair time from time studies?

We have already said that, as far as possible, studies should be taken on qualified workers. If it were possible to obtain the times taken by 500 qualified operatives for a single operation and plot them in the manner shown in figure 106, a reliable average time would be obtained. Unfortunately, this is hardly ever possible. It is not always possible to time a job on an average qualified worker; moreover, even if it were, people do not work consistently from day to

day or even from minute to minute. The work study person has to have some means of assessing the rate of working of the operative he or she is observing and of relating it to standard pace. This process is known as **rating**.

Rating is the assessment of the worker's rate of working relative to the observer's concept of the rate corresponding to standard pace

By definition, rating is a comparison of the rate of working observed by the work study person with a picture of some standard level in mind. This standard level is the average rate at which qualified workers will naturally work at a job, when using the correct method and when motivated to apply themselves to their work. This rate of working corresponds to what is termed the **standard rating**, and is denoted by 100 on the rating scale recommended to readers of this book (see section 7, below). If the standard pace is maintained and the appropriate relaxation is taken, a worker will achieve **standard performance** over the working day or shift.

Standard performance is the rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift, provided that they know and adhere to the specified method and provided that they are motivated to apply themselves to their work

This performance is denoted as 100 on the standard rating and performance scales

The rate of working most generally accepted in the United Kingdom and the United States as corresponding to the standard rating is equivalent to the speed of motion of the limbs of a man of average physique walking without a load in a straight line on level ground at a speed of 4 miles an hour (6.4 kilometres per hour). This is a brisk, business-like rate of walking, which a man of the right physique and well accustomed to walking might be expected to maintain, provided that he took appropriate rest pauses every so often. This pace has been selected, as a result of long experience, as providing a suitable benchmark to correspond to a rate of working which would enable the average qualified worker who is prepared to apply himself to his task to earn a fair bonus by working at that rate, without there being any risk of imposing on him any undue strain that would affect his health, even over a long period of time. (As a matter of interest, a man walking at 4 miles an hour (6.4 km/hr.) appears to be moving with some purpose or destination in mind: he is not sauntering, but on the other hand he is not hurrying. People hurrying, to catch a train for instance, often walk at a considerably faster pace before breaking out into a trot or a run, but it is a pace which they would not wish to keep up for very long.)

It should be noted, however, that the "standard pace" applies to Europeans and North Americans working in temperate conditions; it may not be a proper pace to consider standard in other parts of the world. In general, however, given workers of proper physique, adequately nourished, fully trained and suitably motivated, there seems little evidence to suggest that different standards for rates of working are needed in different localities, though the periods of time over which workers may be expected to average the standard pace will vary very widely with the environmental conditions. At the very least, the standard rate as described above provides a theoretical datum line with which comparisons of performance in different parts of the world could be made in order to determine whether any adjustment may be necessary. Another accepted example of working at the standard rate is dealing a pack of 52 playing cards in 0.375 minutes.

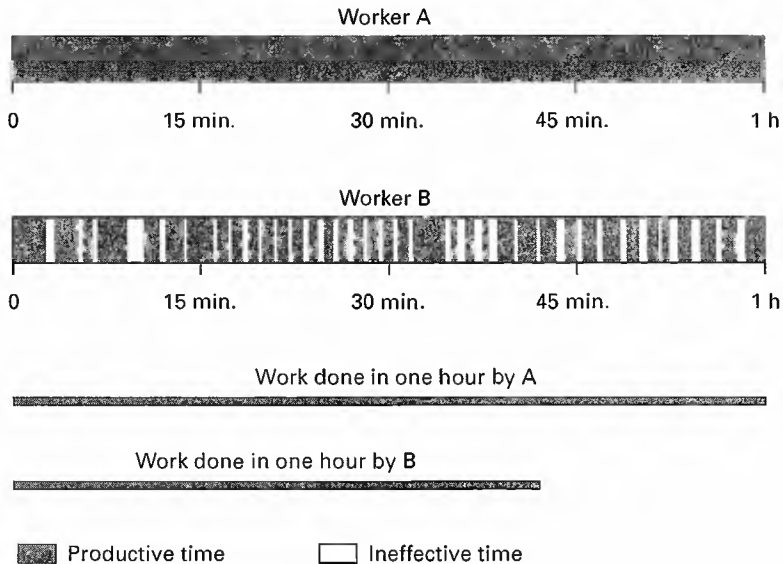
Standard performance on the part of average qualified workers (that is, those with sufficient intelligence and physique, adequately trained and experienced in the job they are doing) will probably show as such only over a period of several hours. Those doing manual work will generally carry out the motions directly concerned with their work at their own natural working rate, which may not be exactly the standard rate, since some people work faster than others. There will of course be different standard paces (or speeds of movement) for different activities, according to the complexity or arduousness of the element making up the activity (among other things), so that working at the standard rate will not always mean moving the hands or limbs at the same speed. And in any event, it is not uncommon for workers to work faster at some periods of the day than at others, so that the standard performance is rarely achieved as the result of working, without any deviation, at the standard rate throughout the working periods of the shift, but rather as the cumulative outcome of periods of work at varying paces.

When time standards are used as a basis for payment by results, many union-management agreements stipulate that the time standards should be such that a representative or average qualified worker on incentive pay can earn 20-35 per cent above the time rate by achieving the standard performance. If these workers have no target to aim at and no incentive to make them desire a higher output, they will (apart from any time consciously wasted) tolerate the intrusion of small amounts of ineffective time, often seconds or fractions of seconds between and within elements of work. In this way they may easily reduce their performance over an hour or so to a level well below that of the standard performance. If, however, they are given enough incentive to make them want to increase their output, they will get rid of these small periods of ineffective time, and the gaps between their productive movements will narrow. This may also alter the pattern of their movements.² The effect of the elimination of these small periods of ineffective time under the influence of an incentive can be illustrated diagrammatically (figure 107).

What happens may be seen in the case of operatives working a lathe who have to gauge their workpiece from time to time. The gauge is laid on the tool

² Research carried out under the late Professor T. U. Matthew at the University of Birmingham (United Kingdom) tended to confirm this.

Figure 107. Effect of ineffective time on performance



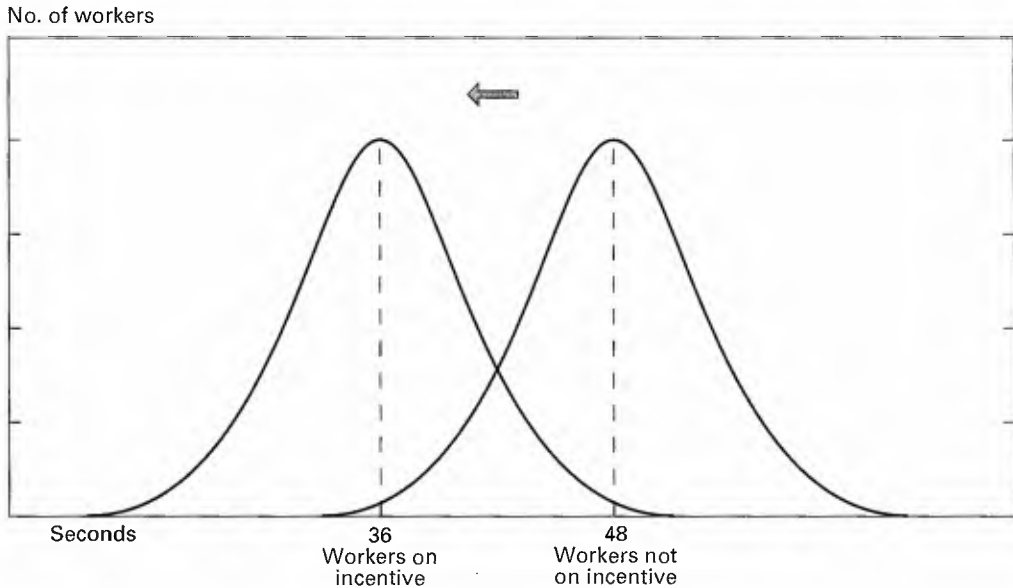
locker beside them. If they have no particular reason to hurry, they may turn the whole body round every time they wish to pick up the gauge, turn back to the lathe, gauge the workpiece and turn again to put the gauge down, each of these movements being carried out at their natural pace. As soon as they have reason to speed up their rate of working, instead of turning the whole body they will merely stretch out an arm, perhaps glancing round to check the position of the gauge on the locker, pick up the gauge, gauge the workpiece and replace the gauge on the locker with a movement of the arm, without bothering to look. In neither case would there be a deliberate stopping of work, but in the second, some movements — effective from the point of view of furthering the operation — would have been eliminated.

The effect of putting a whole working area or a plant (such as the 500 workers in figure 106) on an incentive is shown in figure 108.

Offering an incentive in the form of payment in proportion to output will not make the unskilled or slow worker as fast or as skilled as the skilled or naturally fast worker; but if everyone in the working area is put on a well-designed incentive plan, other conditions remaining the same, the result will be that everyone will tend to work more consistently. The short periods of ineffective time discussed above will disappear, and everyone's average time for the job will be reduced. (This is an over-simplification but true enough for purposes of illustration.) The normal distribution curve shown in figure 106 will move to the left while retaining approximately the same shape. This is quite clearly shown in figure 108, where the peak of the curve (the average time) now comes at 36 seconds instead of 48 — a reduction of 25 per cent.

It should be added that, although the standard rate of working is that at which average qualified workers will naturally perform their movements when motivated to apply themselves to the task, it is of course quite possible and indeed normal for them to exceed this rate of working if they wish to do so.

Figure 108. Effect of a payment-by-results incentive on the time taken to perform an operation



Operators will be observed to be working, sometimes faster, sometimes slower than the standard rate, during short periods. Standard performance is achieved by working over the shift at paces which average the standard rate.

4. Comparing the observed rate of working with the standard

How is it possible accurately to compare the observed rate of working with the theoretical standard? By long practice.

Let us return once more to our walker. Most people, if asked, would be able to judge the rate at which a person is walking. They would start by classifying rates of walking as slow, average or fast. With a little practice they would be able to say: "About 3 miles an hour, about 4 miles an hour, or about 5 miles an hour" (or of course the equivalent rates in kilometres if they are more used to kilometres). If, however, a reasonably intelligent person were to spend a great deal of time watching people walking at different speeds, the point would soon be reached where he or she could say: "That person is walking at $2\frac{1}{2}$ miles an hour and this one at $4\frac{3}{4}$ miles an hour", and this would be right, within close limits. In order to achieve such accuracy, however, some particular rate would need to be borne in mind with which to compare those observed.

That is exactly what the work study person does in rating; but, since the operations observed are far more complex than the simple one of walking without load, training takes very much longer. Judgement of walking pace is only used for training work study persons in the first stages; it bears very little resemblance to most of the jobs that have to be rated. It has been found better to use films or live demonstrations of industrial operations.

Confidence in the accuracy of one's rating can be acquired only through long experience and practice on many types of operation — and confidence is essential to a work study person. It may be necessary to back a particular judgement in arguments with management, supervisors or workers' representatives; unless this can be done with assurance, the confidence of all parties in the work study person's ability will quickly disappear. This is one of the reasons why trainees may attempt method study after a comparatively short training but should on no account try to set time standards — except under expert guidance — without long practice, especially if the standards are to be used for incentive payments.

5. What is rated?

The purpose of rating is to determine, from the time actually taken by the operative being observed, the standard time which can be maintained by the average qualified worker and which can be used as a realistic basis for planning, control and incentive schemes. What the study person is concerned with is therefore the speed with which the operative carries out the work, in relation to the study person's concept of a normal speed. In fact, speed of working as recorded by the time taken to carry out the elements of the operation is the only thing which can be measured with a stop-watch. Most authorities on time study agree on this point.

Speed of what? Certainly not merely speed of movement, because an unskilled operative may move extremely fast and yet take longer to perform an operation than a skilled operative who appears to be working quite slowly. The unskilled operative puts in a lot of unnecessary movements which the experienced operative has long since eliminated. The only thing that counts is the effective speed of the operation. Judgement of effective speed can only be acquired through experience and knowledge of the operations being observed. It is very easy for an inexperienced study person either to be fooled by a large number of rapid movements into believing that an operative is working at a high rate or to underestimate the rate of working of the skilled operative whose apparently slow movements are very economical of motion.

A constant source of discussion in time study is the rating of effort. Should effort be rated, and if so, how? The problem arises as soon as it becomes necessary to study jobs other than very light work where little muscular effort is required. Effort is very difficult to rate. The result of exerting effort is usually only seen in the speed.

The amount of effort which has to be exerted and the difficulty encountered by the operative is a matter for the study person to judge in the light of experience with the type of job. For example, if an operative has to lift a heavy mould from the filling table, carry it across the working area and put it on the ground near the ladle, only experience will tell the observer whether the speed at which it is being done is normal, above normal or subnormal. Those who had never studied operations involving the carrying of heavy weights would have great difficulty in making an assessment the first time they saw such an operation.

Operations involving **mental activities** (judgement of finish, for example, in inspection of work) are most difficult to assess. Experience of the type of work is required before satisfactory assessments can be made. Inexperienced study persons can be made to look very foolish in such cases, and moreover can be unjust to above-average and conscientious workers.

In any job the speed of accomplishment must be related to an idea of a normal speed for the same type of work. This is an important reason for doing a proper method study on a job before attempting to set a time standard. It enables the study person to gain a clear understanding of the nature of the work and often enables the elimination of excessive effort or judgement. The rating process is thus brought nearer to a simple assessment of speed.

In the next section some of the factors affecting the rate of working of the operative will be discussed.

6. Factors affecting the rate of working

Variations in actual times for a particular element may be due to factors outside or within the control of the worker. Those outside this control may be:

- variations in the quality or other characteristics of the material used, although they may be within the prescribed tolerance limits;
- changes in the operating efficiency of tools or equipment within their useful life;
- minor and unavoidable changes in methods or conditions of operation;
- variations in the mental attention necessary for the performance of certain of the elements;
- changes in climatic and other surrounding conditions such as light, temperature, etc.

These can generally be accounted for by taking a sufficient number of studies to ensure that a representative sample of times is obtained.

Factors within the operative's control may be:

- acceptable variations in the quality of the product;
- variations due to the individual's ability;
- variations due to the attitude of mind, especially the attitude to the organization for which he or she works.

The factors within the worker's control can affect the times of similarly described elements of work by affecting:

- the pattern of the worker's movements;
- the individual working pace;
- both, in varying proportions.

The study person must therefore have a clear idea of the pattern of movement which a qualified worker should follow, and of how this pattern may be varied to meet the range of conditions which that worker may encounter. Highly repetitive work likely to run for long periods should have been studied in detail through the use of refined method study techniques, and

the worker should have been suitably trained in the patterns of movement appropriate to each element.

The optimum pace at which the worker will work depends on:

- the physical effort demanded by the work;
- the care required on the part of the worker;
- training and experience.

Greater physical effort will tend to slow up the pace. The ease with which the effort is made will also influence the pace. For example, an effort made in conditions where operatives cannot exert their strength in the most convenient way will be made much more slowly than one of the same magnitude in which they can exert their strength in a straightforward manner (for instance, pushing a car with one hand through the window on the steering-wheel, as opposed to pushing it from behind). Care must be taken to distinguish between slowing up due to effort and slowing up due to fatigue.

When the element is one in which the workers are heavily loaded, so that they have to exert considerable physical effort throughout, it is unlikely that they will perform it at anything other than their natural best pace. In such circumstances rating may be superfluous: it may be sufficient to determine the average of the actual times taken during an adequate number of observations. This was very strikingly shown during an ILO study of manual earth-moving operations carried out in India. The workers — men, women and youths — carried loads of earth up to 38 kg (84 lb) in weight on their heads, in wicker baskets. People with 38 kg on their heads do not dawdle. They are anxious to get to the end of the walk and get rid of the load, and so perform the task at the best rate that they can naturally achieve. In doing so they shorten their stride, taking very short paces very quickly so that it looks almost as though they are going to break out into a trot at any moment. In point of fact, the stop-watch showed that the time taken for the loaded walk was a good deal longer than that needed for the apparently more leisurely return unloaded, so that the study person without experience of the effort involved in the operation could very easily be led into making false ratings. In fact, for the loaded walk, ratings were not necessary, except when contingencies occurred. Similar heavily loaded elements occur in factories, as in carrying sacks, picking them up, or throwing them down on to stacks. These operations are most likely to be carried out at the best natural pace which the worker can manage.

An increased need for care in carrying out an element will reduce the pace. An example is placing a peg with parallel sides in a hole, which requires more care than if the peg is tapered.

Fumbling and hesitation on the part of the worker are factors which the study person must learn to recognize and cope with. A worker's natural skill and dexterity combined with training and experience will reduce the introduction of minor method variations (fumbling), and also the foreign element "consider" (hesitation). Very slight deviations from the standard method can be taken into account by assigning a lower rating, but fumbling and hesitation usually signal a need for further training.

The study person should be careful not to rate too highly when:

- the worker is worried or looks hurried;
- the worker is obviously being over-careful;
- the job looks difficult to the study person;
- the study person is working very fast, as when recording a short-element study.

Conversely, there is a danger of rating too low when:

- the worker makes the job look easy;
- the worker is using smooth, rhythmic movements;
- the worker does not pause to think when the study person expects this;
- the worker is performing heavy manual work;
- the study person is tired.

The study person must take such factors into account. Rating is very much easier if a good method study has been made first, in which the activities calling for special skill or effort have been reduced to a minimum. The more the method has been simplified, the less the element of skill to be assessed and the more rating becomes a matter of simply judging pace.

7. Scales of rating

In order that a comparison between the observed rate of working and the standard rate may be made effectively, it is necessary to have a numerical scale against which to make the assessment. The rating can then be used as a factor by which the observed time can be multiplied to give the basic time, which is the time it would take the motivated, qualified worker to carry out the element at standard rating.

There are several scales of rating in use, the most common of which are those designated the 60-80, 75-100 and 100-133 scales, and the British Standard scale used in this book (essentially a restatement of the 75-100 scale), which is termed the 0-100 scale.

Table 17 shows examples of various rates of working on the scales mentioned.

In the 60-80, 75-100 and 100-133 scales, the lower figure in each instance was defined as the rate of working of an operative on time rates of pay; and the higher, in each case one-third higher, corresponded to the rate of working we have called the standard rate, that of qualified workers who are suitably motivated to apply themselves to their work, as for instance by an incentive scheme. The underlying assumption was that workers on incentive perform, on average, about one-third more effectively than those who are not. This assumption has been well substantiated by practical experience over many years, but it is largely irrelevant in the construction of a rating scale. All the scales are linear. There is therefore no need to denote an intermediate point between zero and the figure chosen to represent the standard rating as we have defined it. Whichever scale is used, the final time standards derived should be equivalent, for the work itself does not change even though different scales are used to assess the rate at which it is being carried out.

Table 17. Examples of various rates of working on the principal rating scales

Scales				Description	Comparable walking speed ¹	
60-80	75-100	100-133	0-100 Standard		(mi/h)	(km/h)
0	0	0	0	No activity		
40	50	67	50	Very slow; clumsy, fumbling movements; operative appears half asleep, with no interest in the job	2	3.2
60	75	100	75	Steady, deliberate, unhurried performance, as of a worker not on piece work but under proper supervision; looks slow, but time is not being intentionally wasted while under observation	3	4.8
80	100	133	100 (Standard rating)	Brisk, business-like performance, as of an average qualified worker on piece work; necessary standard of quality and accuracy achieved with confidence	4	6.4
100	125	167	125	Very fast; operative exhibits a high degree of assurance, dexterity and coordination of movement, well above that of an average trained worker	5	8.0
120	150	200	150	Exceptionally fast; requires intense effort and concentration, and is unlikely to be kept up for long periods; a "virtuoso" performance achieved only by a few outstanding workers	6	9.6

¹ Assuming an operative of average height and physique, unladen, walking in a straight line on a smooth level surface without obstructions. Source: Freely adapted from a table issued by the Engineering and Allied Employers (West of England) Association, Department of Work Study.

The newer 0-100 scale has, however, certain important advantages which have led to its adoption as the British Standard. It is commended to readers of this book and is used in all the examples which follow. In the 0-100 scale, 0 represents zero activity and 100 the normal rate of working of the motivated qualified worker — that is, the standard rate.

8. How the rating factor is used

Figure 100 represents standard performance. If the study person decides that the observed operation is being performed with less effective speed than a particular concept of standard, a factor of less than 100 will be used, say 90 or 75 or whatever is considered as representing a proper assessment. If, on the other hand, the study person decides that the effective rate of working is above standard, it will be given a factor greater than 100 — say, 110, 115 or 120.

It is usual practice to round off ratings to the nearest multiple of five on the scale; that is to say, if the rate is judged to be 13 per cent above standard, it would be put down at 115. During the first weeks of their training, study persons are unlikely to be able to rate more closely than the nearest ten.

If the study person's ratings were always impeccable, then however many times an element were rated and timed the results should be that:

$$\text{observed time} \times \text{rating} = \text{a constant}$$

provided that the element is of the type described as a constant element in section 6 of the previous chapter, and that it is always performed in the same way.

An example, expressed numerically, might read as follows:

<i>Cycle</i>	<i>Observed time (decimal minutes)</i>		<i>Rating</i>		<i>Constant</i>
1	0.20	×	100	=	0.20
2	0.16	×	125	=	0.20
3	0.25	×	80	=	0.20

and so on.

The reader may be puzzled that, in the figures above, 0.20×100 is shown as equal to 0.20 rather than 20. It must be remembered, however, that rating does not stand by itself: it is always a comparison with the standard rating (100) so that, when the amended time is being calculated, the assessed rating is the numerator of a fraction of which the denominator is the standard rating. In the case of the 100 standard this makes it a percentage which, when multiplied by the observed time, produces the constant known as the "basic time" for the element.

$$\text{observed time} \times \frac{\text{rating}}{\text{standard rating}} = \text{basic time}$$

For example:

$$0.16 \text{ min.} \times \frac{125}{100} = 0.20 \text{ min.}$$

This basic time (0.20 minutes in the example) represents the time the elements would take to perform (in the judgement of the observer) if the operative were working at the standard rate, instead of the faster one actually observed.

If the operative was judged to be working more slowly than the standard, a basic time less than the observed time would be arrived at, for example:

$$0.25 \text{ min.} \times \frac{80}{100} = 0.20 \text{ min.}$$

In actual practice, the multiple observed time \times rating is very rarely exactly constant when taken over a large number of readings, for various reasons such as:

- variations in the work content of the element;
- inaccuracies in noting and recording observed times;
- inaccuracies in rating;
- variations due to rating to the nearest five points.

9. Recording the rating

We have discussed the theory of rating at some length and are now in a position to undertake the complete study.

In general, each element of activity must be rated during its performance before the time is recorded, without regard to previous or succeeding elements. No consideration should be given to the aspect of fatigue, since the allowance for recovery from fatigue will be assessed separately (see Chapter 23).

In the case of very short elements and cycles this may be difficult. If the work is repetitive, every cycle or possibly the complete study may be rated. This is done when the short cycle study form (figure 101, Chapter 20) is used.

It is most important that the rating should be made while the element is in progress and that it should be noted before the time is taken, as otherwise there is a very great risk that previous times and ratings for the same element will influence the assessment. For this reason the "Rating" column on the time study sheet in figures 99 and 100 is placed to the left of the "Watch reading" column. It is, perhaps, a further advantage of the cumulative method of timing that the element time does not appear as a separate figure until the subtractions have been made later in the office. If it did, it might influence the rating or tempt the study person to "rate by the watch".

Since the rating of an element represents the assessment of the average rate of performance for that element, the longer the element the more difficult it is for the study person to adjust this judgement to that average. This is a strong argument in favour of making elements short, subject to the conditions discussed in Chapter 21. Long elements, though timed as a whole up to the break points, should be rated every half-minute.

Rating to the nearest five is found to give sufficient accuracy in the final result. Greater accuracy than this can be attained only after very long training and practice.

We may now refer back to the time study form in figures 99 and 100. We have discussed the filling-in of two columns, namely "Watch reading" (WR) and "Rating" (R), both entries being made on the same line.

These readings are continued for a sufficient number of cycles, at the end of which the watch is allowed to run on until compared with the clock with which it was synchronized when started. The "time after" can then be noted and recorded. The study is then at an end. The next step, after thanking the operative for his or her cooperation, is to work out the basic time for each element. How to do this is described in the next chapter.

Time study: From study to standard time

1. Summarizing the study

At the stage we have now reached, the study person has completed the observations at the workplace and has returned to the work study office with the study. No doubt later further studies will be made on the same job or operation as performed by different operatives, but for the moment we shall consider how the study which has just been taken is worked up and how the results obtained on the analysis of studies sheet for the operation are entered. Later in the chapter we shall see how standard times are compiled from the entries on the analysis of studies sheet.

All the entries made so far on the time study top sheet (figure 99) and the continuation sheets (figure 100) have been written in pencil. As well as the heading details shown in the data block on the top sheet, there will be the “time before”, the first entry on the study proper; the “time after”, which will be the last entry; and two entries for each watch reading made — the rating and the watch reading itself. The ratings will all be in the column headed “R” and will consist of numbers such as 95, 115, 80, 100, 75, 105, and so on, though until the study person has had considerable practice the ratings should be confined to steps of ten, such as 80, 90, 100, and so on. In the next column, that headed “WR”, will be the watch readings in decimal minutes. Since watch readings will have been made at intervals of half a minute or less (long elements being rated and timed every half-minute during the element as well as at the break point which signals its end), most of the entries will consist of two figures only, with a three-figure entry occurring whenever a full minute has been crossed. It is usual to omit the decimal points. This saves the study person a certain amount of writing and in practice gives rise to no ambiguity.

Let us assume that the “time before” was 2.15 minutes. The first entry on the study proper will thus be 215. The next may be 27, indicating that the watch was read 2.27 minutes after it was started. If the next three entries are 39, 51 and 307, these will signify that the watch was read at 2.39, 2.51 and 3.07 minutes after it was started. Two- and three-figure entries will continue in this way down the sheet until ten minutes have elapsed, when the next entry will be a four-figure one. Most study persons then revert to three-figure and two-figure entries again until another ten minutes have passed, using four figures only for the first entries after the ten-minute intervals. The study will close with the “time after” entry, at which time also the “time off” will be noted in the data panel on the study top sheet. Every now and then in the study there may be

watch readings without accompanying ratings, when some delay or stoppage has occurred. These of course cannot be rated, for they are not work.

It should be made a working rule that none of these pencil entries may ever be erased and replaced. Occasionally a study may contain a very obvious error, of a sort which may be corrected without invalidating the study. If so, the correction should be made in ink, over the original pencil entry, so that it may always be seen later as a change made in the study office, not at the place where the study was made. Whenever there is an error about which there is doubt as to how it should be corrected, that part of the study should be ignored. It may be necessary to scrap the study and make another.

It is good practice to carry out all subsequent work on the study sheets either in ink or in pencil of a different colour from that used for the initial recordings. Many study departments make this a standing rule also. There is then no doubt whatever about what was actually recorded from direct observation and what represents subsequent calculation. Quite apart from its merits in obtaining orderly processing of the data recorded, the practice helps also to maintain the confidence of workers and their representatives that nothing improper is permitted in the working up of studies.

2. Preparing the study summary sheet

As will be seen a little later, much of the work necessary before the study summary sheet can be completed consists of quite simple routine calculations which may be done by a clerk while the study person gets on with something else. In the beginning, however, the study person should do everything personally, until so thoroughly familiar with all the procedures involved that he or she can not only instruct the clerk on what has to be done but can also check the calculations easily and quickly.

The first step is to complete the data at the head of the study summary sheet (figure 104), copying the details neatly, in ink, from the study sheets. From the time off and the time on, the elapsed time may be calculated and entered. When cumulative timing is being practised, the elapsed time should of course agree with the final watch reading. If it does not, there is an error which must at once be investigated. It is no use doing further work on the study until this is cleared up, for a serious error may be cause for scrapping the study and starting again. Deducting from the elapsed time the total "check time" — the sum of the "time before" and the "time after" — yields the net time. This should agree with the sum of all the observed times when using flyback timing, or the sum of all the subtracted times with cumulative timing. If flyback timing has been used, this check should be made before proceeding further, by adding up all the element times recorded and seeing how the total compares with the net time. It is unlikely that there will be exact agreement, for the reasons noted earlier, but the discrepancy should be within 2 per cent. If it is greater than this, some departments make it their practice to ignore the study and make another.

When cumulative timing has been used, the check cannot be made until the subtracted times have been obtained and totalled. The comparison then serves as a check on the accuracy with which the subtractions have been made.

Any error should be investigated and corrected before the work of extension is undertaken.

On the body of the study summary sheet the study person next lists all the repetitive elements observed, in order of their occurrence, noting the break points used on the reverse of the sheet.

Some of these repetitive elements may be variable elements, which will have to be treated in a different way from the constant elements. These variable elements are therefore listed again in a fresh tabulation below the full list of repetitive elements. Below the variable elements the study person next lists any occasional elements observed, including with them any contingency elements of work which actually occurred during the study. Below these again are listed any foreign elements and ineffective time. When these entries have been made, the sheet should provide for a summarized record of everything that has been observed during the study.

Enter frequencies

The next step is to enter against each element listed on the study summary sheet the frequency with which that element occurred. Repetitive elements, by definition, occur at least once in every cycle of the operation so the entry to be made against a repetitive element will read 1/1, or 2/1, etc., indicating that the element concerned occurs once in every cycle (1/1), twice (2/1), or whatever may be the case. Occasional elements (for example, the element "sharpen tools") may occur only once every ten or 50 cycles, when the entry would be 1/10, 1/50 or as appropriate. The entries are made in the column headed "F" on the study summary sheet.

Frequencies are normally derived from observations undertaken during the study. However, for occasional elements which occur at long intervals, the study may not be long enough to include a representative sample of occurrences that offers a true picture of the frequency of occurrence. Although this can be considered unimportant, in terms of its effect on the overall standard time that will be developed — since the time for such an element will be a very small proportion of the overall time — it is important in gaining the confidence of the workers. If, when examining a study, they see a frequency which they know from experience to be incorrect, they will lose confidence in the study and may use that small point as the basis of a challenge of the entire study. For such elements, it is necessary to confirm the frequency with the supervisor or by analysis of historical records. For example, with an element such as "Replace tool", it should be possible to find the number of tools issued from the stores in a given time period and to relate this to the number of components produced in the same period. A frequency of occurrence of the element "Change tool" can then be determined.

3. Extension: The calculation of basic time

The study person has now completed the entries in the heading block of the study summary sheet, listed the elements, entered frequencies and (if

necessary) made a clear sketch of the workplace layout on the reverse of the sheet (when appropriate, the use of a simple instant-print-type camera can save a great deal of time and money; it is usually necessary to include in the photograph a simple scale, such as a square rod painted in 1 cm bands). The study person must turn next to the calculations which have to be made on the time study sheets themselves before proceeding any further with the study summary. The results of the calculations will be entered on the time study sheets in ink or pencil of a different colour from that used when recording observations at the workplace. If an electronic study board is used, the calculation will be indicated as shown in section 6 of this chapter.

When flyback timing has been used, the study person may proceed directly to extension. When using cumulative timing, however, it is first necessary to subtract each watch reading from the one following it, in order to obtain the observed time for each element. The entries obtained in this way should properly be styled "subtracted times" rather than "observed times"; they are entered in the third column on the time study sheets, that headed "ST". The subtracted times derived when using cumulative timing are of course exactly equivalent to the observed times entered directly at the workplace when using flyback timing, so for the sake of simplicity the single term "observed time" is used during the rest of this chapter to mean both directly observed and subtracted times.

The next step is to convert each observed time to a basic time, entering the result in the column headed "BT" on the time study sheets.

Basic time is the time for carrying out an element of work at standard rating, i.e.

$$\frac{\text{observed time} \times \text{observed rating}}{\text{standard rating}}$$

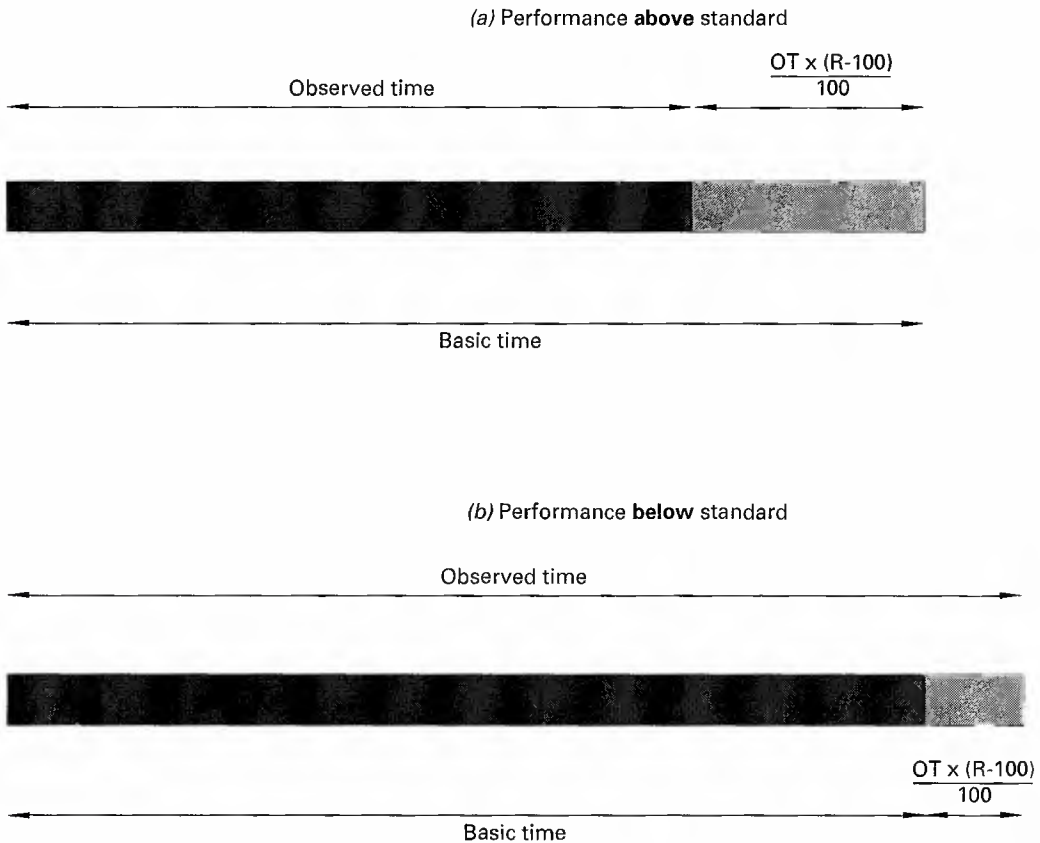
Extension is the calculation of basic time from observed time

The effect of extending an observed time for an element to the basic time is shown graphically in figure 109.

4. The selected time

The selected time is the time chosen as being representative of a group of times for an element or group of elements. These times may be either observed or basic and should be denoted as selected observed or selected basic times

Figure 109. Effect of extension on the time of an element



Constant elements

In theory the results of all the calculations of the basic time for any single constant element should be the same, but for the reasons given in Chapter 21 this is rarely so. It is necessary to select from all the basic times which have been entered on the time study sheets a representative time for each element. This will be recorded against the element description on the study summary sheet and will later be transferred to the analysis of studies sheet as the end result of the study, at least in so far as that particular element is concerned.

The calculations necessary to arrive at the selected basic time are carried out on the working sheet. As was noted in Chapter 20, it is quite common to use simple lined sheets for making the analysis (or, for variable elements, squared paper), without having any special forms printed. The working sheets, when completed, are stapled to the time study sheets and filed with them. Much time can be saved and accuracy can be greatly improved by using a small calculator or computing equipment, such as a personal computer.

There are various methods of examining and selecting the representative basic time for a constant element. Perhaps the most common, and in many

ways often the most satisfactory, is by making a straight average of the element times arrived at, adding all the calculated basic times together and dividing the total by the number of occasions on which the element was recorded. Before doing this, however, it is usual to list all the basic times for the element and scrutinize the list, ringing out any times which are excessively high or low, well outside the normal range. These ringed times are sometimes styled "rogues"; they should be examined carefully.

An exceptionally high time may be due to an error in timing. If cumulative timing is being used, an error of this sort will be revealed by examining the study, because an excessively long time for one element will cause shortening of the recorded time for the next. A high time may also be due to an error having been made in extension. But perhaps the most common cause, apart from errors, is that there has been some variation in the material being worked on or in some other aspect of the working method, which has caused a higher work content on the particular occasion recorded. If so, it is necessary to establish the cause and to consider whether it is likely to recur frequently or only very rarely. If the latter, it is usual to exclude the element basic time from the total from which the average is derived and then, having calculated the average time for the element, to carry the excess-over-average time contained in any ringed times down to contingencies, adding it to any other contingency time which may have been observed and recorded during the study. In this way the extra time is fully accounted for, but it is treated as an exceptional event or contingency, which it properly is. On the other hand, if minor variations in the work content of an element are at all common, it will be much better not to exclude any calculations at all when calculating the average. Frequent minor variations should always be treated as signals to alert the study person. If they are unavoidable they at least indicate that time study will have to be continued until a large number of observations have been taken on the element concerned, so that the resulting average of all the basic times may be sufficiently representative. Very often, however, they indicate that a further study should be made of the operation to find out the reason for the variations, and, if possible, to eliminate it.

Exceptionally short times should also be examined with great care. They too may be due to the study person's error. On the other hand, they may indicate that a minor method improvement was adopted on the occasion during which the much shorter time than usual was noted. If so, it will be well to study the job again, giving special and more detailed attention to the working methods used.

The approach outlined above is valid so long as the exceptional times are either very infrequent or, if frequent, only minor in character. Frequent large variations indicate that the element is not constant but variable, and it must be treated as such.

During a time study made on the operation of inspecting and jacketing a book, one element was described as: "Pick up one book, inspect, initial back end paper (break point: book closed)". This element was observed 31 times, and the basic minutes calculated were as shown below:

In the tabulation above, all the 30 observed times from which the basic times shown in the earlier example were calculated are listed, the one ringed observation having been excluded. The observed times are then totalled under each rating, and these totals are then extended by multiplying by the corresponding ratings, to yield the basic times (totals) shown in the line below. The grand total of all these basic times comes to 7.92 minutes, which, when divided by 30 (the number of observations) given the selected basic time for the element — 0.264 minutes. This may be compared with the result of 0.266 minutes achieved by averaging the individual basic times.

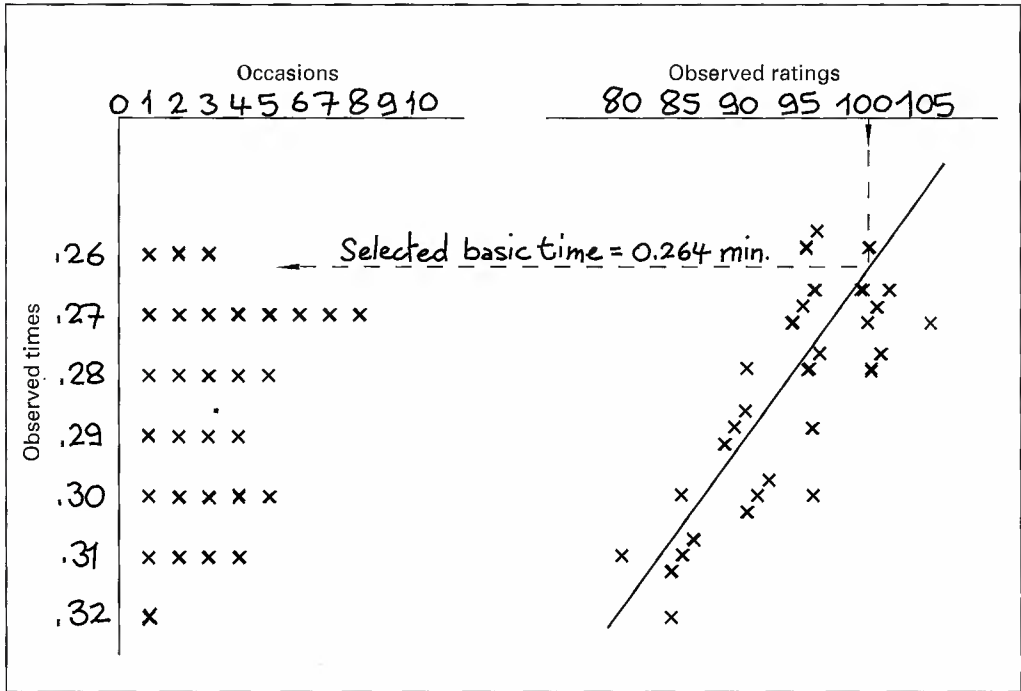
A third method also avoids the need to extend each observed time, the selection being made by constructing a plot as shown in figure 110. In this method there are two sections to the plot, and two entries are made for each observation, but the entries are crosses or dots. The left-hand axis contains the time scale and shows the range of times observed for the element, in this case from 26 to 32. The scale at the top of the right-hand part of the plot shows the ratings observed, from 80 to 105. To make the plot, the study person runs down the study, and each time the element is recorded a cross is made against the time observed, followed by a second cross, also against the observed time but under the rating observed, on the right-hand side of the plot.

When all these entries are made, the left-hand side of the diagram will exhibit a frequency distribution of observed times. On the right-hand side, the best straight line is through the points plotted. The selected basic time for the element can then be read off by entering the right-hand plot under 100 rating, going vertically down until the line through the points is reached, and then reading on the scale at the left the time which corresponds to the intersection.

It is essential that the plot on the left-hand side be completed, in order to check whether the distribution follows the normal pattern. If it does not, the method should not be used. Distributions which are irregular — lopsided, skewed, or having two humps — should be treated as signals that the method will not be reliable, at any rate in the simple form here described. The different distribution patterns which can be produced each have significant meanings, indicating different variations in the work itself, in the operative's rate of working, or in the study person's rating efficiency; but it will be better not to get involved in sophisticated analyses of this sort until considerable experience has been gained. The method is illustrated briefly here because it is typical of several which make use of graphical means to select representative basic times without extending each observation. Most of them are valid only when the distribution is normal or when the precise significance of any abnormality is thoroughly understood. It is recommended that the graphical methods be avoided unless expert guidance is available. The first two methods described will suffice for all normal needs, and have the merit that they are more easily understood by workers or their representatives.

Before leaving the subject of constant elements, the reader may like to refer again to the comments made in Chapter 22 about certain manual elements when the worker is heavily loaded, so that in all probability he or she normally performs the element at the best natural pace. Such elements are comparatively rare, but when they occur it may be sufficient to calculate the selected basic

Figure 110. A graphical method of selecting basic time



time by simply averaging observed times, without recourse to extension. It is essential, however, to have a large number of observations if this is to be done.

Variable elements

The analysis of variable elements presents more difficulty. It is necessary to find out what it is that causes the basic time to vary, and quite often there may be several variables to take into account at once. For example, consider the operation of cross-cutting wooden planks with a handsaw. The basic time needed to make the cut will vary with the width of the plank, which establishes the length of cut that has to be made, and also with the thickness of the planks and the hardness of the wood being cut. If the saw needs sharpening, the cut will take longer; however, this would be considered to be the use of an incorrect method, and any observations made while the operative is using a blunt saw would therefore be disregarded.

The first step in the treatment of variable elements is almost always to extend observed times to basic times. The basic times will then be plotted on squared paper against the known variables. Thus for variable elements the analysis of studies sheet takes the form of graph paper, and the graph constructed at the time of summarizing the study will probably be attached to the analysis of studies sheet, in place of the entries made on this sheet for constant elements.

Whenever possible, the basis chosen for the plot should be some variable which yields a straight line when the basic times are entered. Sometimes this

can be done by using logarithmic paper, when analysis of the operation suggests that the variability with time may not be arithmetically linear. Quite often, however, it is not possible to discover a straight-line relationship between time and the main variable, or with any combination of variables which is tried. In these cases the end product will be a curved line, drawn as smoothly as possible between all the plots made from all the studies on the element. Basic times for the element will then be selected by reading off the curve at the appropriate point on each occasion on which a standard time has to be compiled.

The treatment which the study person would accord to the times derived from studying the cross-cutting of planks would depend on whether the operation is an incidental one, performed only rarely, or whether it is an element performed many times each day, forming a substantial proportion of the total work done. In the latter case a series of graphs will probably need to be built up, each for a different hardness of wood, with each graph having a family of lines on it, one for each thickness of plank. Basic times would be plotted on these graphs against length of cut. The relationship should be linear, so that once it has been discovered the lines can be expressed as formulae, with factors to take into account the variables, thus dispensing with the graphs for the calculation of basic times. If the element is not of sufficient importance to warrant so much detail, the study person would probably try plotting basic times against the product (width of plank \times thickness of plank), thus combining two of the main variables, and would also try to establish a factor by which to multiply the relationship discovered to take account of different hardnesses of wood. The statistical technique of multiple regression analysis is highly suitable for the calculation of variable times. A description of this technique will be given in Chapter 27.

It will be evident that, in general, many more observations of a variable element than of a constant element will be necessary before reliable representative basic times can be established. It is well to recognize this at the outset, so that the studywork can be planned to span all the different conditions and variables which are likely to be encountered in practice. It is as well also to give close attention from the beginning to discovering the best basis against which to plot the times, essaying trial plots against different possibilities until some satisfactory indicator of the cause of the variable times is revealed. When the basis of the relationship has been discovered, further studywork can be directed to filling any gaps in the information so far compiled. If the essential analysis is left until a later stage, many of the studies taken may turn out to be needless duplication.

It is not possible to prescribe any one method of approach which will yield satisfactory results in the analysis of all variable elements. Each must be treated on its merits. It is here, perhaps more than anywhere else in time study, that close attention to the detailed methods of working is amply repaid; otherwise it will rarely be possible to discover just what it is that causes basic times to vary. Even when the causes are known, there is often scope for considerable ingenuity in devising a simple basis which will reflect the major variables and reveal a definite and repeatable relationship.

5. Completing the study summary sheet

Having completed the calculations, the study person is now ready to enter on the study summary sheet the information which will make it a clear and concise record of all the results obtained from the observations at the workplace. Against each of the constant elements listed on the sheet the selected basic time for the element and the number of occasions on which the element was observed will be entered. The frequencies of occurrence have already been entered. Against the variable elements will be noted the relationship between basic time and the controlling variable, if this has been discovered, or a reference to the graph sheet or other study analysis sheet on which the basic times derived have been analysed will be recorded.

To complete the summary, he or she must enter a record of any occasional elements observed which have not already been included, and also any foreign elements which may have appeared during the study. Contingency elements and any contingency time extracted during the calculations must be shown. It is usual to express the contingency basic minutes as a percentage of the total basic minutes of repetitive work observed during the whole of the study, so that there may be a basis for comparing the contingencies occurring during one study with those in another.

All the entries which have so far been made represent work, in one form or another. All except any foreign elements will figure later in the calculation of a standard time for the operation, and since they are all work they will all attract relaxation allowances (see section 12). Besides the elements of work, however, there may well have been periods when no work was done during the study, either because the operatives were resting or because they were engaged on one or other of the activities which were described earlier in this book as "ineffective time". The time so spent must now be totalled and entered on the summary. It is useful to break down such time into a few main categories, such as "relaxation", "ineffective time", and so on. The entries will all be in terms of observed times, of course — periods when no work is done cannot be rated.

6. Electronic time study

The above procedure applies equally to studies taken with an electronic stop-watch.

Where the study has been taken with an electronic study board or data capture device, the procedure will be different and will depend on the degree of sophistication of the system being used.

In the simplest systems (and as the first stage in more complex systems) the recording device simply prints out (via a small in-built printer or after connection to an external printer) a listing of all the observation data in terms of element identification, rating and elapsed time, together with basic summary data such as total elapsed time and possibly average rating. These data are then handled just as if the study had been taken with a conventional stop-watch. It is important that this basic record of the study data is maintained as part of the study file so that the source of subsequent time values can be identified and

validated. Equally, the system should ensure that the basic computerized record is tamper-proof, especially before this first printout of data is taken.

Most electronic systems offer additional functions and take the user through subsequent stages of extension, frequency allocation, and so on. Although much of this is automatic (such as the extension of observed times to basic times), the system must offer the analyst the opportunity to identify and ring out "rogue times" referred to earlier in section 4, and omit them from subsequent analysis. The analyst will also need to input element frequencies and allowances if the calculation of a standard time is to be carried out. Electronic time study systems take the drudgery out of analysis but the responsibility for that analysis and the results of it rests with the study person.

Many systems transfer the data from the recording device to a personal computer for this analysis stage. This has the advantage of releasing the study board for further studywork. It also allows the transfer of data over telephone lines so that studies taken at a remote site can be transmitted to "base" for the analysis and reporting stages to be carried out. (A second advantage is that the analysis software has to be provided only once — if it were part of the study board itself, the analysis facility would be duplicated in each device.) This allows the situation to be established where a team of study persons can take a large number of studies in a relatively short space of time and have those studies analysed by a separate analysis team or support officer. It is important though that the person taking the study should examine any such analysis before final results are derived from it and issued, and "signs off" the analysis as being validated.

The final result of this process will be a study summary sheet containing the same data as for a manually taken study. This sheet may be produced directly by the system, after the input of all relevant data by the analyst, or by the analyst using data output from the system.

An example of such a summary sheet, produced by the Tectime system in the United Kingdom, is shown in figure 111.

When the system in use is a full-time study system, it will also allow the continuation of support into other areas such as the merging of several studies of the same job and the establishment of work content and standard times for such work. The principles to be followed are exactly the same as those for manually derived study data. Further computer support, in the area of standard data systems, is discussed in Chapter 27.

7. How many studies?

We dealt with this problem in Chapter 21, outlining a statistical and a conventional method for determining the number of elements and cycles to be studied. When the working conditions vary, studies must be made in each of the different sets of conditions which will be met with in practice: at different times of day if atmospheric conditions change markedly during the shift, for instance, and on all the types of material which have to be processed if the material is not rigidly standard.

Figure 111. An example of a study summary sheet produced using electronic capture devices

Tectime Data Systems Ltd. Demonstration Package		Summary to standard time for study MANUFACT/SOCK1 by cycles			Singleman V5 System	
Study name: Sock1		Job Ref: Socks	Second Ref: A	Analyst: P.S.	Operator: K. Hayes	
Date: 01/02/91		Start time: 06.00:00	Finish time: 15.31:00		Elapsed time: 571.70	
Site: Number 3		Section: CORTESE	Dept:		Area: CORTESE	
Remarks: 315 dozen produced 1 3/24 damages/grades.						
Job on file: FACTORY – STRAIGHTENING – LOADING OPERATIVE – HOLD UPS – LINKED TO MACHINES.						
Unit A: Pair of socks = 2000.00						

Element Code type	Total obs. time	Total bm's	Total obn's	Bm's/ obn	Frequency	Bm's/ cycle	RA %	Sms.
1 Repetitive Pick up sock from bench adjacent to m/c Open and present to m/c	406.220	402.627	3727	0.108	2/1	0.216	12.00	0.242
2 Repetitive Pick up first sock and load onto form Reject and place aside	0.680	0.664	5	0.133	2/100	0.003	12.00	0.003
3 Repetitive Load 1st – Reject and place aside Load next	4.450	4.314	21	0.205	2/100	0.004	12.00	0.005
5 Repetitive Obtain full bag of work and empty onto bench	2.510	2.340	8	0.293	2/500	0.001	12.00	0.001
CY1 Contingency Relevant talking	2.720	2.710	4	0.677	4/2000	0.001		
CY2 Contingency Clean machine	0.650	0.650	1	0.650	1/2000	0.000		
CY10 Contingency File nails	2.220	2.220	2	1.110	2/2000	0.001		
IF1 Ineffective Operative not working	14.710		1					
IF3 Ineffective Operative at break	71.520		3					
IF4 Ineffective Operative in restaurant	50.810		4					
IF5 Ineffective Personal needs	3.650		1					

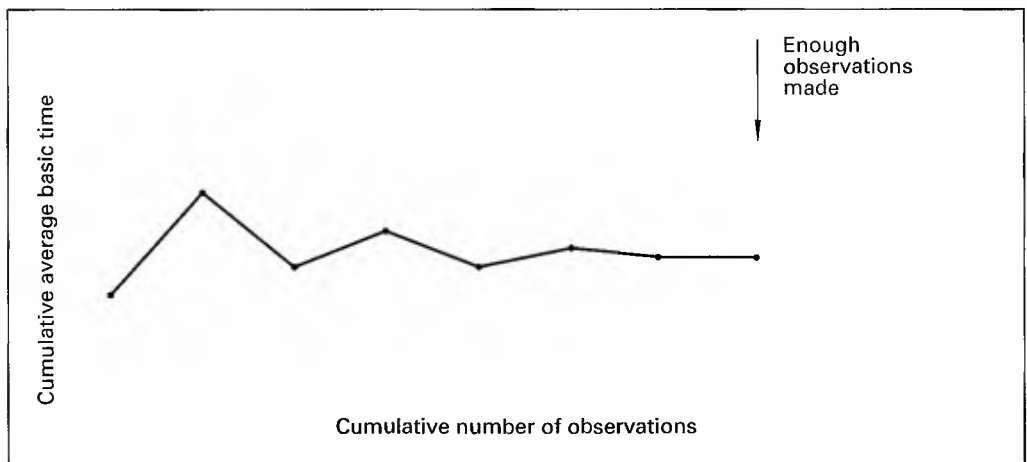
Totals Box	Observed time		Basic time		Standard time	
	Min.	% Total	Min.	% Total	Min.	% Total
Repetitive	413.86	73.9	409.94	98.7	0.25	100.0
Contingency	5.59	1.0	5.58	1.3		
Ineffective	140.69	25.1				
Total time	560.14		415.52		0.25	
Total SMs			0.2509			
Contingency		4.000%	0.0100			
Policy		3.000%	0.0075			
Total SMV			0.2684			
Parts per hour @ 100:			223.5204			

Average rating = 99.06

The study person must be prepared to study all the work involved in starting up at the beginning of a shift and in shutting down at the end of it. Start-up and shut-down times are part of the work and may need a separate work value, or they may be taken into account (if appropriate) by making an allowance for them when calculating the standard times for individual jobs. In industries such as printing, presses are not normally left inked up overnight, as the ink would dry before morning. Time may have to be allowed for cleaning machines and the workplace, and for changing clothes in industries where special clothing is required. Activities of this sort are not usually taken into account in the calculation of standard times for individual jobs but are more often dealt with by time allowances. Allowances are discussed later in this chapter: at this point it is sufficient to note that studies will have to be made on all the ancillary and incidental activities which are undertaken during the working day before the matter of allowances can be properly considered.

A simple method of determining when enough cycles of a constant element have been observed — enough, that is, to permit a representative basic time for the element to be selected — is to plot the cumulative average basic time for the element each time a study is made on it and summarized. The plot is started with the basic time derived from the first study. When the second study comes in, the figure then plotted is the average, calculated by adding the basic time from the first study multiplied by the number of observations during the first study to the product (basic time \times observations) from the second study, and then dividing by the total number of observations made during both studies. Further plots are made in the same fashion as successive studies are worked up. When the line on the graph ceases to “wag” and settles down at a constant level, enough studies have been made on this element. An example is shown in figure 112.

Figure 112. Cumulative average basic times for a constant element



With variable elements it is convenient to start by making several short studies which together span the full range of variability, so that an early attempt may be made to establish the relationship between basic time and the indicative

variable. Subsequent studywork may then be directed to obtaining the information needed to complete, modify or validate the apparent relationship suggested by the first studies.

8. The analysis of studies sheet

An example of an "analysis of studies sheet" is shown in figure 105 (Chapter 20). The results obtained in each study on an operation are entered on this sheet by copying from the study summary sheet, as soon as the study has been worked up. A form of the type illustrated provides for a list of all the elements which make up a job or operation, and also for full details in respect of repetitive and occasional elements, together with a record of the contingency and ineffective times observed. Graphs are appended to the sheet to record the results obtained from studying variable elements.

When it is considered that enough observations have been made, the next step is to calculate the final representative basic times for each element. This is done on the analysis of studies sheet. The process of selection is essentially similar to that described in section 4 of this chapter, the usual method being to calculate the overall weighted average of all the basic times recorded for each element, disregarding any entries which subsequent studywork has shown to be erroneous. The weighted average is obtained by multiplying the basic time recorded from a study by the number of observations of the element made in that study, adding up the products so derived for all the studies, and dividing the total by the sum of all the observations made in all the studies.

When these final representative basic times have been calculated for each constant element, it is a simple matter to calculate the basic time per cycle, per job or per operation for these elements, by multiplying the time per occasion by the frequency per cycle with which each element recurs. Variable elements cannot be dealt with in this way, of course. For them, the basic time may have to be read off the appropriate graph, or, if a straight-line relationship has been established, calculated from the formula which expresses the line in algebraic terms, or derived by regression analysis.

If it is considered appropriate to make provision in the job time for contingencies, the allowance necessary is also calculated on the analysis of studies sheet. The first step in doing this is to calculate the percentage which the total observed contingencies represent of the total other work observed. Time spent on contingencies is just as much work as that devoted to repetitive and occasional elements, so contingency time will also be recorded in basic minutes. If the percentage is a very small one, it will probably be convenient to adopt the figure as the percentage allowance to be made; but if it comes out at more than about 4 or 5 per cent, the better course is to inquire into the causes of the contingencies so as to eliminate or reduce them as far as possible. When action of this sort has been taken as a result of the studies, the percentage observed during the earlier studywork will no longer be valid and it will be necessary to make fresh observations.

At the stage now reached a basic time has been built up for the job or operation, including all repetitive and occasional elements and also any small

amount of extra work which may be met with occasionally as a contingency. The compilation has been done element by element, so that, if at any time in the future the job is changed slightly by deleting or changing an element or by adding a fresh one, it will not be necessary to restudy the whole job. The entries on the analysis of studies sheet will still hold good for all the unchanged elements in the new job sequence, and therefore it will be possible to make a fresh compilation after studying the new elements only.

The basic time, however, forms only a part of the standard time which has to be established for the job or operation. Certain allowances must be added before the standard time can be derived. These allowances must now be discussed; before doing so, however, it is necessary to state clearly what is meant by two terms which have been mentioned frequently in the preceding pages but which have not yet been precisely defined: namely **work content** and **standard time**.

9. Work content

In the chapters at the beginning of this book, the term “work content” was used frequently to describe what the words themselves suggest: the amount of work which has to be done to complete a job or operation, as distinct from any ineffective time which may occur. In time study practice, however, the word “work” is accorded a meaning which is slightly different from its usual meaning in ordinary English usage. An observer who was familiar with the word only in its usual sense would say, when watching operatives at their jobs, that when the workers were actually doing something they were working, and that when they were resting or doing nothing they were not working. In time study practice, however, we are concerned with measuring work in numerical terms, and for this purpose the word “work” is extended to include not only the physical labours performed but also the proper amount of relaxation or rest necessary to recover from the fatigue caused by those labours. We shall see later that relaxation allowances are made for other purposes besides recovery from fatigue; but for the moment the important point is that, when in time study we speak of “work” and set out to measure it, we define work to include the appropriate relaxation allowance, so that the amount of work in a job is taken to be not only the time needed at standard performance to do whatever the job requires but also the additional time which is considered necessary for relaxation.

The work content of a job or operation is defined as: basic time + relaxation allowance + any allowance for additional work — e.g. that part of contingency allowance which represents work

10. Allowances

We have seen that, during the method study investigation which should be carried out before any job is timed, the energy expended by the worker in performing the operation should be reduced to a minimum through the development of improved methods and procedures, in accordance with the principles of motion economy and, wherever practicable, by mechanization. Even when the most practical, economic and effective method has been developed, however, many jobs will still require the expenditure of human effort, and some allowance must therefore be made for recovery from fatigue and for relaxation. Allowance must also be made to enable a worker to attend to personal needs; and other allowances (e.g. contingency allowances) may also have to be added to the basic time in order to give the work content.

The determination of allowances is probably the most controversial part of work study. For reasons that will be explained later, it is very difficult to determine precisely the allowances needed for a given job. What should therefore be attempted is an objective assessment of the allowances that can be consistently applied to the various elements of work or to various operations.

The fact that the calculation of allowances cannot be altogether accurate under all circumstances is no excuse for using them as a dumping ground for any factors that have been missed or neglected in making the time study. We have seen how the study person can go to great lengths to arrive at fair and accurate time standards. These should not be spoilt by the hasty or ill-considered addition of a few percentage points here and there "just in case". Above all, allowances should not be used as "loosening" factors.

The difficulty experienced in preparing a universally accepted set of precise allowances that can be applied to every working situation anywhere in the world is due to various reasons. The most important among them are:

- (1) **Factors related to the individual.** If every worker in a particular working area were to be considered individually, it might well be found that a thin, active, alert worker at the peak of physical condition required a smaller allowance to recover from fatigue than an obese, inept worker. Similarly, every worker has a unique learning curve or a rate of learning which can affect the manner in which the work is conducted. There is also some reason to believe that there may be ethnic variations in the response to the degree of fatigue experienced by workers, particularly when engaged on heavy manual work. Undernourished workers take a longer time than others to recover from fatigue.
- (2) **Factors related to the nature of the work itself.** Many of the tables developed for the calculation of allowances give figures which may be acceptable for light and medium work in industry but which are inadequate when applied to operations involving very heavy and strenuous work, such as work beside furnaces in steel mills. Moreover, every working situation has its own particular attributes which may affect the degree of fatigue experienced by the worker or may lead to unavoidable delay in the execution of a job. Examples of these factors are: whether a worker has to perform the work standing up or sitting

down, and posture during work; whether force has to be exerted to move or carry loads from one place to another; whether the work itself results in undue eye or mental strain, and so on. Other factors inherent in the job can also contribute to the need for allowances, although in a different way — for example, when protective clothing or gloves have to be worn, or when there is constant danger, or when there is a risk of spoiling or damaging the product.

- (3) **Factors related to the environment.** Allowances, in particular relaxation allowances, have to be determined with due regard to various environmental factors such as heat, humidity, noise, dirt, vibration, lighting intensity, dust, wet conditions, and so on. Each of these will affect the amount of relaxation allowances needed. Environmental factors may also be seasonal in nature. This is particularly so for those who work in the open air, such as workers in the construction industry or in shipyards.

It should now be more clear to the reader why it is so difficult to devise an internationally accepted scheme of allowances to meet every working situation in the world. It should also be stated here, in very clear terms, that **the ILO has not adopted, nor is it likely to adopt, any standards relating to the determination of allowances.** In fact, over the years, the ILO has received a great number of queries about its stand with respect to allowances. The answer has always been that it does not specifically endorse a particular standard which can be universally applicable. The following discussion quotes examples of the calculation of allowances under different conditions. They are quoted here as examples for training purposes and not as an ILO stand on the matter.

It should also be mentioned that this particular aspect of work study has been the subject of extensive research by various organizations which have put forward their own recommendations for the calculation of allowances. Of the more important research carried out, mention should be made of the work of the Max Planck Institut für Arbeitsphysiologie¹ and of REFA Verband für Arbeitsstudien,² in Germany, of G. C. Heyde in Australia,³ and more recently of the British Standards Institution, which summarizes some past research on the subject and proposes a methodology.⁴

11. Calculation of allowances

The basic model for the calculation of allowances is shown in figure 113. It will be seen from this model that relaxation allowances (which are intended to aid recovery from fatigue) are the only essential part of the time added to the basic time. Other allowances, such as contingency, policy and special allowances, are applied under certain conditions only.

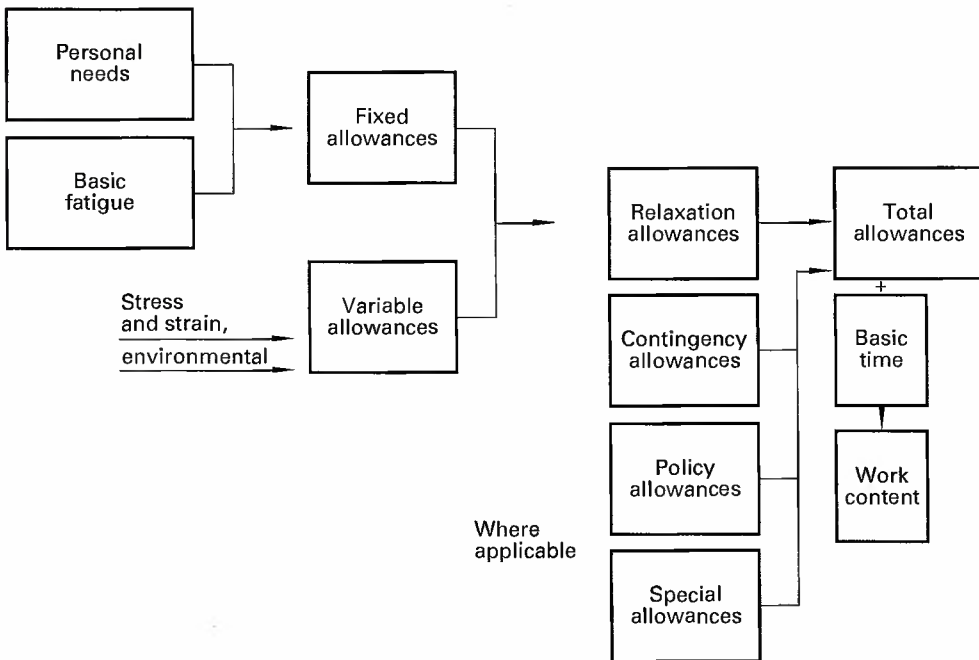
¹ G. Lehmann: *Praktische Arbeitsphysiologie* (Stuttgart, Georg Thieme Verlag, 1953).

² REFA: *Methodenlehre des Arbeitsstudiums*, Vol. 2: *Datenermittlung* (Munich, Carl Hanser Verlag, 1971), pp. 299-335.

³ Chris Heyde: *The sensible taskmaster* (Sydney, Heyde Dynamics, 1976).

⁴ British Standards Institution. Draft text for development on work measurement: Exposure limits, recovery times and relaxation times (London, July 1989).

Figure 113. Allowances



12. Relaxation allowances

Relaxation allowance is an addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of allowance will depend on the nature of the job

Relaxation allowances are calculated so as to allow the worker to recover from **fatigue**. Fatigue may be defined as a physical and/or mental weariness, real or imagined, existing in a person and adversely affecting the ability to perform work. The effects of fatigue can be lessened by rest pauses, during which the body recovers from its exertion, or by slowing down the rate of working and thus reducing the expenditure of energy.

Allowances for fatigue are normally added **element by element** to the basic times, so that a work value for each element is built up separately, the element standard times being combined to yield the standard time for the whole job or operation. In this way it is possible to deal with any extra allowance which may be required to compensate for severe climatic conditions, since the element may sometimes be performed in cool weather and sometimes when it is very hot. Allowances for climatic conditions have to be applied to the

working shift or **working day** rather than to the element or job, in such a way that the amount of work which the worker is expected to produce over the day or the shift is reduced. The standard time for the job remains the same, whether the job is performed in summer or winter, since it is intended to be a measure of the work that the job contains.

Relaxation allowances have two major components: **fixed allowances** and **variable allowances**.

Fixed allowances are composed of:

- (1) Allowances for **personal needs**. This allowance provides for the necessity to leave the workplace to attend to personal needs such as washing, going to the lavatory or fetching a drink. Common figures applied by many enterprises range from 5 to 7 per cent.
- (2) Allowances for **basic fatigue**. This allowance, always a constant, is given to take account of the energy expended while carrying out work and to alleviate monotony. A common figure is 4 per cent of basic time. This is considered to be adequate for a worker who carries out the job while seated, who is engaged on light work in good working conditions and who is called upon to make only normal use of hands, legs and senses.

Variable allowances are added to fixed allowances when working conditions differ markedly from those stated above, for instance because of poor environmental conditions that cannot be improved, added stress and strain in performing the job in question, and so on.

As was mentioned above, a number of important studies have been carried out by various research organizations to try to develop a more rational approach to the calculation of variable allowances. There are an enormous number of relaxation allowance tables in existence. Most management consultants in all countries have their own tables. In Appendix 3, we give an example of relaxation allowances tables using a points system. This is an example quoted for illustration purposes. It should not be taken as a relaxation allowance set of tables that are endorsed by the ILO. Many of these tables appear to work satisfactorily in practice; however, recent evidence indicates that, although many of the fatigue allowance scales established empirically in a laboratory are satisfactory on physiological grounds for work involving normal or moderately intensive effort, they provide inadequate allowances when applied to very heavy operations such as those connected with furnaces.

For the various reasons mentioned earlier in the chapter, when using one of the standard scales it is always preferable to check the amount of relaxation time they yield by carrying out whole-day studies at the workplace, noting the amount of time which the workers actually spend in relaxation (in one form or another) and comparing this with the calculated allowance. Checks of this sort do at least show whether the scale is, in general, too tight or too loose.

Relaxation allowances are given as percentages of the basic time. As mentioned earlier, they are normally calculated on an element-by-element basis. This is particularly the case when the effort expended on different elements varies widely (for example, where a heavy workpiece has to be lifted on or off a machine at the beginning and end of an operation). If, on the other

hand, it is considered that no one element of a job is any more or any less fatiguing than any of the other elements, the simplest course is to add up all the elemental basic time first and then add the allowance as a single percentage to the total.

Rest pauses

Relaxation allowances can be taken in the form of rest pauses. While there is no hard and fast rule governing rest pauses, a common practice is to allow a ten- to 15-minute break at mid-morning and mid-afternoon, often coupled with facilities for tea, coffee or cold drinks and snacks, and to permit the remainder of the relaxation allowance to be taken at the discretion of the worker.

Rest pauses are important for the following reasons:

- They decrease the variation in the worker's performance throughout the day and tend to maintain the level nearer the optimum.
- They break up the monotony of the day.
- They give workers the chance to recover from fatigue and to attend to personal needs.
- They reduce the amount of time off taken by workers during working hours.

Where workers are working in conditions of heat, cold, noise or vibration it may be necessary to introduce mandatory rest pauses as part of a work-rest regime to ensure the health and safety of the workers.

13. Other allowances

It is sometimes necessary to incorporate allowances other than relaxation allowances in the compilation of standard time. Three such allowances are described below.

Contingency allowances

A contingency allowance is a small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays, the precise measurement of which is uneconomical because of their infrequent or irregular occurrence

Contingency allowances have already been mentioned when we described the calculations which have to be made to complete the study summary sheet and the analysis of studies sheet. The allowance provides for small unavoidable delays as well as for occasional and minor extra work, and so it would be proper to split the allowance into these components, the contingency allowance for work being allowed to attract fatigue allowance, just as any other item of work does, and the delay part of the allowance being given with only a

personal needs increment. In practice this is a distinction which is often ignored. Contingency allowances are always very small, and it is usual to express them as a percentage of the total repetitive basic minutes in the job, adding them to the rest of the work in the job and adding a relaxation percentage to the whole contingency allowance. Contingency allowances should not be greater than 5 per cent, and should only be given in cases where the study person is absolutely satisfied that the contingencies cannot be eliminated and that they are justified. On no account should such allowances be used as "loosening" factors or to avoid carrying out proper time study practice. The duties for which the contingency allowance is given should be specified. However, in fairness, it may be necessary to give contingency allowances as a matter of course in enterprises where the production work is not well organized. This further stresses the need to make the conditions and organization of work as good as possible before setting time standards and is an incentive to the management to do so.

Policy allowances

A policy allowance is an increment, other than bonus increment, applied to standard time (or to some constituent part of it, e.g. work content) to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstances

Policy allowances are not a genuine part of time study, and should be used with the utmost caution and only in clearly defined circumstances. They should always be dealt with quite separately from basic times and, if used at all, should preferably be arranged as an addition to standard times, so as not to interfere with the time standards set by time study.

The usual reason for making a policy allowance is to line up standard times with the requirements of wage agreements between employers and trade unions. In several enterprises in the United Kingdom, for example, the incentive performance is generally set at such a level that the average qualified worker, as defined, can earn a bonus of $33\frac{1}{3}$ per cent of the basic time rate if standard performance is achieved. There is no need to apply a policy allowance to achieve this state of affairs; it is simply necessary to arrange for the rate paid per standard minute of work produced to be $133\frac{1}{3}$ per cent of the basic time rate per minute, and in general it is better to accommodate any special wage requirements in this way, by adjusting the rate paid per unit of work rather than the standard time.

There are, however, certain employer-union agreements under which higher bonuses can be earned, and it may not be opportune to seek a revision of the terms of these agreements to permit the achievement of their terms by modifying the rates paid rather than the times set. In these circumstances a policy allowance is given to make up the difference. It may be applied as a factor to the work content or to the standard time.

This might be an appropriate course to take when standard times are being introduced to only a small proportion of the total workforce covered by the agreement. Similar policy allowances are sometimes made as temporary additions to cover abnormal circumstances, such as the imperfect functioning of a piece of plant or disruption of normal working caused by rearrangements or alterations.

Special allowances

Special allowances may be given for any activities which are not normally part of the operation cycle but which are essential to the satisfactory performance of the work. Such allowances may be permanent or temporary; care should be taken to specify which. Wherever possible, these allowances should be determined by time study.

When time standards are used as the basis for a payment-by-results scheme, it may be necessary to make a **start-up allowance** to compensate for time taken by any work and any enforced waiting time which necessarily occurs at the start of a shift or work period before production can begin. A **shut-down allowance** may similarly be given for work or waiting time occurring at the end of the day. A **cleaning allowance** is of much the same character: it is given when the worker has to give attention from time to time to cleaning his or her machine or workplace. **Tool allowance** is an allowance of time to cover the adjustment and maintenance of tools.

It would be possible, after the time necessary to perform any or all of these activities has been studied, to express the result as a percentage of the total basic time for the operations expected to be performed during a day and to give the allowance as an increment included in the compilation of standard times. Indeed, this is sometimes thought to be the better course with tool allowance; but, in general, it is preferable to give all these allowances as periods of time per day rather than embodying them in the standard times. Usually this is fairer to the operatives, and it has the signal advantage of bringing to the attention of the management the total amount of time which has to be devoted to these activities, thus prompting thoughts about how it could be reduced.

Some allowances are normally given per occasion or per batch. One such allowance is **set-up allowance**, given to cover the time required for preparing a machine or process for production, an operation which is necessary at the start of production on a batch of fresh products or components. Set-up time is sometimes called make-ready time: its opposite is tear-down or dismantling time, for which a **dismantling allowance** may be given, to cover the time needed for making alterations to machine or process settings after completing a run of production. Very similar is **change-over allowance**, usually given to operatives who are not actually engaged in setting-up or dismantling, to compensate them for time on necessary activities or waiting time at the start and/or the end of a job or batch. These allowances should be denoted as "job change-over allowance" or "batch change-over allowance", as appropriate.

A **reject allowance** may be included in a standard time when the production of a proportion of defective products is inherent in the process, but

is perhaps more usually given as a temporary addition to standard times, per job or per batch, if an occasional bad lot of material has to be worked. An **excess work allowance**, if necessary, would also be given as an addition to the standard time, to compensate for extra work occasioned by a temporary departure from standard conditions.

Learning allowances may be given to trainee operatives engaged on work for which standard times have been issued, as a temporary benefit while they develop their ability. A **training allowance** is a similar allowance given to an experienced worker to compensate for the time he or she is required to spend instructing a trainee, while both are working on jobs for which standard times have been set. These allowances are often given as so many minutes per hour, on a declining scale so that the allowances taper off to zero over the expected learning period. Very similar is an **implementation allowance**, given to workers asked to adopt a new method or process to encourage them to attempt an enthusiastic implementation of the new ways and prevent their losing earnings by doing so. In fact, it is sometimes arranged that their earnings will actually be increased during the change-over period, so as to give the new method every chance of success. One system of implementation allowances credits the workers with ten minutes per hour on the first day, nine on the second, and so on down to zero.

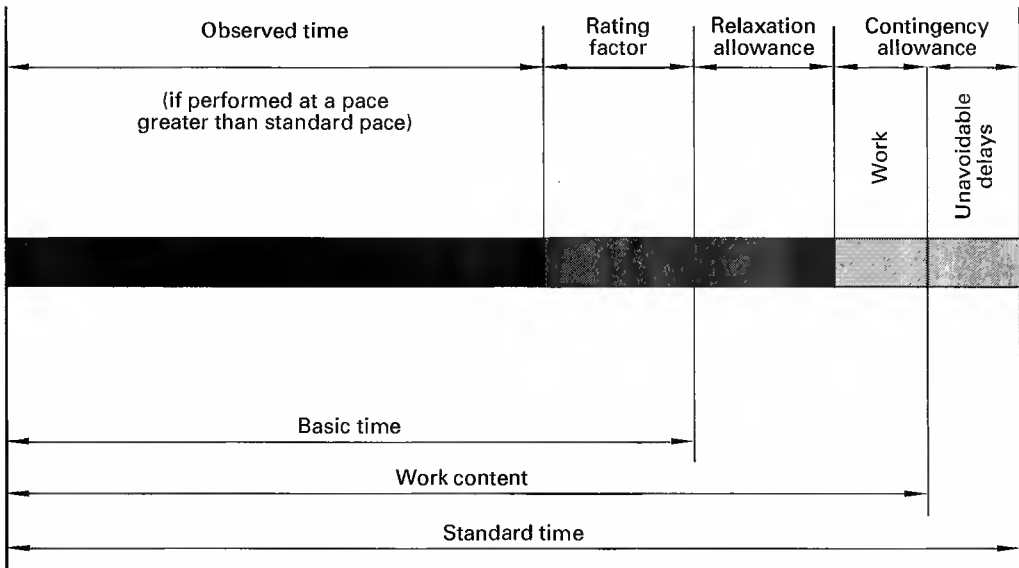
A **small batch allowance** is required to enable a worker working on small batches to decide what to do and how to go about it (from instructions, by experience, or by trial and error) and then to work up to a standard performance by practice and repetition. The calculation of this allowance will depend on whether it is a one-of-a-type batch or not, on the length and batch size or run length, and on the frequency of similar work and its degree of complexity.

14. The standard time

It is now possible to obtain a complete picture of the standard time for a straightforward manual job or operation, one which is considered to attract only the two allowances which have so far been discussed in detail: contingency allowance and relaxation allowance. The standard time for the job will be the sum of the standard times for all the elements of which it is made up, due regard being paid to the frequencies with which the elements recur, plus the contingency allowance (with its relaxation allowance increment). In other words:

Standard time is the total time in which a job should be completed at standard performance

Figure 114. How the standard time for a simple manual job is made up



In a case where the observed time is rated at less than standard pace, the rating factor will, of course, be shown inside the observed time. The contingencies and relaxation allowances, however, are still percentages of the basic time. The standard time is expressed in standard minutes or standard hours.

In Chapter 24 we shall discuss the application of time study to operations involving the use of machinery, in which part of the operation time is taken up by work done by the machine while the operative stands by. An example of a fully worked time study is shown in Chapter 25.

15. Work measurement in the office

Time study or work measurement is equally important in terms of assisting in the planning and control of office work. Without measurement data it is difficult to evaluate capacities, assess workloads, monitor performance and plan staffing levels. However, there has been a reluctance on the part of office workers to be subjected to a work measurement programme. In many organizations this is overcome simply by an effective communication and education programme — carefully explaining the objectives of work measurement and the implications for both the organization and the staff concerned. One of the factors that contribute to the reluctance for measurement is the enhanced status that office workers perceive they have as compared with shop-floor workers. Thus shop-floor techniques are not considered as being appropriate to them. This can be overcome by selecting the measurement technique carefully.

When measuring office work, it is rare that we are attempting to introduce payment-by-results schemes based on measured output. The intention is

normally to provide information which the management of the organization can use to assist in the planning process. Thus, we often do not need information to the same degree of detail as we do when measuring shop-floor work and we can select from a range of techniques that provide information to the appropriate level of detail and yet will be acceptable to those being measured. Some of the "measurement" described below does not actually fit in with our definition of measurement — in that it does not provide times for qualified workers at a defined level of performance, unless we define that level as being "office average" performance. Perhaps we should really have used the word "assessment" to represent something less strict than measurement but for the sake of simplicity we have used the word "measurement" to cover all instances in which we make a quantitative judgement on the quantity of work involved in a given task or series of tasks.

Work measurement techniques

All the techniques referred to in Chapter 18 (and a number of others) can be used in an office environment, but the most commonly used are:

- activity sampling;
- group sampling techniques;
- predetermined time standards (PTS);
- standard data systems;
- self-recording techniques;
- historical records analysis.

Time study has not been used in office environments to any significant degree mainly because it appears to be the measurement technique most tarnished with the "factory" image, in particular due to its association with the concept of performance rating; there are, however, no technical reasons as to why it cannot be used.

Activity sampling is included here since it involves the quantification of work, although it is not often used for true measurement purposes. It is most often used as part of the fact-finding process when investigating a particular area of work. It helps to show clearly the breakdown of work between different activities and can thus help in the prioritization process when selecting areas for method study.

Group sampling techniques have already been discussed in Chapter 19. Predetermined time standards (PTS) and standard data systems will be discussed in Chapters 26 and 27 respectively. There are a number of PTS systems specifically designed for office work (such as Clerical Work Data) and these can be used, with data from other sources, to build up standard data for standard office tasks. There are also proprietary data systems available for measuring office work such as the Clerical Work Improvement Programme which is based on measurement data obtained from film analysis of clerical jobs (in the same way that many basic predetermined time standards systems (PTS) built up their basic data).

Self-recording techniques

As the name suggests, these are techniques which rely on the workers themselves maintaining some form of record of their own workloads and the time they spend on various activities. There are two basic forms of record. The first asks each worker to record each activity together with the time he or she started the activity, and then, on completion, to record the time that he or she finished (and presumably started the next activity). Where the activity produces a definite output, such as invoices passed for payment, the count of this output will also be added to the record. It is then a simple matter of working out elapsed times and dividing this into the count, to get an average time per unit of output. The second version is to ask the workers to record what they are doing at fixed intervals throughout the time of the study — say, every 15 minutes. This is then a sampling study and can be dealt with accordingly.

It is important that the recording process extends over a “representative” period, especially where a job has particular peak periods such as at the end of a week or the end of a month. If such periods are not covered in the study, the workers will feel aggrieved that their work is being devalued.

One common objection to self-recording is that the recording itself interferes with the work and adds an additional burden to the workers. This is often not a real problem and can normally be overcome by the same process of careful communication and explanation that accompanies the introduction of the measurement programme itself.

Self-recording can now be carried out using computer assistance. There is now available a hand-held, bar-code reader which incorporates an electronic timing device. This reader is about the size of a large fountain pen and is used by the workers to record their activities. A sheet containing bar codes is given to the operator and each activity is assigned to one of the bar codes. At the start of the day, the reader (which is battery operated) is started and the timer starts running. Whenever the worker changes activity, he or she simply has to run the reader over the bar code for the new activity and the reader automatically assigns a time to the old activity and starts timing the new one. At the end of the work period, the data from the reader are transferred to a microcomputer for analysis.

Historical records analysis

This is a technique whereby past records of output or work completed are analysed and compared with records of staff time over the same period to obtain crude measures of performance. Generally, it is not possible to break the time down between different activities but in large offices where individual workers are primarily responsible for one class of activity, this may not be a problem. One advantage of this kind of analysis is that it may enable work counts to be interrelated by statistical analysis. This can simplify work and performance measurement in the future.

For example, from past records over a four-week period:

Invoice section

Number of staff in invoice section	= 8
Number of staff hours in invoice section	= 1,152
Number of invoices processed	= 7,360

Debt recovery section

Number of staff in debt recovery section	= 2
Number of staff hours in debt recovery section	= 288
Number of bad debts dealt with	= 350

Then, simple measures are:

Number of invoices processed per hour	= 6.38
Number of bad debts processed per hour	= 1.22

If at some later date this organization takes over another similar organization operating in the same market and decides to merge the two administrative offices, it has information on which to base new staffing levels.

Let us assume that we can predict that the number of invoices processed by the merged organization will be 2,750 per week and that because of the similar customer base, the rate of bad debt to invoice should remain approximately the same.

Then for a typical week:

Number of invoices to be processed	= 2,750
Number of staff hours required for processing	= 2,750/6.38
	= 431
Ratio of bad debts to invoices from previous study	= 350/7,360
	= .04755
Number of bad debts expected	= 2,750 × .04755
	= 131
Number of staff hours required for handling bad debts	= 131/1.22
	= 107
Number of staff required in the merged office (assuming a working week of 35 hours):	
Invoice section	= 12.3
Debt recovery section	= 3

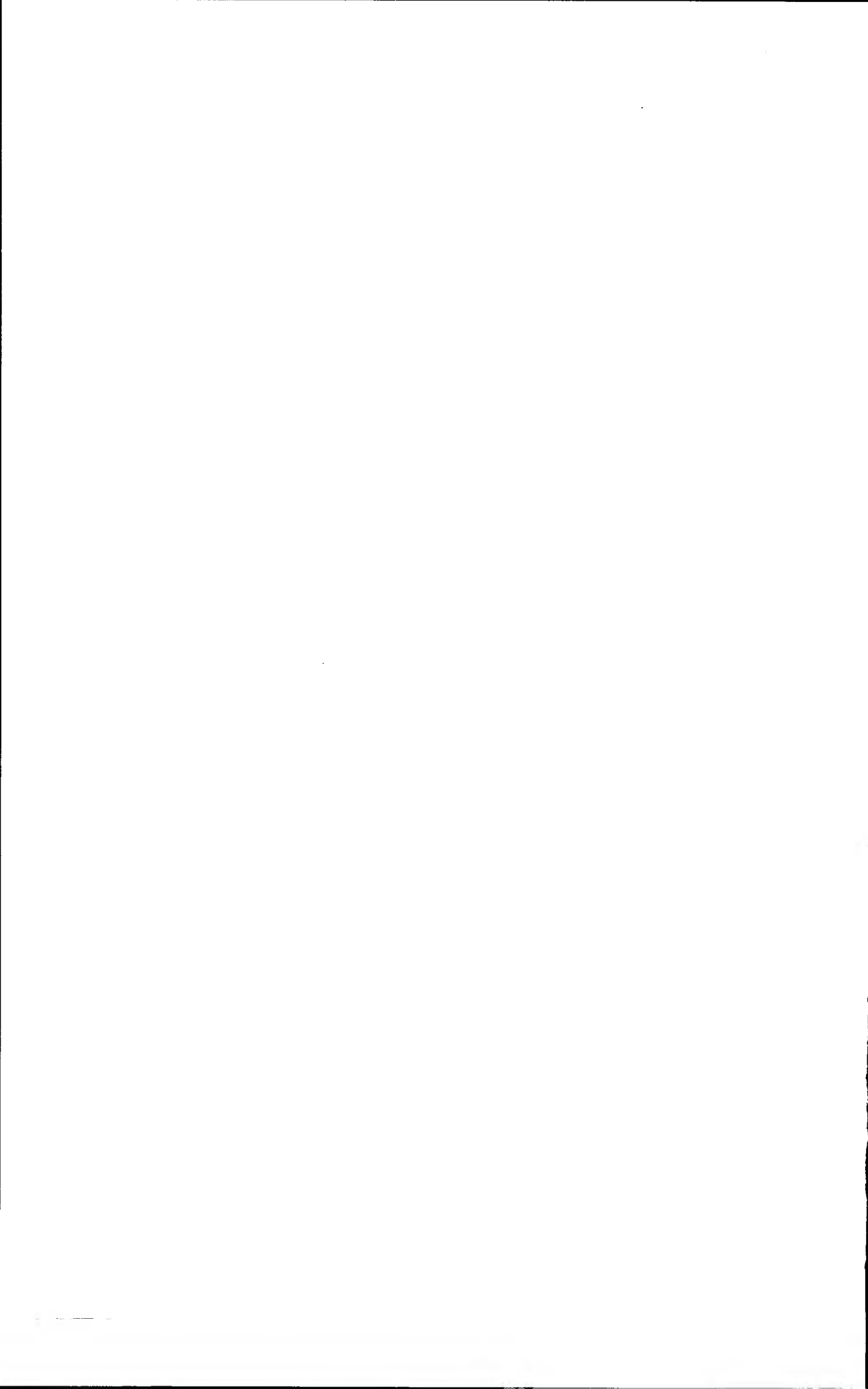
This kind of linking of one count with another often greatly simplifies the measurement of performance. In a branch office of a financial institution, if a number of outputs from different posts can be linked to one fundamental output — especially if that output is counted anyway as part of the normal business of the branch — the performance of the branch can be calculated from the ratio of this composite output to the staff hours put in. New staffing levels can be determined by measuring trends in the fundamental output and relating these to the sub-outputs.

If such a system is in use, it is important to revalidate any statistical linkages at periodic intervals to ensure that times and performance measures remain valid.

Computerized work measurement

The same scope exists in clerical work measurement as in shop-floor work measurement for the introduction of computerized application methods. All measurement needs to be able to respond to changes in work organization, working methods and new technologies. Computerized measurement data systems permit faster updating and re-analysis of time standards, and thus there is a greater chance that the updating actually takes place and that the time standards in use remain valid.

Computerized systems may be built around a specific predetermined time standards system for office work or may be the "empty shell" type of system into which the organization inputs its own time data. The measurement and the application system do not necessarily have to be from the same source.



Setting time standards for work with machines

In Chapters 20 to 23 the basic procedures of time study as applied to manual operations were described. Through the use of the techniques and methods which were discussed, time standards can be compiled for all jobs in which operatives work with hand tools or with power tools which they themselves manoeuvre, as distinct from machines which perform part of the operation automatically. Such work is known as unrestricted work, because the output of the worker is limited only by factors within his or her control. A person grinding a cutting tool on an electrically operated grindstone is engaged on unrestricted work, and so is a person polishing a metal component by holding it against a power-driven polishing mop, for in neither of these cases does the worker clamp the workpiece securely in position and leave the machine to get on with the work.

However, it is becoming increasingly common for industrial jobs to be made up partly of elements performed manually by the worker and partly of elements carried out automatically by machines or process equipment, with the worker either being necessarily idle meanwhile or attending to something else. In order to set time standards for such operations, it is necessary to apply somewhat different methods, in extension of the basic time study procedure. For some highly complex operations special techniques have been devised. In the present chapter, only the more generally applicable methods will be described.

1. Plant and machine control

Plant and machine control is the name given to the procedures and means by which efficiency and utilization of units of plant and machinery are planned and checked

In many enterprises the machines, plant and equipment together account for by far the greatest proportion of the total capital invested in the enterprise. When this is so, the costs incurred in servicing capital, in maintaining the machines, and in providing against depreciation and for the replacement of the equipment may well amount in total to more than any other factory expense

(excluding the cost of raw materials and bought components, which is an external rather than a factory expense). Very often these machinery costs are much greater than the total wage bill for the plant, so that it is of the utmost importance to make the most intensive use possible of the machinery and equipment installed, even though this may be done at the expense of labour productivity. Indeed, it may be very sound policy to increase the manning complement on the machines, if by so doing greater machine utilization can be achieved.

Before focusing on individual jobs, therefore, the work study person will do well to examine first the overall utilization of the machinery in the business; in the enterprise as a whole; in the different departments; and machine by machine in the case of particularly expensive items. It will then be clearer to decide the proper objectives for the application of work study in the plant, and it will be evident whether labour productivity or machine utilization is of primary importance.

The terms and concepts used in the study of machine utilization (or plant or process utilization) are described below. They are largely self-explanatory. The relationship between them is shown graphically in figure 115.

Machine maximum time is the maximum possible time during which a machine or group of machines could work within a given period, e.g. 168 hours in one week or 24 hours in one day.

Machine available time is the time during which a machine could work based on attendance time, i.e. working day or week plus overtime.

Machine idle time is the time during which a machine is available for production or ancillary work but is not used owing to shortage of work, materials or workers, including the time that the plant is out of balance.

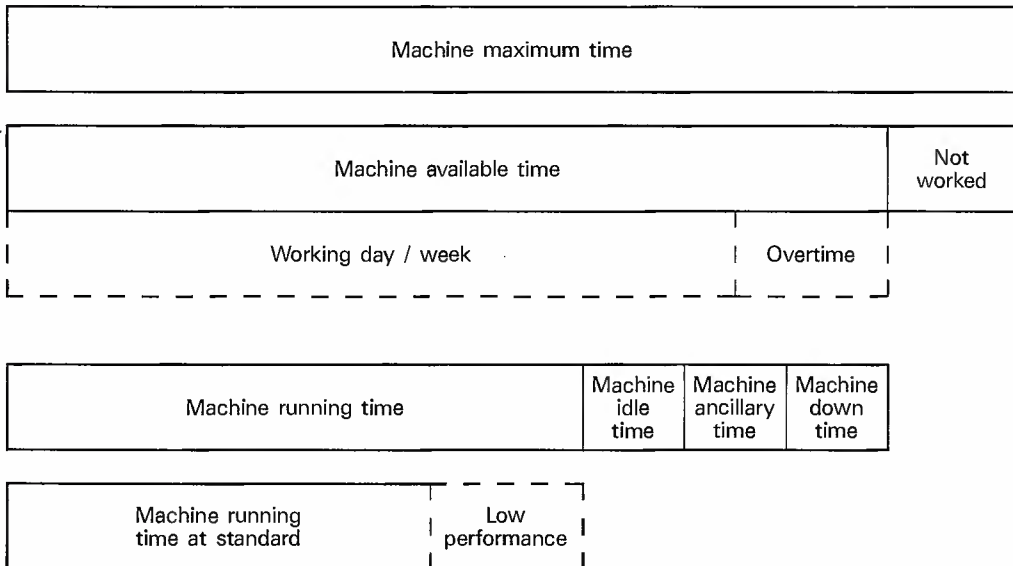
Machine ancillary time is the time when a machine is temporarily out of productive use owing to change-overs, setting, cleaning, etc.

Machine down time is the time during which a machine cannot be operated on production or ancillary work owing to breakdown, maintenance requirements, or for other similar reasons.

Machine running time is the time during which a machine is actually operating, i.e. the machine available time less any machine down time, machine idle time, or machine ancillary time.

The machine running time is a matter of fact, observable by direct study at the workplace. It does not follow, however, that the machine, though running, is actually operating in the manner in which it should, or has been set so as to perform in the very best manner of which it is capable. It is useful therefore to introduce another concept:

Figure 115. Explanatory diagram of machine time



Source: Based on a diagram contained in British Standards Institution: *Glossary of terms used in work study* (London, 1969).

Machine running time at standard. This is the running time that should be incurred in producing the output if the machine is working under optimum conditions.

The most useful work measurement method for studying machine utilization is work sampling, as described in Chapter 19. This technique gives the information required with much less effort than would be needed with time study, especially when many machines are involved.

It is convenient to express the results obtained from studies on machine utilization in the form of ratios or indices. For this purpose three indices are commonly used:

- (1) **Machine utilization index**, which is the ratio of machine running time to machine available time

and thus shows the proportion of the total working hours during which the machine has been kept running.

- (2) **Machine efficiency index**, the ratio of machine running time at standard to machine running time

A ratio of 1.0 (or 100 per cent, as it would usually be expressed) would indicate the ideal state, with the machine always performing to the best of its capability whenever it is running.

- (3) **Machine effective utilization index**, the ratio of

machine running time at standard to
machine available time

This ratio can be used to provide an indication of the scope for cost reduction that would be available if the machine were operated at full efficiency for the whole of the working time.

When work measurement has been applied throughout an organization, it is an easy matter to arrange for these indices and others like them to be reported to top management as routine at regular intervals, for they can be calculated quite simply from the records instituted to maintain labour, output and machine controls. The incidence of idle time, down time and ancillary time can be highlighted by expressing these figures as ratios in a similar way, using either machine available time or machine running time as the base.

In process industries, utilization studies are carried out in much the same way, the terms and concepts applied in the same fashion but substituting "process" or some other suitable word for "machine". The principles are exactly the same when utilization in service enterprises is considered: in a passenger transport enterprise, for example, the same useful results could be expected to accrue from studying the utilization of buses or trains and expressing the results being achieved in the form of indices similar to those described above.

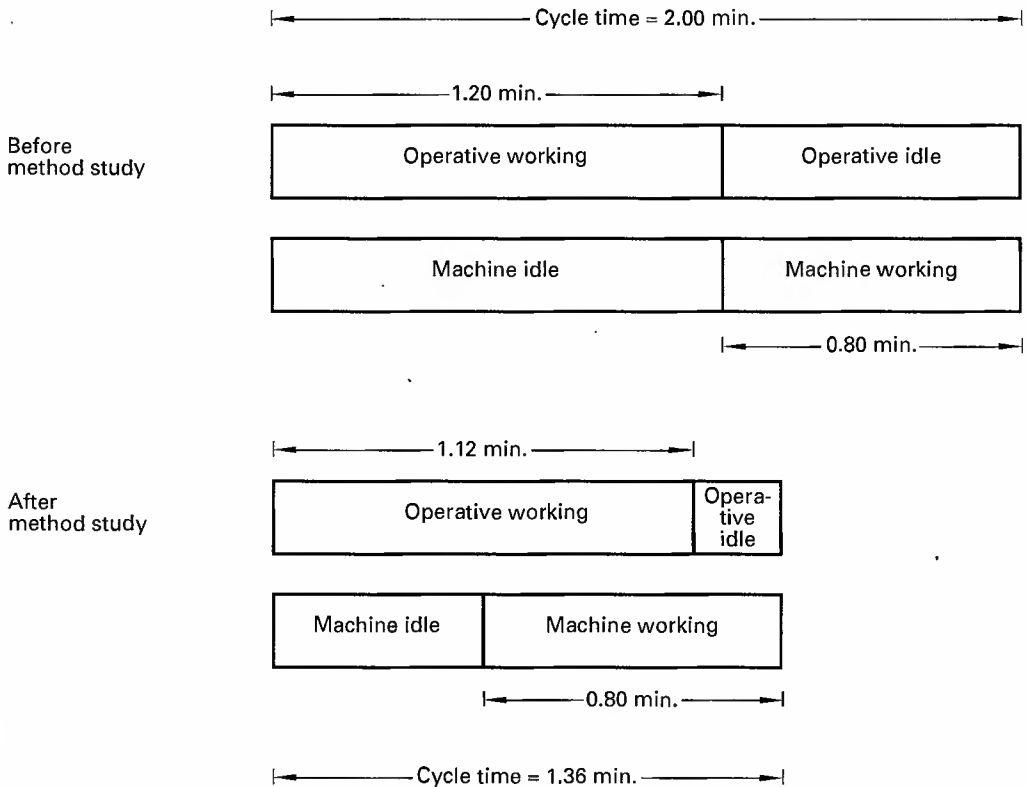
2. Restricted work

Restricted work is work in which the output of the worker is limited by factors outside the control of the worker

A common example of restricted work occurs when an operative is running a single machine and the machine works automatically for part of the work cycle. The operative may perform the manual elements of the task at standard pace, or faster, or slower; but while this will influence the rate at which the operation is completed, it will not govern it, because the time during which the machine is working automatically will remain the same whatever the worker does.

This does not mean, of course, that nothing can be done to shorten the cycle time. The example of finish-milling a casting on a vertical milling machine which was discussed in Chapter 8 (figures 41 and 42) shows what can be achieved by arranging for some of the manual elements which were formerly carried out while the machine was stopped to be done while the machine is running automatically, cutting the next casting. The reduction in cycle time achieved is shown graphically in figure 116, which compares the situation before and after the method study. (A time study on this operation is shown fully worked out in the next chapter.)

Figure 116. Result of method study on milling operation



In this example the machine element remains the same in both cases and takes 0.80 minutes but the cycle time has been reduced from 2 minutes to 1.36 minutes, a reduction of 32 per cent. In the improved method the operative needs 1.12 minutes at standard pace to perform the manual elements of the job, but some of these are carried out while the machine is working. Even if the operative were to do all the manual work at *twice* the standard pace, this would not reduce the cycle time by half, but only by some 20 per cent. Thus the output of the worker is limited by factors outside his or her control: the work is "restricted".

Other examples of restricted work occur when:

- one or more operatives are running several machines under conditions similar to those described above;
- operatives are in control of processes, their principal duties being to observe the behaviour of the processes or instruments recording their behaviour and to take action only in response to changes in behaviour, state or reading;
- two or more operatives are working as a team, dependent on one another, and it proves impossible to balance the workload of each completely, with the result that some workers are left with periods of idleness within the work cycle.

Team working can give rise to restricted work even when no machines are used. This can also occur in assembly work carried out in conjunction with moving conveyors or semi-automated processes. Even if the conveyor is used simply to transport pieces from one workstation to the next, with each operative taking a component off the belt to work on it and returning it when it is finished, a restriction may be imposed by having to wait for the next piece. Again, when assembly operations are carried out directly on the moving conveyor, as is done in motor vehicle manufacture, the conveyor produces conditions equivalent to those imposed by a static production machine.

It will be convenient to examine first the simpler case of one worker operating one machine, before considering multi-machine operation.

3. One worker and one machine

The usual way of depicting graphically and on a time scale a one-worker-and-one-machine operation is as in figure 117, which shows the improved method for the milling machine example quoted above.

The period during which the machine is working is known as the "machine-controlled time".

Machine-controlled time (or process-controlled time) is the time taken to complete that part of the work cycle which is determined only by technical factors peculiar to the machine (or process)

It will be seen that the operative carries out part of the manual work while the machine is stopped, and part while it is running. These parts are called "outside work" and "inside work", respectively.

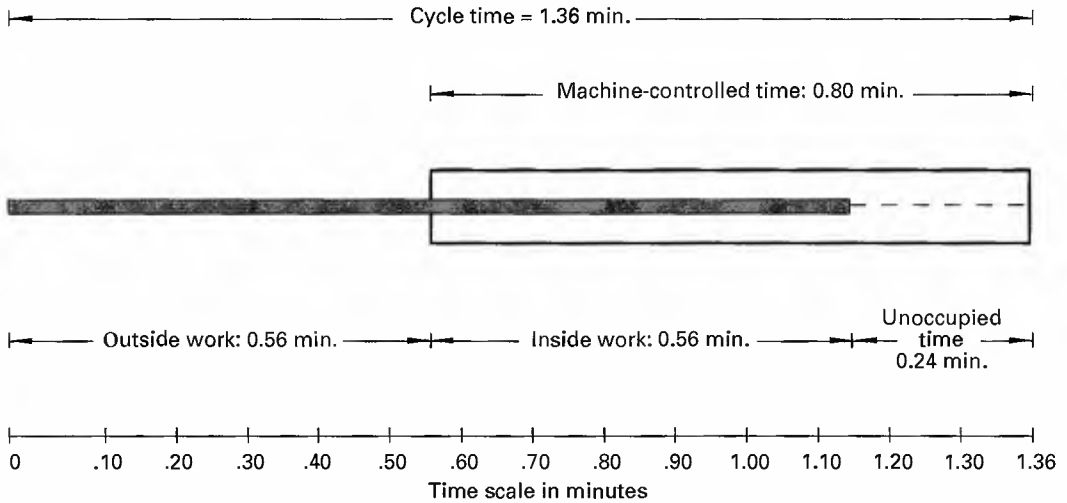
Outside work comprises elements which must necessarily be performed by a worker outside the machine- (or process-) controlled time

Inside work comprises those elements which can be performed by a worker within the machine (or process-) controlled time

Finally, there is the time during which the operative is waiting for the machine to complete the cut, i.e. "unoccupied time".

Unoccupied time comprises the periods during machine- (or process-) controlled time when a worker is neither engaged on inside work nor taking authorized rest

Figure 117. Milling operation: Improved method



Symbols

- Machine working
- Operative working
- Operative not working

In diagrams of this sort the periods of time during which the operative is working (and hence the periods of outside and inside work) are calculated and drawn at standard performance. In figure 117 no account has so far been taken of relaxation or other allowances: manual work has been calculated at standard pace and is thus shown in basic minutes. Machine-controlled time is of course shown in actual minutes, and so, using the 0-100 rating scale advocated in this book, basic minutes for manual work and actual minutes of machine operation are comparable and can be drawn to the same scale.

When unoccupied time is calculated, the working time must first have been calculated at standard performance, that is at standard pace and with proper allowance made for relaxation (the calculation of relaxation allowances is discussed below). In special circumstances the work elements associated with machine operation may be calculated at some defined rate other than standard, but we shall not be concerned with these in this book.

The diagram in figure 117 looks rather like a schematic representation of a bicycle pump, and indeed work study specialists often refer colloquially to such drawings as "pump diagrams". When seeking to improve the method the work study person follows two main approaches. First, he or she tries to "push the handle down into the pump" — that is, to arrange for some of the manual elements which are being performed outside the machine-controlled time to be carried out as inside work, thus shortening the work cycle (this has been done

in the present example). Second, close attention is given to “shrinking the pump” — making the machine-controlled time as short as possible by ensuring that the machine is being used to the best advantage, to the correct speeds and feeds, and using cutting tools which are correctly ground and made of the best type of cutting steel for the sort of work in hand, so that the machine-running time is machine-running time at standard.

4. Calculation of relaxation allowances

In restricted work it is essential that the personal needs allowance and the fatigue allowance be calculated quite separately. The reason for this is that the personal needs allowance has to be calculated not simply on the elements of manual work contained in the work cycle but on the whole of the cycle time, including the machine-controlled time. This is because the percentage figures for the allowance are based on time spent at the workplace rather than on the time actually devoted to work. Fatigue allowance, on the other hand, is necessitated by work and is calculated on the basic minutes of work actually performed.

Apart from this difference, relaxation allowance is calculated in exactly the same way as was described in Chapter 23.

This is not the end of the matter, however. When the allowance has been calculated, it is next necessary to consider whether the operative can be expected to take any or all of it within the work cycle or whether it must be added to the sum of outside work plus machine-controlled time to derive the true cycle time.

If the work cycle is a very long one, and there are lengthy periods of unoccupied time within it, it may be possible in certain circumstances for the whole of the personal needs allowance and the fatigue allowance to be taken within the cycle, during the time when the operative is not working. Such periods can only be considered adequate for personal needs allowance if they are long enough (say, ten or 15 minutes), if they occur in an unbroken stretch, and if it is possible for the operative to leave the machine unattended meanwhile. This may be done safely if the machine has an auto-stop mechanism and needs no attention whatsoever while it is running; alternatively, when groups of operatives work together it is sometimes possible to arrange for neighbouring workers to use some of their own unoccupied time in giving attention to the absent worker's machine. In many industries in which the processing machinery is run continuously, perhaps 24 hours a day, it is common to provide “floating” workers who can fill in at workstations for odd moments and can help to keep the machines running during short meal breaks if these are taken at staggered times.

It is much more usual, however, especially with cycles of short duration, for the whole of the personal needs allowance to be taken outside the working cycle. In the milling example which has been illustrated above and which has a cycle time of 1.36 minutes, it would obviously be impossible for the operative to take any of his or her personal needs allowance within the cycle.

Fatigue allowance is a rather different matter. Quite short periods of unoccupied time can be used for recovery from fatigue, provided that the operative can truly relax during them and is not required to be constantly on the alert or to give attention to the machine during them, and that there is a seat nearby. It is generally considered that any period of 0.50 minutes or less is too short to be counted as available for relaxation, and that any unbroken period of 1.5 minutes or longer can be reckoned as fully available for recovery from fatigue. Periods of 0.50 minutes or less would thus be disregarded. For periods of between 0.50 and 1.50 minutes, it is common to calculate the time which may be considered as effectively available for relaxation by deducting 0.50 minutes from the actual length of the period and multiplying the result by 1.5. The effect of applying this calculation to four periods between 0.50 and 1.50 minutes is shown below:

<i>Actual unbroken period of unoccupied time (min.)</i>	<i>Time calculated as effectively available for recovery from fatigue (min.)</i>
0.50	nil
1.00	0.75
1.25	1.12
1.50	1.50

In the milling machine example, the length of time during which the operative was not working was only 0.24 minutes, which is too short to be taken into account for relaxation. In this particular example the inside work was performed in one unbroken stretch of 0.56 minutes, but it is quite common in machine operations for the workers to have to make adjustments or attend to the machine at intervals, or perhaps carry out manual elements on other workpieces from time to time while the machine is working, so that within the machine-controlled time there will be separated periods of inside work and unoccupied time.

Even where the periods of time available are long enough to be considered as suitable for taking fatigue allowance, other factors may complicate the situation. For example, in a "hostile" environment (heat, cold, noise, dust, vibration) workers may be unable to escape from the effect of the environment even though they may not be actually working. In such situations it is necessary to introduce a formal work-rest regime in which relaxation allowances are consolidated into periods long enough for workers to recover away from the place of work.

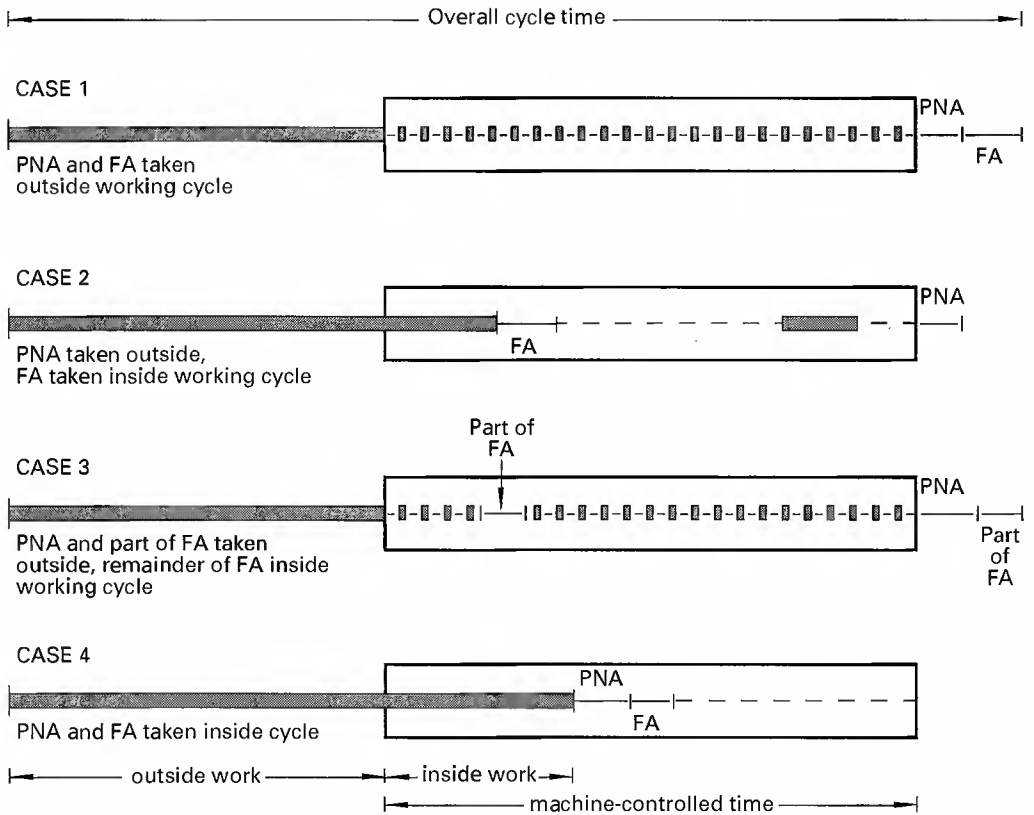
The length of the cycle and the manner in which any inside work occurs thus both affect the way in which relaxation allowance must be treated. Four cases can be distinguished:

- (1) All the personal needs allowance and all the fatigue allowance must be taken outside the working cycle.
- (2) The personal needs allowance must be taken outside the cycle, but all the fatigue allowance can be taken within it.
- (3) The personal needs allowance and some of the fatigue allowance must be taken outside the cycle, but the rest of the fatigue allowance can be taken within it.

- (4) All the personal needs allowance and all the fatigue allowance can be taken within the working cycle.

The effect of these four cases for four different operation sequences is illustrated in figure 118. All the four operations have the following characteristics in common.

Figure 118. Four operations with machine elements



In case 3 there is a period of 1.0 minute within the machine-controlled time when the operative is not working. By using the method of calculation described above, 0.75 minutes of this is considered to be available for recovery from fatigue, so that the remaining 0.75 minutes of the fatigue allowance has to be taken outside the working cycle. In case 4 the assumption has been made that a neighbouring worker could attend to the operation if it should be necessary for the operative to leave the workstation for longer than the ten minutes of non-working time available during the machine element.

It will be seen that the **overall cycle time** differs in each of the four cases, so that the number of units of output which could be expected over an eight-hour day also differs:

	<i>Overall cycle time (min.)</i>	<i>Anticipated daily output (units)</i>
Case 1	27.75	17.3 say, 17
Case 2	26.25	18.3 say, 18
Case 3	27.00	17.7 with overtime, 18
Case 4	25.00	19.2 say, 19

The **overall cycle time** is the total time in which the job should be completed at standard performance, and is made up (in the case of operations of the types so far discussed) of outside work at standard pace, machine-controlled time, and any portion of the relaxation allowance which has to be allowed outside the machine-controlled time. If there are no other allowances to be taken into account (e.g. contingency allowance), and an allowance is made for unoccupied time in actual minutes, the overall cycle time will be numerically equal to the standard time for the operation.

5. Unoccupied time allowance

In the construction of scale diagrams representing restricted work cycles, such as those illustrated in figures 117 and 118, it is usual to show all the manual elements at the times they would take if performed at standard pace. This is convenient for method study, and for the calculations needed to determine relaxation allowances and how they may properly be allocated, after which overall cycle times and hence anticipated outputs may be calculated.

The next step is to calculate the total period of any unoccupied time, in actual minutes. For operations of the types discussed, unoccupied time is calculated by subtracting from the machine-controlled time the sum of all periods of inside work, in basic minutes, plus any part of the relaxation allowance which may be taken within the machine-controlled time. It should be particularly noted that for the calculation of unoccupied time all work elements must be calculated at standard pace.

Standard times for jobs or operations are calculated on the basis of the work done by operatives — that is, the manual work content of the job — not that done by machines. For a job made up solely of manual elements (unrestricted work), the standard time is essentially a measure of the work which the job contains. With restricted work, however, the standard time expresses something more than this. It will be recalled that the definition of standard time is as follows:

Standard time is the total time in which a job should be completed at standard performance

In order to compile the standard time for a restricted operation, therefore, it is not sufficient simply to calculate the work content (inclusive of relaxation

allowances, and the work portion of any contingency allowance considered appropriate), adding to this perhaps some small further contingency allowance for delays. It is necessary to add an allowance for any unavoidable unoccupied time which may be experienced during the machine- (or process-) controlled time.

Unoccupied time allowance is an allowance made to a worker when there is unoccupied time during machine- (or process-) controlled time

Before the allowance is made, the work study person must first be satisfied that the unoccupied time is truly unavoidable and cannot be reduced further by method improvement or by a reallocation of work or machines. It was noted earlier that it may be sound management practice to accept a certain amount of unoccupied time if, by so doing, costly machines can be kept more fully employed, because in restricted work machine utilization is often more important than labour productivity.

Unoccupied time allowance is made in actual minutes.

Payment for unoccupied time

When standard times are used as a basis for payment-by-results schemes, the inclusion of unoccupied time allowances in standard times for restricted work may give rise to payment anomalies, unless special measures are taken to deal with the problems which arise.

The sort of difficulty which can occur is most easily seen by considering an example. Let us assume that in a given enterprise there are three jobs, for each of which the standard time has been calculated as 100 minutes. The first job is made up wholly of manual elements. The other two are both restricted operations, and for both the standard times include allowances for unoccupied time — say, 15 minutes in one case, and 45 minutes in the other.

If all three workers perform the manual elements of their tasks at standard pace and all take exactly the allotted relaxation periods, all three jobs will be completed in the same time (100 minutes). But the operative on unrestricted work will have been working all the time (except, of course, for the relaxation period) while the other two will have been idle for 15 and 45 minutes respectively. If payment is made for unoccupied time at the same rate as that for working time, the more heavily loaded workers will soon become discontented; jobs will become known as “good” jobs or “bad” jobs according to the amount of unoccupied time they contain; and there will be reluctance to undertake tasks with the higher work content.

Usually this difficulty is dealt with not by modifying the standard times but by establishing different rates of payment for work and for idle time. To enable this to be done, it is usual to express standard times not only as totals but also as work credits plus idle time credits (or in similar terms).

Thus, in the example cited above, the standard time (100 minutes in each instance) would be shown as being made up of 100, 85 and 55 work credits plus 0, 15 and 45 idle time credits respectively. It may be noted in passing that idle time credits included in a standard time may be allocated for reasons other than unoccupied time as discussed above. Idle time credits may sometimes be necessary to compensate for delays caused by waiting for work or for instructions, or by machine breakdowns.

The scheme to be adopted to make differential payments for work and for idle time in a particular enterprise is properly a matter of wages administration, rather than of time study practice, and is thus outside the scope of this introductory book. It may be noted, however, that any such scheme should be simple to understand, so that the workers may readily comprehend why jobs taking the same time to complete attract different payments. The scheme should be negotiated and agreed with the workers' representatives before it is applied. In a typical scheme, idle time credits amounting in total to less than 5 per cent of the work credits may be paid for at the same rate as work credits; idle time amounting to 40 per cent or more of the work credits at three-quarters of the rate of working; and idle times between 5 and 40 per cent at varying rates in between.

The scheme which will be most appropriate for a particular organization will depend on local circumstances, and especially on whether jobs with large amounts of unoccupied time are exceptional or common. Sometimes variable rates which have to be read off a curve are adopted, but in general a linear relationship is to be preferred, and always one which is simple.

The time study person is concerned primarily with measuring the amount of time needed to complete a job or operation, rather than with whatever arrangements are agreed for making payment for that time. It is common in industrial wage agreements to take account of different levels of skill required for different operations, by paying differing rates per minute or per hour of work. Other factors may also be taken into account in setting payment rates. None of these matters will affect the calculation of any unoccupied time allowance which may be necessary to compile the standard time for a job. The time allowance will be in minutes or hours: payment for those minutes or hours will be negotiable quite separately.

In the scheme mentioned above, relatively long periods of unoccupied time are paid for at lower rates than those paid for working. In some circumstances, however, it may be appropriate to pay for both working time and unoccupied time at very high rates indeed, in which case the payment actually made to a particular operative for a minute of unoccupied time may be greater than that paid to another for a minute spent working.

An example is the final machining of a shaft for a turbine-driven electricity generating set. Such a shaft may be several metres in length, and by the time the last stages of machining are undertaken the component will represent a large investment, in terms of both labour and the costly materials of which it is made. A faulty cut may result in a diameter becoming undersize, with the result that the whole shaft would have to be scrapped. The operative is thus burdened with a very heavy responsibility, although the actual operation

itself is not particularly complex. Because of this responsibility the rates paid to the operative, both for working and for any necessarily unoccupied time, may be higher than those for the general run of turning operations. Similar “key” operations or tasks occur in many industries and working situations.

6. Multiple machine work

Multiple machine work is work which requires the worker to attend two or more machines (of similar or different kinds) running simultaneously

In section 3 of this chapter the simple case of one worker and one machine was examined. Frequently, however, workers are called upon to look after more than one machine — perhaps many machines — and this poses special problems in time study work. A common example is that of the weaving shed in a textile mill, where a worker may attend anything from four to 40 looms (perhaps even more), depending on the type of loom installed and the characteristics of the cloth being woven. Similar circumstances are often encountered in engineering industries, for example when workers operate batteries of screw-making or coil-winding machines. It is usual in work situations of this sort for the machines to be equipped with automatic cut-out devices which bring them to a standstill when their tasks are completed or when breaks or malfunctioning occur.

Tasks of this sort are all examples of restricted work, as the output of the worker may be limited by factors outside his or her control. So too are team operations, whether the team of workers is concerned with the operation of a single machine, with several machines or indeed with no machines at all, since restrictions can be imposed by lack of balance in the amounts of manual work which have to be performed by different members of the team.

Load factor

The load factor is the proportion of the overall cycle time required by the worker to carry out the necessary work at standard performance, during a machine- (or process-) controlled cycle

The load factor is sometimes known by the alternative terms “extent occupied” or “workload”. In the simplest case of one person operating one machine, as illustrated in figures 117 and 118, if the overall cycle time is ten minutes and the amount of manual work contained within the cycle totals only one standard minute, the load factor would be one-tenth, or 10 per cent.

The reciprocal of the load factor therefore indicates the number of machines which the worker could theoretically tend: in this example, ten machines. In practice, other factors have to be taken into account, so that the load factor can be taken only as a very rough first indication of the number of machines which can usefully be allocated to a worker. It does sometimes occur that the work elements consist solely of unloading finished pieces from machines which have stopped automatically, loading fresh pieces and restarting the machines; and if all the machines are alike and are working on exactly similar pieces, it may be possible to achieve the ideal sequence of operation, with the worker able to operate the number of machines indicated by the reciprocal of the load factor. Much more commonly, however, differences occur in the machines or in the work, and frequently attention has to be given to the machines while they are running, with the result that the worker cannot always get to a machine at the exact moment when attention is needed. The delays which then occur are known as **machine interference**.

Machine interference

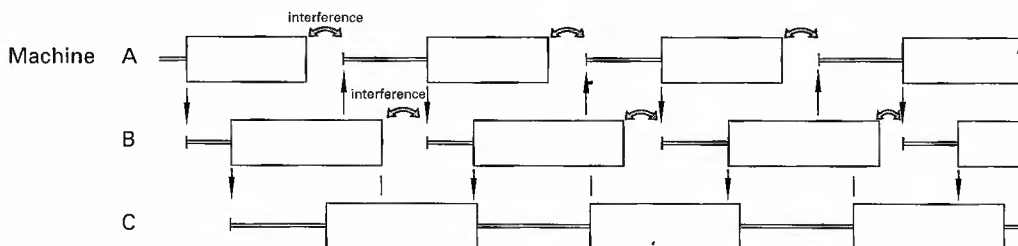
Machine interference is the queuing of machines (or processes) for attention — e.g. when one worker is responsible for attending to more than one machine. Similar circumstances arise in team work where random delays at any point may affect the output of the team

When studying multiple machine working or team working (with or without machines), the work study person has first to examine the methods of working with the object of devising a sequence of operations which will result in the best balance and thus the least interference, and then to use time study techniques to measure the amount of interference which will occur even when the best sequence has been determined. These tasks may sometimes be extremely complicated. They often call for the use of specialized methods which are beyond the scope of this book.

If there are only a few workers in the team, or if one or two workers are operating only a few machines between them, simpler methods will suffice. Operation sequences can be plotted and examined on multiple activity charts (described in Chapter 8), supplemented by cycle diagrams similar to those shown in figures 117 and 118. The diagrams for each machine are drawn one below the other, to the same time scale. A simple example, that of an operative working three machines, is shown in figure 119.

In this example there is no inside work, so that when a machine has been started the operative's attention can be turned to another. The sequence in which this is done is indicated by the small vertical arrows. It will be seen that, with this particular routine, machine C is operated without any delays occurring; but the result of doing this is that both machine A and machine B

Figure 119. Machine interference



switch themselves off at the end of their respective operations and then have to wait a while before the operative can get to them. The interference is indicated on the cycle diagrams for machines A and B by grey arcs.

Interference allowance

An interference allowance is an allowance of time for production unavoidably lost through synchronization of stoppages on two or more machines (or processes) attended by one worker. Similar circumstances arise in team work

By extending the methods so far described, using the same charting conventions and principles, it is possible to establish work sequences and to calculate interference for a fairly wide range of multiple machine operations, including many which will be met with in the engineering and allied industries, and especially those in which machine stoppages occur in regular, predictable fashion rather than at random. In coil-winding, for example, the winding machines switch themselves off when the coil is completed, and contingencies (such as wire breaks) are rare.

For these simpler forms of multiple machine operation, when an operative has only a few machines to look after and the work being done is of a cyclic nature, with definite beginnings and ends of the work cycles, standard times may be calculated and expressed exactly as for unrestricted work: that is, as so many standard minutes (or hours) per piece, per job or per operation. This is quite common in engineering machine shop operations, especially when workers operate several machines in sequence. For these situations standard times are compiled as described earlier in this book, on the basis of the work content for each job or operation. **There is no need to consider machine interference when compiling the standard times**, though it may be necessary to take this into account when making output predictions and other production control calculations. It will be necessary, however, to provide allowances in the standard times for any **unavoidable unoccupied time** which may be experienced as a result of working with the machines, and this too may be done as described above.

When output is continuous rather than cyclic, and especially in process industries, it is more usual to establish standard times for some convenient **volume, weight, or length of output**, rather than per piece or per operation. Thus, in weaving, the standard times may be compiled and expressed as so many standard minutes per 100 metres of cloth woven (this is in fact one of several ways of stating time standards for weaving). When this is done, the focus is shifted from the amount of manual work contained in the operation to the output which may be expected from the machines, though output calculations must of course take into account the quantity of manual work involved in tending the machines. Unoccupied time is of interest, and almost always has to be determined, not for the purpose of making an allowance in the standard time but rather as an indication of the number of machines which a worker can attend. **For the calculation of standard times the allowance which has to be taken into account is interference allowance** — the times during which some of the machines will be stopped while waiting for the operative to get to them.

A case in point is that of a weaver looking after a set of looms. Stoppages in the weaving operation depend upon many circumstances. The strength of the yarn, and hence the frequency of breakages, is influenced by the way the materials forming the warp and weft have been prepared, and also by the temperature and humidity within the weaving shed, both of which may change markedly from time to time during a shift. The state of maintenance of the looms also affects stoppages, while the speed and skill of the weaver have a further influence, since a skilled operative can often prevent stoppages by anticipating trouble and taking preventive action.

In circumstances such as these, it is necessary to evaluate unoccupied time (for work loading and team balancing) and interference (for compiling standard times) by extended studies on the plant floor, covering all the different working conditions and all the different counts of yarn (in weaving) or different materials which have to be worked on. Studies may have to continue for days or weeks, or sometimes extend over several months. Work sampling is an appropriate technique to use for this purpose, and was originally developed expressly for textile operations. It is much more economical than time study, which would be much too long-winded and detailed for this type of observation in any but the smallest plants. Using work sampling, for example, a study person in a weaving department can record all the information needed while observing the operation of ten or 12 looms, which would be impossible with ordinary time study practice.

In a book of this nature it is not possible to cover in detail the specialized methods which are adopted in advanced work study practice to evaluate interference and to calculate interference allowances in complex multiple machine situations. For the most part, these methods are based on statistical procedures and probability theory, and are intended to permit reliable predictions to be made without recourse to either time study or work sampling. For this purpose a number of formulae, curves and sets of tables have been compiled to assist in the determination of interference, and hence probable output, for various worker/machine combinations. The systems, if used with

care, offer the prospect of considerable economy of study time in certain specialized, but complex, multiple machine and teamwork situations. It is essential, however, that any predictions made on the basis of formulae and tables should be validated by direct study at the workplace, so that full account may be taken of local working conditions.

The time study methods described earlier in this chapter, together with work sampling (as described in Chapter 19), will usually be found adequate for the calculation of reliable time standards for the majority of the machine working situations likely to be encountered in general industrial practice. Those readers who are faced with the task of determining standards for complex multiple machine operations may find it useful to consult more advanced texts. It is recommended, however, that the more specialized methods should not be attempted until the work study person has had sufficient experience of both time and work sampling to be sure of being able to use these techniques to verify any statistical predictions made.

* * *

In the next chapter an example of a fully worked time study is shown. The study is one taken on the operation of milling a casting, which was the subject charted on a multiple activity chart on Chapter 8, and for which a cycle diagram appears in section 3 of the present chapter.

Example of a time study

In discussing the making of a time study throughout the previous four chapters we referred to the example based on the milling of a casting which was the subject of the multiple activity chart described in Chapter 8. The complete time study is shown in this chapter. A careful study of the forms shown in the illustrations should enable the reader to follow in detail the processes by which a time study is worked up and a standard time is compiled.

This particular example has been chosen because:

- it is simple;
- it has already been the subject of a method study;
- it includes both manual and machine elements;
- it is typical of the sort of operation met everywhere in the engineering industry and in other industries using machines and semi-automatic processes.

The forms used are simple general-purpose forms such as those illustrated in Chapter 20. Although all the entries made on the forms in this particular example will be handwritten, it is usual to space the lines for use with a typewriter because occasions may arise on which it is required to produce fair copies of original studies for discussion or circulation.

The study illustrated in this chapter was not the first one on this operation. The elements and break points were defined at the time the method study was undertaken, and were then set out on a card prepared and filed by the work study department. This is a useful practice when it is expected that an operation will be studied several times, perhaps by different study persons. It ensures that the recordings made on all the studies are comparable. The elements and break points are shown in figure 120. Figure 121 shows a sketch of a part and the workplace layout.

Although the example which has been studied in detail is a simple one for a manufacturing industry, exactly the same procedure is carried out for non-manufacturing operations or for any other work which is time-studied for the purpose of setting time standards. Entirely manual operations, such as assembly, would be treated in exactly the same way.

Figure 120. Card giving details of elements and break points

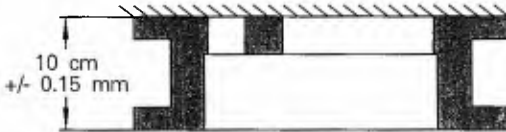
Card No. 1264	
<i>Part:</i> B.239 Gear case	<i>Drawing:</i> 239/1
<i>Material:</i> ISS 2 Cast iron	
<i>Operation:</i> Finish-mill second face	
<i>Machine:</i> No. 4 Cincinnati vertical miller	
<i>Fixture:</i> F.239	
<i>Cutter:</i> 25 cm. TLF	
<i>Gauge:</i> 239/7. Surface plate	
Elements and break points	
<p>A. Pick up casting, locate in fixture, lock two nuts, set guard, start machine and auto feed. Depth of cut 2.5 mm. Speed 80 r.p.m. Feed 40 cm/min. <i>Break point:</i> Machine commences cut.</p> <p>B. Hold casting, break milled edge with file, clean with compressed air. <i>Break point:</i> Air gun dropped on to hook.</p> <p>C. Move depth gauge to casting, check machined surface, move gauge away. <i>Break point:</i> Left hand releases gauge.</p> <p>D. Pick up machined casting, carry to finished parts box and place aside, pick up next part and position on machine table. <i>Break point:</i> Casting hits table.</p> <p>E. Wait for machine to complete cut. <i>Break point:</i> Machine ceases to cut.</p> <p>F. Stop machine, return table, open guard, unlock fixture, remove machined casting and place on surface plate. <i>Break point:</i> Casting hits surface plate.</p> <p>G. Clear swarf from machine table with compressed air. <i>Break point:</i> Air gun dropped on to hook.</p>	

Note: Elements B, C and D are inside work, and are performed on a casting which has already been machined while the milling machine is cutting the next casting. Element D includes bringing up into a handy position a fresh casting which will be machined after the one now in the machine.

Figure 121. Sketch of part and of workplace layout

A sketch of the workplace layout is generally more necessary in assembly or material-handling studies than in studies of machine shop operations where workplaces are likely to be the same for all jobs on the machines. The part should be sketched showing the surfaces machined: in the case of capstan lathes, tool set-ups should be included. This is best done on squared paper and may be on the back of the time study top sheet, if desired, in order to keep all the information relevant to the study on one sheet. To facilitate sketching, the reverse of the top sheet is often printed as squared paper.

(a) Sketch of gear-case casting showing surface to be machined and dimension



(b) Layout of workplace

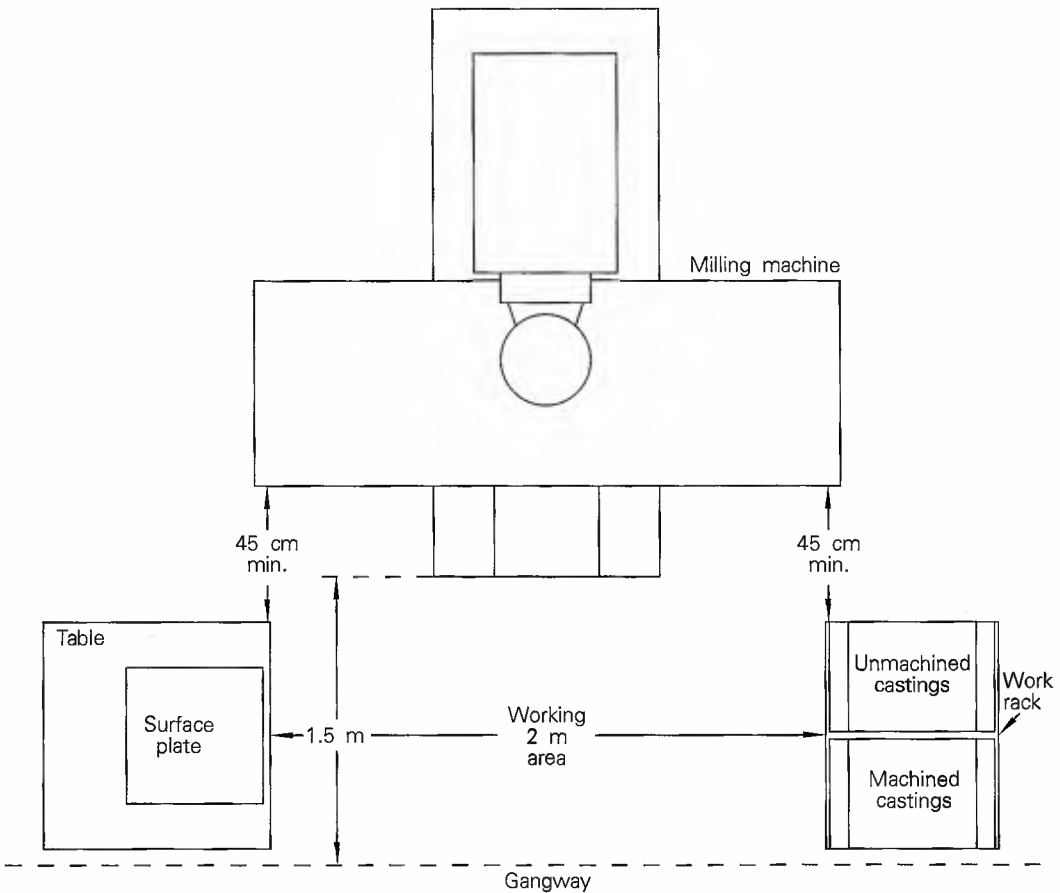


Figure 122. Time study top sheet

All the information in the heading block at the top of the time study top sheet — figure 122 — (except time off and elapsed time) was entered before the stop-watch was started and study commenced.

If the study had been the first one on this operation, the study person would have entered in full the element descriptions and break points in the column headed “Element description” on the left-hand side of the page. In the present instance this was not necessary, as the card shown in figure 120 listed all the details. The study person should watch a few cycles of the operation to make sure that the listed method is being used, and to become familiar with the break points, before starting to record. The elements were identified simply by the letters A to G.

At exactly 9.47 a.m. by the study office clock (or the study person’s wrist-watch) the stop-watch was started. It ran for 1.72 minutes before element A of the first cycle started, so this time is entered at the beginning of the study as the “Time before”. Since this was a study using cumulative timing, the watch ran continuously throughout. When the study was broken off after observing 18 cycles, the study person allowed the stop-watch to run on until the study office clock reached the next full minute (at 10.25 a.m.), noted the “Time after”, and stopped the stop-watch. These terminal entries will be found at the end of the recordings in figure 124.

The four columns used in cumulative timing are respectively “Rating” (R), “Watch reading” (WR), “Subtracted time” (ST) and “Basic time” (BT). The placing of the rating column first is logical and encourages the observer to rate while the element is in progress and not to wait for the watch reading. If flyback timing had been used, the WR column on the form would not be necessary.

Only the entries in the two columns headed R and WR were made during observations at the workplace. The other two columns were completed in the study office after observations had been discontinued. In practice, the “Rating” and “Watch reading” entries would be made in pencil while those in the “Subtracted time” and “Basic time” columns would be made in ink or with a pencil of a different colour from that used for the observations.

The study person numbered the cycles observed, from 1 to 18, with ringed figures at the left of the “Element description” column.

When entering watch readings there is no need to use decimal points. The first entry (Time before, 172) indicates a time of 1.72 minutes. The next watch reading was made 1.95 minutes after the watch was started, but it is only necessary to enter 95. The third entry of 220 indicates that the reading was made at 2.20 minutes after starting; the entries then revert to two figures only until the next minute is passed. During cycle number 15 (recorded on figure 124) the total study time passed 30 minutes, which is the time taken by the hand on the small inner dial on the watch to complete one revolution. As the study continued into a further revolution of the small hand, subsequent watch readings revert to 1 again. It will be seen that the recording against element F of cycle 15 was 106, which of course means 31.06 minutes after the watch was started.

Element E — “Wait for machine to complete cut” — is not work, and was therefore not rated. It will be seen that there is no entry against this element in the “Basic time” column.

Time study top sheet									
Department: <i>Machine shop - Milling section</i>						Study No.: 17 Sheet No.: 1 of 5			
Operation: <i>Finish-mill second face</i>			MS No.: 9			Time off: 10.25 a.m. Time on: 9.47 a.m. Elapsed time: 38.00			
Plant/Machine: <i>Cincinnati No. 4 vertical miller</i>			No.: 26			Operative: Clock No.: 1234			
Tools and gauges: <i>Fixture F 239: Cutter 25 cm TLF Gauge 239/7: Surface plate</i>						Studied by: Date:			
Product/Part: <i>B. 239 gear case</i>			No.: 239/1			Checked:			
DWG No.: <i>B. 239/1</i>		ISS 2		Material: <i>Cast iron</i>					
Quality: <i>As drawing</i>									
<p><i>Note: Sketch the workplace layout/set-up/part on the reverse, or on a separate sheet and attach.</i></p>									
Element description	R	WR	ST	BT	Element description	R	WR	ST	BT
<i>Time before</i>	—	172	—	—	④ A	80	622	32	26
① A	110	95	23	25	B	85	50	28	24
B	100	220	25	25	C	85	63	13	11
<i>Elements & BP</i> A	100	32	12	12	D	85	83	20	17
<i>as Card No. 1264</i> D	95	52	20	19	E	—	703	20	—
E	—	77	25	—	F	105	26	23	24
F	110	300	23	25	G	85	38	12	10
G	110	08	08	09					
					⑤ A	80	70	32	26
② A	110	31	23	25	B	85	97	27	23
B	95	58	27	26	C	85	810	13	11
C	95	71	13	12	D	85	30	20	17
D	100	89	18	18	E	—	53	23	—
E	—	412	23	—	F	105	76	23	24
F	105	37	25	26	G	85	88	12	10
G	100	47	10	10					
					⑥ A	95	915	27	26
③ A	105	72	25	26	B	95	42	27	26
B	105	97	25	26	C	105	54	12	13
C	95	510	13	12	D	80	77	23	18
D	110	28	18	20	E	—	97	20	—
E	—	53	25	—	F	95	1020	23	22
F	100	78	25	25	G	100	30	10	10
G	95	90	12	11					
			418					440	

Figure 123. Time study continuation sheet (page 2)

The recordings covered three sheets in all. Figure 123 shows the first of the two continuation sheets, and it will be seen that it is numbered in the top right-hand corner: Sheet No. 2 of 5. The analysis sheet and study summary sheet eventually completed the set of five sheets, all of which were stapled together after the study was worked up.

Besides the element ratings and timings, continuing as on the top sheet, two interruptions were recorded on this sheet: "Talk to supervisor", and "Break for tea". Neither of these was rated, of course. The first was taken account of when considering contingencies, while the second was covered by the relaxation allowance made when the standard time for the operation was compiled.

Figure 124. Time study continuation sheet (page 3)

The first entry on the second continuation sheet (figure 124) recorded another interruption — the patrol inspector, having checked three workpieces, drew the operative's attention to some feature of them and discussed them. The time taken to do this, like that recorded on the previous sheet against "Talk to supervisor", was later entered as a contingency.

After cycle number 16, a fresh element of work occurred — helping the labourer to move boxes of work off and onto the truck. This was an occasional element, in contrast with elements A to G which are repetitive. The study person rated and timed the element, and it will be noted that, since the element ran on for rather over a minute in all, the study person made a rating and a watch reading at the end of each of the first two half-minutes, as well as during the last part of the element. This practice, which makes for greater accuracy, was referred to in section 9 of Chapter 21.

Back in the study office after breaking off observations, the study person first completed the "Time off" and "Elapsed time" entries in the heading block on the top sheet, and then set about calculating the subtracted times, by deducting each watch reading from the one which follows it and entering the result in the third column, headed ST. It will be seen that these subtracted times were totalled at the foot of each page, and the subtotals were carried forward to the sheet shown opposite, where they were added up to yield 35.20 minutes. When the time before and the time after were added to this figure, the result was 38.00 minutes, which agreed with the elapsed time and thus afforded a check that the work of subtraction had been done correctly.

The next step was "extension": multiplying each subtracted time by the percentage rating recorded against it to yield the basic time, entered in the fourth column. Extension is easily and quickly done with the aid of a pocket calculator. The calculation is made to the nearest second decimal place: that is, to the nearest one-hundredth of a minute. Thus 0.204 would be shown as 20, and 0.206 minutes as 21 — which leaves the problem of what to do with 0.205. Evidently, in this study office the standing rule was to take half-hundredths of a minute down rather than up, as can be seen by the entry against element G of cycle 15. Here, the rating was 105 and the subtracted time 10, so that the extension yields 0.105 minutes to three places. This has been shown as 10, the half-hundredth having been taken down. Other instances will be found in the study. Most study offices apply the reverse rule: that is, taking middle times up.

Study No.: 17		Time study continuation sheet						Sheet No. 3 of 5			
Element description		R	WR	ST	BT	Element description		R	WR	ST	BT
Patrol inspector checks						⑮	A	100	71	27	27
3 pieces: discuss		—	2966	102	—		B	100	96	25	25
							C	95	609	13	12
⑮	A	95	93	27	26		D	75	34	25	19
	B	80	3023	30	24		E	—	52	18	—
	C	100	36	13	13		F	100	77	25	25
	D	100	56	20	20		G	75	92	15	11
	E	—	74	18	—						
	F	80	106	32	26					148	
	G	105	16	10	10						
⑯	A	80	49	33	26	Watch stopped		800			
	B	85	77	28	24	10.25 a.m. (elapsed					
	C	105	89	12	13	time 38.00)					
	D	100	207	18	18	Time after				108	
	E	—	30	23	—						
	F	95	57	27	26						
	G	85	70	13	11						
	Help labourer unload	85	320	50	43						
	boxes of new castings	95	70	50	48						
	and load finished work	95	90	20	19	Check on subtracted				418	
	on truck (30 new+30					times				440	
	fin. in boxes of 10)									631	
⑰	A	100	417	27	27					1203	
	B	85	49	32	27					680	
	C	85	64	15	13					148	
	D	85	86	22	19					3520	
	E	—	509	23	—						
	F	100	34	25	25	Time before				172	
	G	105	44	10	10	Time after				108	
						Elapsed				3800	
				680							

Figure 125. Working sheet

The repetitive elements A, B, C, D, F and G were all constant elements, and selected basic times for them were obtained by averaging, as shown on the working sheet (figure 125). As was noted in Chapter 20, study analyses take several forms and for this reason it is not usual to have specially printed sheets for them. Ordinary lined or squared paper serves very well, and when the time study top sheet has been printed on the reverse as squared paper (to facilitate sketching), it will do well enough to use the back side of a top sheet, entering at the top the study and sheet numbers. For a simple study the analysis is often made straight on to the study summary sheet, a few extra columns being ruled in the space headed "Element description".

Methods of obtaining the selected basic times are discussed in Chapter 23. In this instance, inspection of the basic times tabulated under elements A, B, C, D, F and G showed no anomalies, and therefore no need to ring out "rogue" times. For each of these elements the basic times have been totalled, and the selected basic time was calculated by dividing the total by the number of observations (18).

No figures were listed under element E, "Wait for machine to complete cut". This was unoccupied time, which was not rated in the study. The actual length of unoccupied time experienced in the various cycles observed depended on the speed with which the operative carried out the inside work which was performed on another casting while the machine was cutting automatically.

The time the machine took to make the cut, while on automatic feed, did not vary from cycle to cycle because it was determined by the rate of feed at which the machine was set and the length of cut to be made. It could thus be calculated quite easily. In this study the machine-controlled time started at the end of element A and ended with the conclusion of element E. The machine-controlled time can therefore be obtained from the study sheets by subtracting the watch reading against element A from that against E. This has been done, the results being tabulated under "MCT" at the right-hand side of the working sheet. These times are of course actual minutes, not basic times.

It will be seen that two of the MCT entries have been ringed out. The study person did not enter any explanation of unusual events on the record, and inspection of the observations for the cycles in which these rogue times occurred does not provide any conclusive explanation. Possibly the explanation for the shorter time is to be found in the fact that the operative can start the cut on hand-feed before locking on the auto-feed, and on this occasion, unnoticed by the study person, a longer time was spent on hand-feed than usual. The explanation for the longer time in cycle 17 may be that the operative failed to switch the machine off quite as quickly as usual on this occasion, and again this escaped notice. The two ringed times were excluded from the total of 13.05 actual minutes for the machine-controlled times, so that this total was divided by 16 instead of 18 to derive the average MCT of 0.816.

Element E, the unoccupied time, was dealt with by subtracting the total of the selected basic times for elements B, C and D, the inside work elements, from the average MCT. The resulting figure for the average unoccupied time was 0.257 minutes.

At this stage in the calculations, it is usual to make use of three decimal places for the selected basic times, and to retain the third place on the study summary sheet and the analysis of studies sheet.

Study No.: 17		Working sheet					Sheet 4 of 5	
Element:	A	B	C	D	E	F	G	MCT
		(Basic times)						(Actual minutes)
Cycle No.								
1	25	25	12	19		25	09	82
2	25	26	12	18		26	10	81
3	26	26	12	20		25	11	81
4	26	24	11	17		24	10	81
5	26	23	11	17		24	10	83
6	26	26	13	18		22	10	82
7	26	26	12	19		26	11	81
8	28	24	13	18		29	10	82
9	26	25	12	17		28	10	81
10	21	26	12	19		24	11	82
11	29	26	11	19		25	10	82
12	26	24	12	19		27	09	72
13	27	26	13	20		24	11	82
14	26	25	13	19		26	10	82
15	26	24	13	20		26	10	81
16	26	24	13	18		26	11	81
17	27	27	13	19		25	10	92
18	27	25	12	19		25	11	81
Totals	4.69	4.52	2.20	3.35		4.57	1.84	13.05
Occasions	18	18	18	18		18	18	16
Average	0.261	0.251	0.122	0.186		0.254	0.102	0.816
		MCT = 0.816		Actual minutes				
		B+C+D = 0.559		Basic minutes				
		Element E (unoccupied) = 0.257						

Figure 126. Study summary sheet

The study summary sheet (figure 126), when completed, was stapled on top of the other four study sheets and was eventually filed with them. The sheets which have been used for recording observations at the workplace often become somewhat dirty as a result of the conditions in which they have to be used. Moreover, because of the speed with which the observations have to be written down, the study person may have used many abbreviations, and perhaps the hurried writing may be difficult for anyone except the writer to read. The study summary sheet therefore not only presents concisely all the results obtained from the study but also records in the heading block, in ink and neatly written, all the information about the operation which was originally entered on the time study top sheet.

The repetitive elements A to G, excluding E, were entered first, and it has been noted that three of these were inside work and the other three outside work. The entries in the column headed "BT" are the basic times per occasion, and were taken from the working sheet shown in figure 125. For each of these elements the frequency of occurrence is shown as 1/1, indicating that each occurred once in every cycle of the operation. The time calculated for the machine element, and hence the unoccupied time (element E), is shown below. The column headed "Obs." shows the number of observations of the element which have been taken into account in deriving selected basic times. This information will be carried to the analysis of studies sheet where it will be of use when the final selected basic times are derived for the compilation of the standard time.

Under the heading "Occasional elements and contingencies" is shown the basic time for the element of helping the labourer to load and unload boxes of castings. It is noted that this element was observed once only, and that its frequency ought to be 1/30 since three boxes of ten fresh castings were brought, and three boxes of finished castings loaded. The other two non-repetitive occurrences observed were "Talk to supervisor", and "Inspector checks three pieces and discusses". Neither of these periods was rated, so the times are shown in actual minutes (a.m.).

Finally, the study person recorded, in actual minutes, the amount of relaxation taken during the period of the study.

Basic times were entered to the third decimal place, and have been carried forward in this form to the analysis of studies sheet (figure 127). It may be thought that this is a degree of refinement which is not warranted in view of the accuracy of the data on which the entries are based. There is a good reason for the practice, however. If it is eventually decided to make the final selection of basic times, on the analysis of studies sheet, by the process of averaging, each of the entries from this study will be multiplied by the corresponding number of observations to yield the total basic minutes observed for the element. The totals from all the studies taken on this operation will be added, and an average obtained by dividing by the aggregate number of observations. At that stage, when the whole chain of arithmetical calculations has been completed, the final selections will be expressed to the nearest second decimal place only, that is to the nearest one-hundredth of a minute.

Study summary sheet					
Department: <i>Machine shop</i>		Section: <i>Milling</i>		Study No.: 17 Sheet No.: 5 of 5	
Operation: <i>Finish mill second face</i>		MS No.: 9		Date:	
Plant/Machine: <i>Cincinnati No. 4 vertical miller</i>		No.: 26 <i>25 cm TLF cutter</i>		Time off:	<i>10.25 a.m.</i>
Tools and gauges: <i>Fixture F.239</i>		<i>Gauge 239/7 Surface plate</i>		Time on:	<i>9.47</i>
Product/Part: <i>B.239 gear case</i>		No.:		Elapsed time:	<i>38.00</i>
DWG No.: <i>B.239/1</i>		Material: <i>Cast iron to ISS2</i>		Check time:	<i>2.80</i>
Quality: <i>as dwg</i>		Working conditions: <i>m/c 9 cutter OK; light good</i>		Net time:	<i>35.20</i>
Operative: M/F Clock No.: 1234				Obs. time:	<i>35.20</i>
				Unacc. time:	—
				UT as %	—
				Studied by:	
				Checked:	
Sketch and notes on back of sheet 1.					
El. No.	Element description	BT	F	Obs.	
	<i>Repetitive</i>				
A	<i>Outside work</i>	<i>0.261</i>	<i>1/1</i>	<i>18</i>	
B	<i>Inside work</i>	<i>0.251</i>	<i>1/1</i>	<i>18</i>	
C	<i>As card No. 1264 Inside work</i>	<i>0.122</i>	<i>1/1</i>	<i>18</i>	
D	<i>Inside work</i>	<i>0.186</i>	<i>1/1</i>	<i>18</i>	
F	<i>Outside work</i>	<i>0.254</i>	<i>1/1</i>	<i>18</i>	
G	<i>Outside work</i>	<i>0.104</i>	<i>1/1</i>	<i>18</i>	
	<i>Machine element</i>	<i>0.816</i>	<i>1/1</i>	<i>16</i>	
E	<i>Unoccupied time within MCT</i>	<i>0.257</i>	<i>1/1</i>	<i>18</i>	
	<i>Occasional elements and contingencies</i>				
	<i>Help unload boxes of new castings and load boxes of finished castings to truck</i>	<i>1.100</i>		<i>1</i>	<i>Freq. 1/30 castings (boxes hold 10 castings)</i>
	<i>(outside work)</i>				
	<i>Talk to supervisor (OW) (a.m.)</i>	<i>0.400</i>	<i>1/18</i>	<i>obs.</i>	
	<i>Inspector checks 3 pieces and discusses (a.m.)</i>	<i>1.020</i>	<i>1/18</i>	<i>obs.</i>	
	<i>(OW)</i>				
	<i>Relaxation time (a.m.)</i>	<i>6.120</i>			

Figure 127. Extract from the analysis of studies sheet

As each time study on the operation was worked up and summarized, the entries from the study summary sheet were transferred to an analysis of studies sheet as illustrated in figure 127. These sheets are often printed on paper of A3 or double foolscap size or larger, and so only a portion of the whole sheet is reproduced.

It will be seen that five studies were made in all on this operation, a total of 92 cycles being observed. The work of three different operatives was studied by four different study persons. Standard times for regular machine shop operations are usually compiled from predetermined time standards (see Chapter 26), and when a considerable body of data has been built up it is often possible to derive accurate time standards with fewer studies, or by observing a smaller number of cycles of the operation.

Inspection of the study results for the elements A, B, C, D, F and G indicated normal consistency, with no reading suggesting a need for further investigation. The work of proceeding to the final selected basic times for the elements was therefore undertaken next. The selection was made by taking the weighted average for each element. All the repetitive elements were constant elements, so that there was no need for graphical presentation. In the first of the four columns in the block at the right-hand side of the sheet, the total basic time was entered against each element. Dividing these totals by 92, the aggregate number of cycles, yielded the figures for basic minutes per occasion, entered in the next column. These are now shown to the second decimal place only; that is, to the nearest one-hundredth of a minute.

The third column records the frequency of occurrence per cycle — for all the repetitive elements 1/1 — and thus the entries in the last column, which show the basic minutes per cycle, are for this operation the same as those in the second column of the right-hand block. The unoccupied time, element E, has been arrived at in the same manner as on the study summary, by deducting the sum of the inside work basic minutes from the machine-controlled time. Usually the unoccupied time would not be evaluated until after relaxation allowance had been added to the work elements, but in this instance, as is indicated when discussing these allowances on page 376 (figure 128), there was no need for such a refinement.

The occasional element “Help labourer” was observed on three occasions only, in three different studies. Since it is known that the truck carries three boxes each containing ten castings, it is clear that the frequency with which this element will occur is once every 30 castings, or cycles. The average basic time per occasion was therefore divided by 30 to yield the basic time per cycle of 0.04 minutes.

“Talk to supervisor” was dealt with by dividing the total time observed by the 92 cycles observed, giving a time of 0.01 minutes per cycle. The “Inspector checks” element was treated similarly, though in this instance as it was learned from the supervisor that the inspector’s duty was to check three castings in every 100 the frequency has been taken as 1/100. These two very small periods of time, both entered in actual minutes, were eventually considered to be best dealt with as contingencies and were covered by the contingency allowance given.

		Study No.:	3	9	17	25	28	Totals	Selected basic time per occasion	Frequency of occurrence per cycle	Basic minutes per cycle
		Date:	27/4	1/5	4/5	7/5	11/5				
		Operative:	CAA	TBN	CAA	TBN	CRW				
		Clock No.:	1234	1547	1234	1547	1846				
		Machine No.:	26	34	26	127	71				
		Study taken by:	BDM	CEP	MN	DFS	BDM				
		No. of cycles studied:	15	26	18	13	20	Cycles 92			
El. No.	Elements	Basic time per occasion					BT	BM		BM	
A	<i>P/U casting, locate, lock, set on</i>	0.276	0.257	0.261	0.270	0.281	24.645	0.27	1/1	0.27	
B	<i>Hold, break milled edge, clean</i>	0.240	0.266	0.251	0.252	0.244	23.305	0.25	1/1	0.25	
C	<i>Gauge</i>	0.114	0.127	0.122	0.128	0.111	11.089	0.12	1/1	0.12	
D	<i>Aside finished part, position new</i>	0.197	0.196	0.186	0.191	0.180	17.485	0.19	1/1	0.19	
E	<i>Wait m/c (actual minutes)</i>	0.264	0.222	0.257	0.253	0.275			1/1	0.26	
F	<i>Stop m/c, unlock, aside part</i>	0.271	0.270	0.254	0.250	0.245	23.820	0.26	1/1	0.26	
G	<i>Clear swarf</i>	0.096	0.112	0.104	0.090	0.092	9.240	0.10	1/1	0.10	
	<i>Machine-controlled time (actual minutes)</i>	0.821	0.811	0.816	0.824	0.810	75.000	0.82	1/1	0.82	
	<i>Help labourer U/L and load boxes of castings</i>	-	-	1.100 (1 occ.)	1.420 (1 occ.)	1.310 (1 occ.)	3.830	1.28	1/30	0:04	
	<i>Talk to supervisor (actual minutes)</i>	1.140	-	0.400	0.870	-	2.410	0.80	1/92	0.01	
	<i>Inspector checks, discuss (a.m.)</i>	-	1.470 (1 occ.)	1.020 (1 occ.)	-	1.770 (1 occ.)	4.260	1.42	1/100	0.01	

Figure 128. Calculation of relaxation allowance

A form such as that shown in the figure reproduced below is often used for the compilation of relaxation allowances. It provides a convenient way of ensuring that no item of relaxation allowance is omitted. The derivation of the allowances is based on the data given in the tables reproduced in Appendix 3. In this example the weight in kg has been converted into lb. so that the points can be derived from these tables. The total figure for relaxation allowances (which represents both fixed and variable allowances) has also an added 5 per cent personal needs allowance. By deducting this figure for each element from the total allowances figure, one can arrive at fatigue allowances alone.

Since this is an example of restricted work the fatigue allowance has been calculated separately.

Relaxation											
Product: <i>B. 239 gear case</i> Weight : <i>6.8 kg each (15 lb.)</i>		Physical strains									
Operation: <i>Finish-mill second face</i>		Average force	Posture	Vibration	Short cycle	Restrictive clothing					
Working conditions: <i>Good</i>											
El. No.	Element description	Strain ²	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points
A	<i>Pick up casting, locate in fixture, lock 2 nuts, set guard, start machine</i>	M	20	L	1	—	—	—	—	—	—
B	<i>Break edges with file, and clean</i>	L	—	L	1	—	—	—	—	—	—
C	<i>Gauge</i>	L	—	L	1	—	—	—	—	—	—
D	<i>Pick up casting, place in box, pick up new casting and place near machine</i>	M	20	L	1	—	—	—	—	—	—
E	<i>Wait for machine (unoccupied time)</i>	—	—	—	—	—	—	—	—	—	—
F	<i>Stop machine, open guard, unlock nuts, remove casting, place on surface plate</i>	M	20	L	1	—	—	—	—	—	—
G	<i>Clean fixture with compressed air</i>	—	—	L	3	—	—	—	—	—	—
Occasional element	<i>Help labourer load and unload boxes of castings (10 per box = 68 kg/ 2 workers, 1/30 cycles)</i>	H	89	H	12	—	—	—	—	—	—

¹ The percentages of total allowances, as derived from the points conversion table in Appendix 3, cover both basic and variable allowances and a built-in personal needs allowance of 5 per cent.

² Severity of strain: L = low; M = medium; H = high.

The only period of unoccupied time during the machine-controlled time totalled 0.26 actual minutes. This was considered to be too short a period for recovery from fatigue (see Chapter 23, section 12), so the whole of the relaxation allowance, both the personal needs part and the fatigue allowance, was considered as an addition to outside work and was added to the cycle time.

The personal needs allowance of 5 per cent was calculated on the sum of the outside work plus the machine-controlled time. Fatigue allowance was calculated on the work elements only.

It will be seen from table 18 that the total relaxation allowance amounted to 0.21 minutes. This is less than the period of unoccupied time (0.26 minutes), but is nevertheless to be added outside the machine-controlled time as periods of 0.50 minutes or less of unoccupied time are ignored for fatigue allowance purposes.

allowance																											
Mental strains								Working conditions																			
Concentration/anxiety		Monotony		Eye strain		Noise		Temperature/humidity		Ventilation		Fumes		Dust		Dirt		Wet		Total points		Total relaxation allowance ¹ (%)		Fatigue allowance (relaxation allowance less 5%)			
Strain	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points	Strain	Points						
L	1	M	1	L	2	L	1	M	6	L	1	—	—	—	—	—	—	—	—	—	—	33	16	11			
L	1	M	1	L	2	L	1	M	6	L	1	—	—	—	—	—	—	—	—	—	—	13	11	6			
L	1	M	1	L	2	L	1	M	6	L	1	—	—	—	—	—	—	—	—	—	—	13	11	6			
L	1	M	1	L	2	L	1	M	6	L	1	—	—	—	—	—	—	—	—	—	—	33	16	11			
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
L	1	M	1	L	2	L	1	M	6	L	1	—	—	—	—	—	—	—	—	—	—	33	16	11			
—	—	—	—	—	—	L	1	M	6	L	1	—	—	—	—	—	—	—	—	—	—	11	11	6			
—	—	—	—	—	—	L	1	M	6	L	1	—	—	—	—	—	—	—	—	—	—	109	74	69			

Table 18. Final calculation of relaxation allowance

Fatigue allowance		Basic time	Fatigue (%)	Allowance min.
Inside work elements:	B	0.25	6	0.015
	C	0.12	6	0.007
	D	<u>0.19</u>	11	<u>0.0209</u>
		<u>0.56</u>		<u>0.0429</u>
Outside work elements:	A	0.27	11	0.0297
	F	0.26	11	0.0286
	G	0.10	6	0.006
	Occasional element help labourer	0.04	69	0.0276
Contingency allowance — 2.5 per cent of total basic time, inclusive of relaxation allowance		<u>0.03</u>	—	<u>—</u>
		<u>0.70</u>		<u>0.0919</u>
Total fatigue allowance				<u>0.1348</u>
Personal needs allowance				
5 per cent of Outside work plus machine-controlled time:				
5 per cent of (0.70 + 0.82)				<u>0.076</u>
Total relaxation allowance				
Fatigue allowance plus personal needs allowance				<u>0.2108</u>
				i.e. <u>0.21 min</u>

The allowance which resulted from applying the percentage figures built up in figure 128 is shown above. It will be seen that a contingency allowance of 2.5 per cent, inclusive of relaxation, was included under the heading of outside work, to cover the periods spent in discussions with the supervisor and the inspector.

Table 19. Computation of standard time

Computation of standard time

Outside work	0.70 basic min.
Inside work	0.56 basic min.
Relaxation allowance	0.21 min.
Unoccupied time allowance	<u>0.26 min.</u>
Standard time	<u>1.73 standard min.</u>

Alternatively:

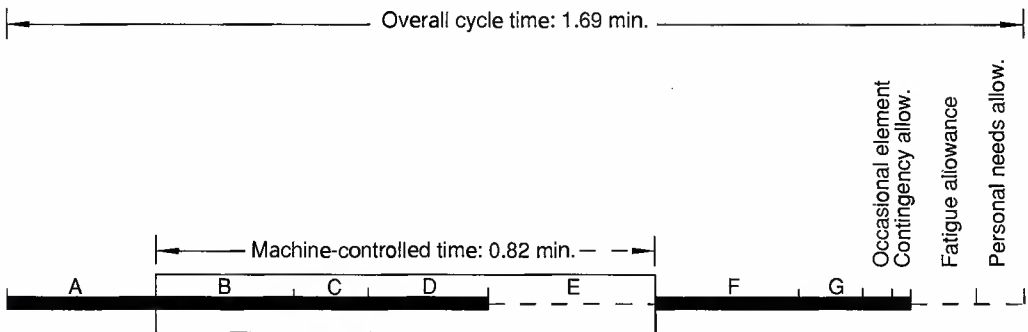
Outside work	0.70 basic min.
Machine-controlled time	0.82 min.
Relaxation allowance	<u>0.21 min.</u>
	<u>1.73 standard min.</u>

Calculation and issue of the standard time

The method of calculation shown in table 19 is that appropriate to restricted work. When standard times for jobs made up wholly of manual elements are compiled, it is common to add the appropriate relaxation allowances element by element, thus building up standard times for each element, the sum of which of course represents the standard time for the whole job. In such instances it is usual to show the final calculations on a job summary sheet which lists the elements in full, with their descriptions, and all relevant details of the job for which the standard time has been built up. This would be done also for restricted work such as that in the present example, though inside and outside work would be shown separately. It is good practice to add a cycle diagram to the job summary sheet (figure 129).

The methods adopted to issue — or publish — standard times vary according to the circumstances of the work situation. In jobbing shops, and for non-repetitive work (such as much maintenance work), jobs may be studied while they are in progress and the time standards be issued directly to the workers concerned, by annotation on the job sheet or other work instruction, after approval by the shop supervisor. When the work is mainly repetitive, with the same operations being performed many times over, for perhaps weeks or months on end, tables of values, derived after extensive studywork, may be issued by the work study department.

Figure 129. Machine time and allowances





Predetermined time standards

1. Definition

Predetermined time standards (PTS), also referred to as predetermined motion time systems (PMTS) or synthetic time standards, are advanced techniques which aim at defining the time needed for the performance of various operations by derivation from pre-set standards of time for various motions and not by direct observation and measurement. These techniques are not normally considered suitable for trainees to use until they have gained a real understanding of, and considerable experience in, work study practice. They will also require specialized PTS training. The essential nature of these standards will be explained in this chapter.

A predetermined time standard is a work measurement technique whereby times established for basic human motions (classified according to the nature of the motion and the conditions under which it is made) are used to build up the time for a job at a defined level of performance

As the definition indicates, PTS systems are techniques for synthesizing operation times from standard time data for basic motions. Synthesis and standard data are discussed more fully later in this book.

The nature of PTS systems can be easily illustrated by reference to a simple work cycle, such as putting a washer on a bolt. The operator will **reach** to the washer, **grasp** the washer, **move** the washer to the bolt, **position** it on the bolt and **release** it.

Many operations consist, broadly speaking, of some or all of these five basic motions. To these are added other body motions and a few other elements. Table 20 illustrates the components of a basic PTS.

By examining a given operation and identifying the basic motions of which it is composed, and by referring to PTS tables which indicate standard times for each type of motion performed under given circumstances, it is possible to derive a standard time for the operation as a whole.

Table 20. Components of a basic PTS

Motion	Description
REACH	Move hand to destination
GRASP	Secure control of object with fingers
MOVE	Move object
POSITION	Line up and engage object
RELEASE	Let go of object
BODY MOTIONS	Leg, trunk movements

2. Origins

The pioneer of motion classification was Frank B. Gilbreth, whose "therblig" subdivisions of hand or hand and eye motions were the key concept in the development of motion study. Two main ideas underlying Gilbreth's approach were that the act of making a detailed critical analysis of work methods stimulates ideas for method improvement; and that the evaluation of alternative work methods can be achieved by a simple comparison of the number of motions, the better method being the one requiring fewer motions.

The credit for adding the time dimension to motion study is attributed to A. B. Segur, who in 1927 stated that "within practical limits the time required for all experts to perform true fundamental motions is a constant".¹ Segur developed the first predetermined time standards, calling his system Motion Time Analysis. Little is known publicly about the system since he exploited it as a management consultant and bound his clients to secrecy.

The next important development was the work of J. H. Quick and his associates, who originated the Work Factor system in 1934. Like Segur's system, this was exploited on a management consultancy basis and little information was published about it. However, it was eventually adopted by a large number of companies and is now in active use.

A considerable number and variety of PTS systems were produced during and following the Second World War. Among these was a system which has become very widely used throughout the world, Methods-Time Measurement (MTM). Because of its importance MTM will be used here to illustrate the way in which predetermined time standards are arrived at.

MTM was first developed by three men working on the system at the Westinghouse Electric Corporation in the United States: H. B. Maynard, G. J. Stegemerten and J. L. Schwab. Their findings were published, and thus, for the first time, full details of a PTS system were made freely available to everyone. MTM has also set up, in various countries, independent non-profit-making MTM associations to control the standards of training and practice and to continue research into and the development of MTM. These associations have established an international coordinating body, the International MTM Directorate. In 1965 a simplified form of MTM known as MTM-2 was

¹ A. B. Segur: "Labour costs at the lowest figure", in *Manufacturing Industries* (New York), Vol. 13, 1927, p. 273.

developed, and this led to a rapid increase in the use of the system. In addition, a number of other systems were also derived for particular categories of work such as maintenance work or office work which were intended to permit a faster and easier derivation of standard times.

3. Advantages of PTS systems

PTS systems offer a number of advantages over stop-watch time study. With PTS systems one time is indicated for a given motion, irrespective of where such a motion is performed. In stop-watch time study it is not so much a motion as a sequence of motions making up an operation that is timed. Timing by direct observation and rating can sometimes lead to inconsistency. A PTS system, which avoids both rating and direct observation, can lead to more consistency in setting standard times.

Since the times for the various operations can be derived from standard-time tables, it is possible to define the standard time for a given operation even before production begins, and often while the process is still at the design stage. This is one of the great advantages of PTS systems, as they allow the work study person to change the layout and design of the workplace and of the necessary jigs and fixtures in such a way that the optimum production time is achieved. They also make it possible, even before starting the operation, to draw up an estimate of the cost of production, and this could obviously be valuable for estimating and tendering purposes or for budgeting. PTS systems are not too difficult to apply and can be less time-consuming than other methods when time standards for certain operations are being determined. They are particularly useful for very short repetitive time cycles such as assembly work in the electronics industry.

4. Criticisms of PTS systems

In view of the value of PTS systems, it is surprising that it took so long for them to become part of general work study practice. The main reason for this delay is probably the considerable number and variety of systems that have been produced, together with the fact that many of them could be obtained only by employing consultants. At present, over 200 such systems exist. This proliferation has led to complaints from management, trade unions and work study specialists.

Furthermore, any PTS system is rather complicated. It is not easy to learn, and a work study person needs a good deal of practice before being able to apply it correctly. The task of learning enough about the various systems to be able to judge their claims and their relative merits is an almost impossible one. For example, some systems do not go into sufficient detail in defining a certain motion. They might, for instance, give the same time for the movement both of an empty cup and of one full of water, or for the movement of a dry brush and of one laden with paint, which must be moved with care. PTS systems cannot also cope readily with movements made under abnormal conditions, for

example, movements made when the worker is wearing protective clothing or when the movements are made in an abnormal position, such as a worker reaching into a confined space behind a pipe. The situation was made more complicated by the lack of freely available information on many systems, whose tables were considered to be the property of their developers and were thus not available for publication.

Some work study researchers also questioned the basic assumptions of PTS systems. In part, these criticisms were justified, although some appear to have arisen through misinformation or misunderstanding. PTS systems do not, as was claimed, eliminate the need for the stop-watch, any more than they eliminate method study or work sampling. Machine time, process time and waiting time are not measurable with PTS systems, and occasional or incidental elements are often more economically measured by using other techniques. In fact, it is difficult to obtain 100 per cent coverage in a plant using only a PTS system, and for certain operations such as batch production or non-repetitive jobs the use of such a system can be an expensive proposition.

One type of criticism stems from a too literal interpretation of the basic assumption of Segur, quoted above. In fact, absolute constant times are not implied. The times indicated in PTS tables are **averages**, and the limits associated with the averages are small enough to be neglected in all practical circumstances.

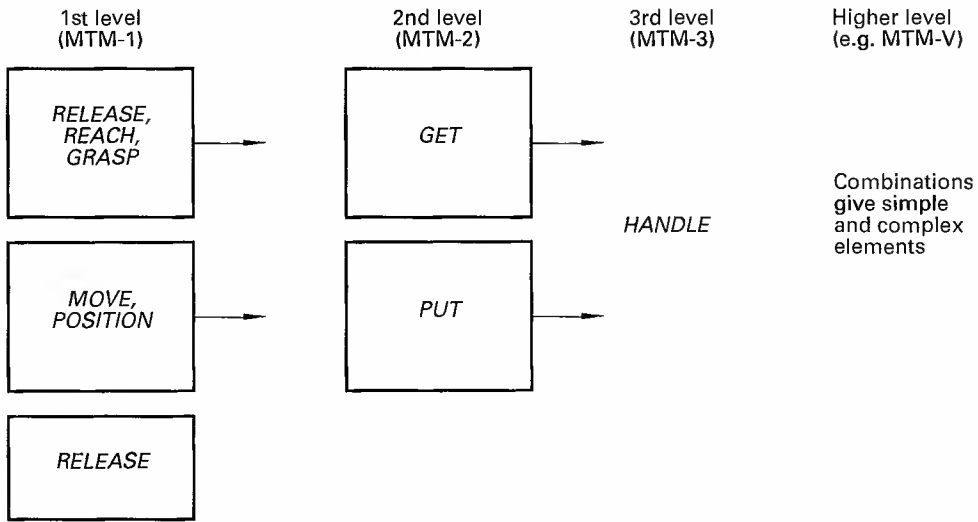
Another common criticism is that it is invalid to add up times for individual small motions in the way required by PTS systems because the time taken to perform a particular motion is influenced by the motions preceding and following it. It is unfair to criticize the more important PTS systems on these grounds, because not only were these relationships clearly recognized by their originators but also special provision was made to ensure that the essential correlations were maintained. In the case of MTM, for example, this was achieved by establishing subdivisions of the main classes of motions and by creating special definitions and rules of application to ensure their essential linking. The relationships are also preserved in simplified systems such as MTM-2.

It has also been declared that the direction of the motion influences the time — for example, that it takes longer to cover the same distance when moving upwards than when moving downwards — and that no PTS system isolates this variable. MTM researchers would agree that the direction of the motion is an important variable. However, they argue that in a single work cycle the operative will not be reaching only upwards, nor always away from the body, nor making only anti-clockwise turns: he or she will reach downwards or towards the body or make clockwise turns also, and so justify the use of average values.

5. Different forms of PTS systems

384 A work study person is likely to encounter a number of different forms of PTS systems, and will therefore find it useful to understand the main ways in which

Figure 130. PTS data levels: Basic motions



the systems vary, as well as differences as regards levels and scope of application of data, motion classification and time units.

Data levels

Figure 130 illustrates data levels by means of the official international MTM systems: MTM-1, MTM-2 and MTM-3.

The first level comprises the motions *RELEASE*, *REACH*, *GRASP*, *MOVE*, *POSITION*, *RELEASE*. At the second level these motions are combined: in MTM-2, for instance, the motions are *GET* and *PUT*. At the third level, the motions have been further combined as *HANDLE*, to give a description of the complete work cycle. Beyond the third level there are as yet no completely clear-cut rules, and methods of classification vary according to the work area for which the data are intended.

Scope of application of data

PTS systems vary as regards the universality of their application. It is difficult to explain this concept exactly, but table 21 attempts some clarification.

First of all there are systems of universal application, which cover all work anywhere. This is so for motion data at the MTM-1, 2 or 3 levels and for the Work Factor systems. Second, there are data which relate to a main occupation, for example office work, maintenance work or some kinds of production work. Examples of these are Master Clerical Data for the office and MTM-V, the Swedish MTM Association data for machine shops. Finally, there is the least general category: the specific data systems which are developed for use in particular factories or departments. These data are not transferable without validation studies.

Table 21. Scope of application of data

Degree	PTS system	Scope of application
1 — Universal	MTM-1, 2, 3; Work Factor	Transferable throughout the world and applicable in all manual work areas
2 — General	Master Clerical Data (office); MTM-V (machine shops)	Transferable but within a work area
3 — Specific	Standard data for particular departments in a plant	Not transferable without validation studies

Motion classification

PTS systems provide information about manual work cycles in terms of basic human motions. There are differences between the criteria adopted for the classification of these motions. Broadly speaking, there are two main sets:

- object-related classification;
- behaviour-related classification.

The object-related classification is employed in the majority of PTS systems (including Work Factor, Dimensional Motion Times and MTM-1) and virtually all the data systems relating to main occupational groups or specifically designed for use within a plant. In an object-related system, reference may be made to characteristics of parts (such as grasping a $6 \times 6 \times 6$ mm object), or to the nature of the surrounding conditions (such as reaching out to an object which is jumbled with other objects, or reaching out to an object which is lying flat against a surface). The classification is, however, not entirely object-related since motions such as Release Load or Disengage have behavioural definitions.

Unlike most systems, MTM-2 employs exclusively behavioural concepts. This is also true of MTM-3, Master Standard Data and a few less well-known systems. The behaviour-related systems classify motions according to what they look like to an observer: for example, a movement of the empty hand for a distance of between 5 and 15 cm followed by a grasping action made by a simple closing of the fingers defines the *GET* motion in the MTM-2 system (see below).

Time units

No two PTS systems have the same set of time values. This is partly due to the fact that different systems have different motion classes and the time data therefore refer to different things. Again, the choice of the basic unit (fractions of a second, minutes, hour) may vary, and some systems follow the practice of adding contingency allowances to motion times, whereas others do not. A final major cause of variations arises from the differences in the performance level implied in the time data. The methods adopted for standardizing, normalizing or averaging the motion times are not uniform. Consequently, PTS time data

are divided into one of two sets: Work Factor systems, which express their data in minutes; and MTM systems, expressed in time measurement units (tmu) which represent one hundred-thousandth of an hour or about one twenty-eighth of a second. The MTM time values, which were derived mainly from film analysis of a variety of industrial operations (the method was to count the number of "frames" occupied by each motion), were standardized using the well-known "Westinghouse" or "Levelling" system. The times are stated to be those which are achieved by an experienced operative of average skill, working with average effort and consistency under average conditions. The performance level, MTM 100, is therefore somewhat less than BSI 100. A public statement on this by the United Kingdom Institute of Management Services and the MTM Association suggests that MTM 100 equals BSI 83.²

Other considerations

Some important properties of PTS systems are much less easy to establish and to compare than the aspects discussed in the previous subsections. Examples of these are the precision and accuracy of the time data, speed of application, methods description capability, and learning time. The lack of reliable, detailed information and, to some extent, the lack of agreed design criteria hamper comparison of these properties.

6. Use of PTS systems

The system most likely to be used by the work study person is MTM-2. The following categories constitute the MTM-2 system. Each will be explained in detail in the following subsection.

Category	Code
<i>GET</i>	GA GB GC
<i>PUT</i>	PA PB PC
<i>REGRASP</i>	R
<i>APPLY PRESSURE</i>	A
<i>EYE ACTION</i>	E
<i>FOOT MOTION</i>	F
<i>STEP</i>	S
<i>BEND AND ARISE</i>	B
<i>WEIGHT FACTORS</i>	GW PW
<i>CRANK</i>	C

² "MTM and BSI rating scale", in *Work Study and Management Services* (London), Feb. 1969, p. 97.

Table 22. MTM-2 data card

Code	Time in tmu					
	GA	GB	GC	PA	PB	PC
- 5	3	7	14	3	10	21
-15	6	10	19	6	15	26
-30	9	14	23	11	19	30
-45	13	18	27	15	24	36
-80	17	23	32	20	30	41
GW: 1 per 1 kg			PW: 1 per 5 kg			
A	R	E	C	S	F	B
14	6	7	15	18	9	61

Warning: Do not attempt to use these data unless you have been trained and qualified under a scheme approved by the International MTM Directorate.

The MTM-2 system provides time standards ranging from 3 to 61 tmu. These are shown on the data card reproduced in table 22. As stated above, one tmu equals one hundred-thousandth of an hour.

MTM-2 Categories

GET (G)

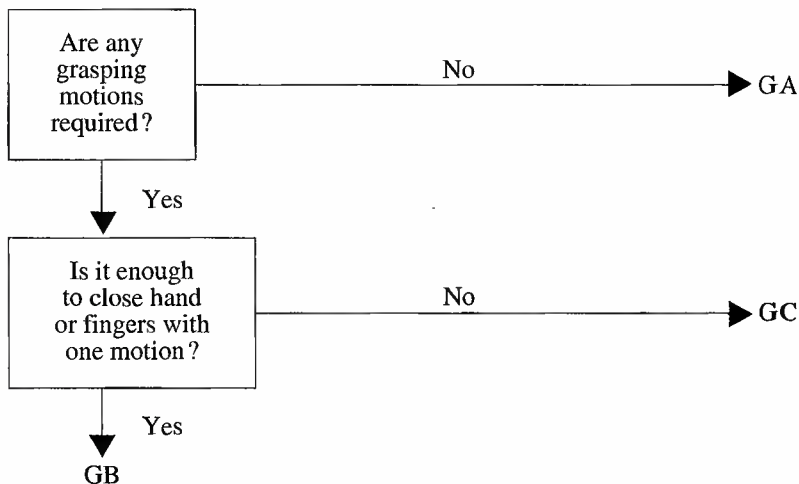
GET is an action with the predominant purpose of reaching out with the hand or fingers to an object, grasping the object and subsequently releasing it.

The scope of *GET* starts: with reaching out to the object;
 includes: reaching out to, gaining control and subsequently releasing control of the object;
 ends: when the object is released.

Selection of a *GET* is done by considering three variables:

- (1) case of *GET* — distinguished by the grasping action employed;
- (2) distance reached;
- (3) weight of the object or its resistance to motion.

Cases of *GET* are judged by the following decision model:



An example of GA is putting the palm of the hand on the side of a box in order to push it across a table.

An example of GB is getting an easy-to-handle object, such as a one-inch cube, which is lying by itself.

An example of GC is getting the corner of a page of this book in order to turn it over.

Distance is a principal variable in *GET*, and five distance classes are provided. Distances are judged by the upper limits of the classes, which are 5, 15, 30, 45 and over 45 cm. The code 80 is assigned to the highest class. Distances are estimated from the path of travel of the hand, less any body assistance.

cm		Code
Over	Not over	
0.0	5.0	— 5
5.0	15.0	— 15
15.0	30.0	— 30
30.0	45.0	— 45
45.0	—	— 80

GET WEIGHT (GW)

GET WEIGHT is the action required for the muscles of the hand and arm to take up the weight of the object.

- The scope of *GET WEIGHT* starts: with the grasp on the object completed;
- includes: muscular force necessary to gain full control of the weight of the object;
- ends: when the object is sufficiently under control to permit movement of the object.

GET WEIGHT occurs after the fingers have closed on the object in the preceding *GET*. It must be accomplished before any actual movement can take place. When the weight or resistance is less than 2 kg per hand, no GW is assigned. When resistance exceeds 2 kg, 1 tmu is assigned for every kg including the first two.

PUT (P)

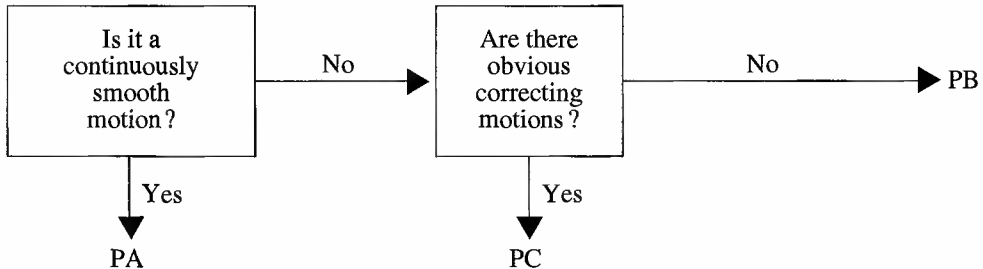
PUT is an action with the predominant purpose of moving an object to a destination with the hand or fingers.

- The scope of *PUT* starts: with an object grasped and under control at the initial place;
- includes: all transporting and correcting motions necessary to place an object;
- ends: with object still under control at the intended place.

Selection of a *PUT* is done by considering three variables:

- (1) case of *PUT* — distinguished by the correcting motions employed;
- (2) distance moved;
- (3) weight of the object or its resistance to motion.

Cases of *PUT* are judged by the following decision model:



An example of PA is tossing aside an object.

An example of PB is the action of putting a 12 mm ball in a 15 mm diameter hole.

An example of PC is inserting a Yale or similar key in a lock.

A correction is not likely to be confused with a short PA. A correction is a very short unintentional motion at the terminal point; a PA is purposive, usually of easily discernible length.

The motion distance is handled in a similar manner to *GET*.

When there is an engagement of parts following a correction, an additional *PUT* will be allowed when the distance exceeds 2.5 cm.

PUT WEIGHT (PW)

PUT WEIGHT is an addition to a *PUT* motion depending on the weight of the object moved.

The scope of *PUT WEIGHT* starts: when the move begins;
 includes: the additional time, over and above the move time in *PUT*, to compensate for the differences in time required in moving heavy and light objects over the same distance;
 ends: when the move ends.

PW is assigned when resistance to movement exceeds 2 kg per hand.

Weights are calculated as in *GET WEIGHT*. Between 2 kg and 5 kg, 1 tmu is allowed and coded PW 5; between 5 kg and 10 kg 2 tmu are allowed and coded PW 10; and so on.

REGRASP (R)

REGRASP is a hand action with the purpose of changing the grasp on an object.

The scope of *REGRASP* starts: with the object in the hand;
 includes: digital and hand muscular re-adjustment on an object;
 ends: with the object in a new location in the hand.

A single *REGRASP* consists of not more than three fractional movements.

Digital and muscular readjustments, while performing an *APPLY PRESSURE*, are included in *APPLY PRESSURE*. A *REGRASP* should not be assigned in combination with *APPLY PRESSURE*.

If the hand relinquishes control and then secures another grasp on the object, the action will be a *GET*, not a *REGRASP*.

An example of R is changing the grasp on a pencil in order to get into the position for writing.

APPLY PRESSURE (A)

APPLY PRESSURE is an action with the purpose of exerting muscular force on an object.

The scope of *APPLY PRESSURE* starts: with the body member in contact with the object;
 includes: the application of controlled increasing muscular force, a minimum reaction time to permit the reversal of force and the subsequent releasing of muscular force;
 ends: with the body member in contact with the object, but with muscular force released.

The minimum dwell time covers mental reaction time only. Longer dwells, in holding actions, must be separately evaluated.

APPLY PRESSURE applies to the action of exerting muscular force on an object to achieve control, to restrain or to overcome resistance to motion. The object is not displaced more than 6 mm during the action of *APPLY PRESSURE*.

APPLY PRESSURE, which can be performed by any body member, is recognized by a noticeable hesitation while force is applied.

An example of A is the final tightening action made with a screwdriver or spanner.

EYE ACTION (E)

EYE ACTION is an action with the purpose of

either: recognizing a readily distinguishable characteristic of an object;
 or: shifting the aim of the axis of vision to a new viewing area.

The scope of *EYE ACTION* starts: when other actions must cease because a characteristic of an object must be recognized;

includes:

either: muscular readjustment of the lens of the eyes and the mental processes required to recognize a distinguishable characteristic of an object;

or: the eye motion performed to shift the aim of the axis of vision to a new viewing area;

ends: when other actions can start again.

A single eye focus covers an area 10 cm in diameter at 40 cm from the eyes. Recognition time included is sufficient only for simple binary decision.

An example of E is the action of determining whether a coin is showing head or tail.

□ *FOOT MOTION* (F)

FOOT MOTION is a short foot or leg motion when the purpose is not to move the body.

The scope of *FOOT MOTION* starts: with the foot or leg at rest;

includes: a motion not exceeding 30 cm that is pivoted at the hip, knee or instep;

ends: with the foot in a new location.

FOOT MOTION is judged by the decision model for *FOOT MOTION* and *STEP*.

□ *STEP* (S)

STEP is

either: a leg motion with the purpose of moving the body;

or: a leg motion longer than 30 cm.

The scope of *STEP* starts: with the leg at rest;

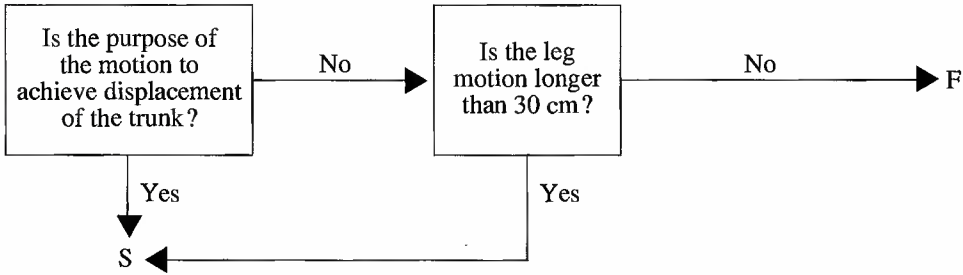
includes:

either: a motion of the leg where the purpose is to achieve displacement of the trunk;

or: a leg motion longer than 30 cm;

ends: with the leg at a new location.

STEP or *FOOT MOTION* is judged by the following decision model:



To evaluate walking, count the number of times the foot hits the floor.

An example of F is depressing a foot pedal in a car.

An example of S is making a single step to the side to enable the arm to reach further.

BEND AND ARISE (B)

BEND AND ARISE is a lowering of the trunk followed by a rise.

The scope of *BEND AND ARISE* starts: with motion of the trunk forward from an upright posture;

includes: movement of the trunk and other body members to achieve a vertical change of body position to permit the hands to reach down to or below the knees and the subsequent arise from this position;

ends: with the body in an upright posture.

The criterion for *BEND AND ARISE* is whether the operative is able to reach to below the knees, not whether he or she actually does so.

Kneeling on both knees should be analysed as 2B.

CRANK (C)

CRANK is a motion with the purpose of moving an object in a circular path of more than half a revolution with the hand or finger.

The scope of *CRANK* starts: with the hand on the object;

includes: all transporting motions necessary to move an object in a circular path;

ends: with the hand on the object when one revolution is completed.

There are two variables to consider in applying the *CRANK* motion:

- (1) the number of revolutions;
- (2) weight or resistance.

The time value of 15 tmu per revolution may be used for any crank diameter and applies to both continuous and intermittent cranking. *CRANK* applies to motions in a circular path whether or not the axis of cranking is perpendicular to the plane of rotation.

The number of revolutions should be rounded to the nearest whole number.

The weight or resistance influences the time for moving an object. The rules of adding *GW* and *PW* to *PUT* motions also apply to *CRANK*. *PW* applies to each revolution, whether continuous or intermittent. *GW* is applied once only to a continuous series of revolutions, but to each revolution where these are intermittent.

No correcting motions as applied to *PUT* are included in *CRANK*. If correcting motions occur in putting the object at the intended place an extra *PUT* must be allowed.

An example of *C* is turning a hand wheel through one revolution.

Training requirements

In the preceding subsection the essentials of the MTM-2 system were outlined. To obtain an adequate understanding of the system, however, a trainee will require at least two weeks of formal training in MTM-2 theory and practice, followed by guided application on the shop floor with an MTM instructor. A trainee who is already competent in work study practice should reach a reasonable standard in the use of MTM-2 after about a month of guided application. MTM-1 will require a longer training period. It is helpful if part of this training can be carried out in a plant where MTM standards are already in use. When trainees find that their own analyses compare closely with established standards their confidence is rapidly built up. Without guidance it is very difficult for a trainee to learn how to use MTM adequately.

Most PTS training courses end up with an examination in which the trainee carried out a measurement study of a real or simulated job, sometimes on film. Only if a specified pass mark is obtained in this examination is the trainee validated to apply the PTS in question at the place of work as a consultant in that particular PTS system.

7. Application of PTS systems

PTS systems can be applied in three main ways:

- direct observation of the motions used by the operative;
- mental visualization of the motions needed to accomplish a new or alternative work method;
- from analysis of a film/video taken of the operative at the place of work.

The overall approach adopted when one of the PTS systems, such as MTM-2, is used for direct observation is not very different from that adopted for making a time study (see Chapter 21). Indeed, a person experienced in the procedures described in that chapter — selecting the job, approach to the

worker, recording job information, breakdown into elements, allowances, compiling total job times — is well equipped to become a good PTS practitioner. The main difference in the approach is that at the point in the total time study procedure where the observer is ready to time and rate the work cycle, he or she will instead make an MTM-2 analysis and then enter the motion times on the analysis sheet from the MTM-2 data card. The calculation of allowances, completion of the documentation and issuing of the job times are then done in much the same way as in a time study. If the same type of summary sheets can be used, so much the better. The study summary sheet shown as figure 104 and the short cycle study form (figures 102 and 103) can be adapted to summarize the information from the MTM-2 analysis sheets.

Choosing the operative

In the choice of operative to be observed, it is just as desirable to have a cooperative, good-average worker for PTS analysis as it is for time study. Exceptionally fast or abnormally slow performances are difficult for time study specialists to rate, and they present problems for PTS analysts too. The super-skilled operative combines and overlaps motions in a manner beyond the capabilities of the average worker, while an abnormally slow or reluctant operative will make separate, one-handed, hesitant motions which the average operative will perform smoothly and simultaneously. The rules and motion combination tables of the MTM system, like those of other systems such as Work Factor, do provide information for adjusting the observed motion pattern to that applicable to the good-average worker; this additional work can, however, be avoided by an intelligent choice of operative in the first place. Of course, the very experienced PTS analyst may also study extreme performances with advantage. The performance of an exceptionally fast operative may give clues as to how all operatives might be trained to reach a higher-than-average performance level, and the study of slow operatives would show where difficulties are being encountered and whether further training might eliminate these.

Recording job information

In recording job information, it is important to remember that distance is a significant variable in PTS systems. The plans for the workplace layout should therefore be accurately drawn to scale. This will help in judging or checking the length of motions shown in the analyses.

Breakdown into elements

In PTS systems the division of the operation into work elements follows the same principles as for time study. The breakdown can be made very much finer, if required, because the difficulty of timing short elements does not arise. If necessary, the break points can also be changed easily and without having to retime the cycle. This flexibility is illustrated in table 23, which shows a very common work cycle — that of fitting a nut and washer on a stud. For example, if a change of method eliminates the need for a washer, the appropriate motions

Table 23. Fitting a nut and washer on a stud

Element	tmu	Code	Description
Fit washer	23	GC30	Washer
	30	PC30	To stud
	3	PA5	On stud
Fit nut and turn down by hand	10	GB15	Nut
	26	PC15	To stud
	6	2PA5	Engage threads
	42	6GB5	
	18	6PA5	Turn down nut
Tighten nut using spanner	23	GB30	Spanner
	30	PC30	To nut
	6	PA15	Turn nut
	14	A	Tighten
	231		

(GC30, PC30, PA5) and time (56 tmu) can easily be removed from the analysis. Finger turns can also be readily separated from spanner turns and, indeed, from the fitting actions and subsequent turns.

Allowances and job times

There is no problem of rating with a PTS system such as MTM-2, since the times have been rated once and for all. All that needs to be done is to add up the motion times and transfer the totals to the study summary sheet. If times are to be issued at BSI 100 and not MTM 100, the tmu total from the study summary sheet should be multiplied by 0.83. (This means that, if times are issued in standard minutes, the total tmu can be divided by 2,000.) It should be understood that the general relationship between the scales applies only to the time totals, and most definitely not to the individual motion times shown on the MTM data cards. Converting individual motion times is quite improper since these are not improved uniformly when a higher performance of a cycle time is achieved.

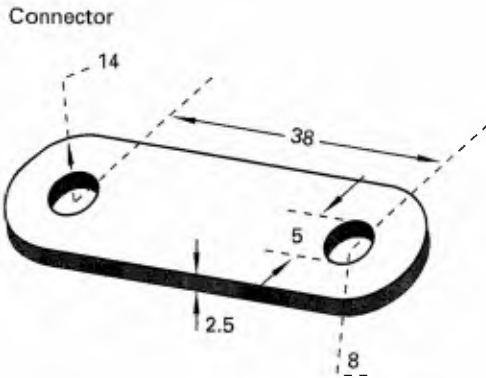
The times for low control motions (such as GA and PA) are improved only a little compared with those for the highly complex motions (such as GC and PC). The issue is, however, more complicated than this because one would also need a different set of motion combinations when considering a different performance level. Some sophisticated MTM users prefer to issue values at MTM 100.

Relaxation and other allowances are added in exactly the same way as for time study, in order to give the total job time.

Visualization

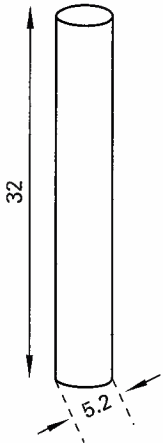
When the work study person does not have the opportunity of observing the work cycle, for example when designing a new work method or constructing

Figure 131. Base assembly

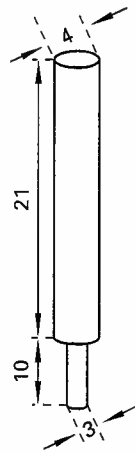


Measurements in millimetres

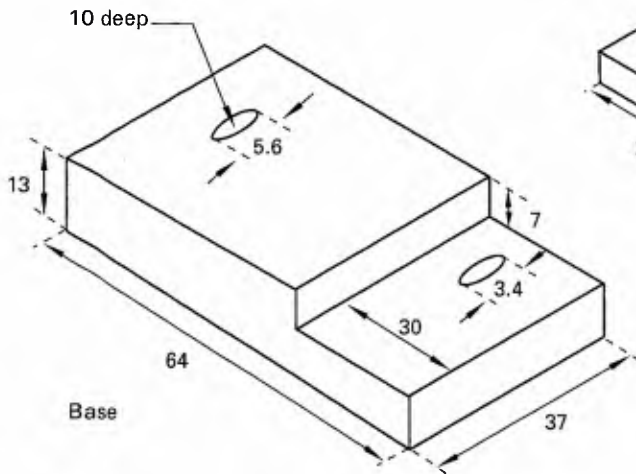
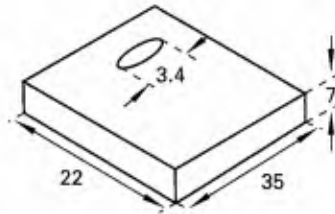
Pin



Stud



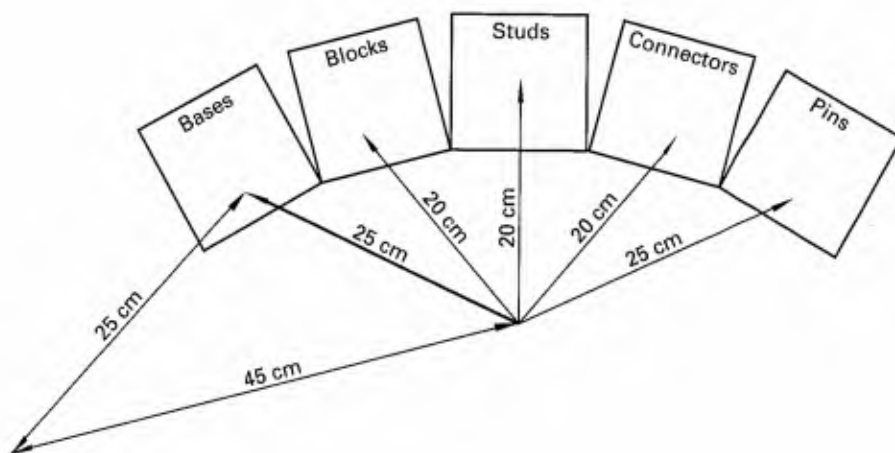
Block



alternative methods during method study of an existing job, he or she must mentally visualize the motions needed. Figures 131 and 132 give an example of a PTS problem which can be solved by visualization of the various motions involved, as can be seen from figure 133.

The ability to visualize motion patterns depends on the study person's intelligence and on practical experience. The more familiar he or she is with work study, the more readily the person can picture the motions necessary to pick up and fit parts together, as well as visualizing which motions can be performed together easily and which motions are difficult to carry out simultaneously (table 24).

Figure 132. Base assembly workplace layout



In designing work methods, it can be helpful to use a methods laboratory. However, when motion analysis is undertaken there is a need for caution, just as there is with time standards. The experiments with new methods will probably be performed by the work study person or by colleagues, and it is important that they should bear in mind that their own performances will generally fall far short of those which will be achieved by the regular shop-floor operatives. Even where shop-floor operatives are assisting in the methods laboratory, their performance of a new work cycle will fall short of the standard they will achieve when they have had sufficient practice in working the cycle under shop-floor conditions.

In both these instances the rules for work design, particularly those of the motion combination possibilities expected of the average experienced operative, must be used to arrive at a correct shop-floor method.

It is in the work design process that a work study person who chooses to use an MTM-2 system, for example, will reap the benefit of a full training in the detailed MTM-1 system on which MTM-2 was founded. However, at the very minimum the classification details of MTM-1 together with the basic motions which make up the MTM-2 motions and the rules covering the motion combination possibilities of the basic motions must be understood, particularly in relation to practice opportunity, area of normal vision and difficulty of

handling. With this knowledge it will become evident, for example, that in designing the workplace for the parts to be kept in tote pans, a separate GC with either hand will be required. It will also be apparent that even expert operatives cannot perform these motions simultaneously, since each motion involves a kind of minute searching and selecting activity, because the objects are jumbled together. Similarly, the work study specialist will know that putting loose-fitting round plugs into round holes can be done with both hands simultaneously, provided that the workplace is designed so that the targets are within the area of normal vision as defined above under *EYE ACTION*. The rules provide many such guidelines.

PTS systems and the broader techniques

The nature and value of PTS systems should now be reasonably clear. If a work study person intends to become a specialist, for example in MTM, full training in MTM-1 and MTM-2 and in all the advanced techniques outlined in this book will be necessary. In the more general case, where both work study and other jobs will probably be undertaken as well (such as production planning and control — a common combination in small plants, particularly in the developing countries), an MTM-2 training may be sufficient.

However, it is most important that the study person should not lose sight of the fact that the PTS technique is a fine precision tool. Before getting down to minute detail, it should first be seen what can be accomplished by using the broader, simpler approaches. In companies where work study practice has not yet been introduced, intelligent broad thinking will usually reveal ways of bringing about considerable initial improvements in productivity.

Table 24. Methods-Time Measurement application data in tmu (Based metric weights and measures)

I. REACH — R

Distance (cm)	Time (tmu)				Hand in motion		Case and description
	A	B	C or D	E	A	B	
2 or less	2.0	2.0	2.0	2.0	1.6	1.6	A. Reach to object in fixed location, or to object in other hand or on which other hand rests
4	3.4	3.4	5.1	3.2	3.0	2.4	
6	4.5	4.5	6.5	4.4	3.9	3.1	
8	5.5	5.5	7.5	5.5	4.6	3.7	
10	6.1	6.3	8.4	6.8	4.9	4.3	
12	6.4	7.4	9.1	7.3	5.2	4.8	B. Reach to single object in location which may vary slightly from cycle to cycle
14	6.8	8.2	9.7	7.8	5.5	5.4	
16	7.1	8.8	10.3	8.2	5.8	5.9	
18	7.5	9.4	10.8	8.7	6.1	6.5	
20	7.8	10.0	11.4	9.2	6.5	7.1	
22	8.1	10.5	11.9	9.7	6.8	7.7	C. Reach to object jumbled with other objects in a group so that search and select occur
24	8.5	11.1	12.5	10.2	7.1	8.2	
26	8.8	11.7	13.0	10.7	7.4	8.8	
28	9.2	12.2	13.6	11.2	7.7	9.4	
30	9.5	12.8	14.1	11.7	8.0	9.9	
35	10.4	14.2	15.5	12.9	8.8	11.4	D. Reach to a very small object or where accurate grasp is required
40	11.3	15.6	16.8	14.1	9.6	12.8	
45	12.1	17.0	18.2	15.3	10.4	14.2	
50	13.0	18.4	19.6	16.5	11.2	15.7	
55	13.9	19.8	20.9	17.8	12.0	17.1	
60	14.7	21.2	22.3	19.0	12.8	18.5	E. Reach to indefinite location to get hand in position for body balance or next motion or out of way
65	15.6	22.6	23.6	20.2	13.5	19.9	
70	16.5	24.1	25.0	21.4	14.3	21.4	
75	17.3	25.5	26.4	22.6	15.1	22.8	
80	18.2	26.9	27.7	23.9	15.9	24.2	

II. MOVE—M

Distance (cm)	Time (tmu)				Wt allowance			Case and description
	A	B	C	Hand in motion B	Weight (kg) up to	Static constant (tmu)	Dynamic factor	
2 or less	2.0	2.0	2.0	1.7	1	0	1.00	A. Move object against stop or to other hand
4	3.1	4.0	4.5	2.8	2	1.6	1.04	
6	4.1	5.0	5.8	3.1				
8	5.1	5.9	6.9	3.7	4	2.8	1.07	
10	6.0	6.8	7.9	4.3				
12	6.9	7.7	8.8	4.9				
14	7.7	8.5	9.8	5.4	6	4.3	1.12	
16	8.3	9.2	10.5	6.0				
18	9.0	9.8	11.1	6.5	8	5.8	1.17	
20	9.6	10.5	11.7	7.1				
22	10.2	11.2	12.4	7.6				
24	10.8	11.8	13.0	8.2	10	7.3	1.22	B. Move object to approximate or indefinite location
26	11.5	12.3	13.7	8.7				
28	12.1	12.8	14.4	9.3	12	8.8	1.27	
30	12.7	13.3	15.1	9.8				
35	14.3	14.5	16.8	11.2	14	10.4	1.32	
40	15.8	15.6	18.5	12.6				
45	17.4	16.8	20.1	14.0	16	11.9	1.36	
50	19.0	18.0	21.8	15.4				
55	20.5	19.2	23.5	16.8				
60	22.1	20.4	25.2	18.2	18	13.4	1.41	C. Move object to exact location
65	23.6	21.6	26.9	19.5				
70	25.2	22.8	28.6	20.9	20	14.9	1.46	
75	26.7	24.0	30.3	22.3				
80	28.3	25.2	32.0	23.7	22	16.4	1.51	

IIIA. *TURN — T*

Weight (kg)	Time (tmu) for degrees turned										
	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
Small (0) to (1)	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium (1) to (5)	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large (5.1) to (16)	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

IIIB. *APPLY PRESSURE — AP*

Full cycle			Components		
Symbol	tmu	Description	Symbol	tmu	Description
APA	10.6	AF + DM + RLF	AF	3.4	Apply force
			DM	4.2	Dwell, minimum
APB	16.2	APA + G2	RLF	3.0	Release force

IV. GRASP — G

Case	Time (tmu)	Description
1A	2.0	Pick up grasp — small, medium or large object by itself, easily grasped
1B	3.5	Very small object or object lying close against a flat surface
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than 12 mm
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter 6 to 12 mm
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than 6 mm
2	5.6	Regrasp
3	5.6	Transfer grasp
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 25×25×25 mm
4B	9.1	Object jumbled with other objects so search and select occur. 6×6×3 mm to 25×25×25 mm
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than 6×6×3 mm
5	0	Contact, sliding or hook grasp

V. POSITION* — P

Class of fit	Symmetry	Easy to handle	Difficult to handle
1. Loose — No pressure required	S	5.6	11.2
	SS	9.1	14.7
	NS	10.4	16.0
2. Close — Light pressure required	S	16.2	21.8
	SS	19.7	25.3
	NS	21.0	26.6
3. Exact — Heavy pressure required	S	43.0	48.6
	SS	46.5	52.1
	NS	47.8	53.4

*Distance moved to engage — max. 25 mm.

VI. *RELEASE - RL*

Case	Time (tmu)	Description
1	2.0	Normal release performed by opening fingers as independent motion
2	0	Contact release

VII. *DISENGAGE — D*

Class of fit	Easy to handle	Difficult to handle
1. Loose — Very slight effort, blends with subsequent move	4.0	5.7
2. Close — Normal effort, slight recoil	7.5	11.8
3. Tight — Considerable effort, hand recoils markedly	22.9	34.7

VIII. *EYE TRAVEL and EYE FOCUS — ET and EF*

Eye travel time = $15.2 \times \frac{T}{D}$ tmu, with a maximum value of 20 tmu

where T = the distance between points from and to which the eye travels,
 D = the perpendicular distance from the eye to the line of travel T.

Eye focus time = 7.3 tmu.

X. SIMULTANEOUS MOTIONS

REACH			MOVE			GRASP			POSITION			DISEN- GAGE		Case	Motion	
A,E	B	C,D	A, Bm	B	C	G1A G2 G5	G1B G1C	G4	P1S	P1SS P2S	P1NS P2SS P2NS	D1E D1D	D2			
		W O	W O	W O	W O		W O	W O	E	D	E	D	E	D		
					X X						X X X				A, E	REACH
		X		X X	■		X X	■	X X	■	■		X		B	
		X X	■	X	■		X	■	■	■	■	■	X	■	C, D	
											X X X				A, Bm	MOVE
							X X	■	X X	■	■		X		B	
					X	■	X	■	■	■	■	■	X	■	C	
															G1A, G2, G5	GRASP
							■	■	■	■	■	■	■	■	G1B, G1C	
							■	■	■	■	■	■	■	■	G4	
									X	■	■	■	■	■	P1S	
															P1SS, P2S	POSITION
															P1NS, P2SS, P2NS	
												X	X X	D1E, D1D		
													X X	D2		DISENGAGE

□ = EASY to perform simultaneously.

⊗ = Can be performed simultaneously with PRACTICE.

■ = DIFFICULT to perform simultaneously even after long practice. Allow both times.

Motions not included in above table: *TURN* — Normally *EASY* with all motions except when *TURN* is controlled or with *DISENGAGE*.

APPLY PRESSURE, CRANK — May be *EASY*, require *PRACTICE*, or *DIFFICULT*. Each case must be analysed.

POSITION — Class 3 — Always *DIFFICULT*. *DISENGAGE* — Class 3 — Normally *DIFFICULT*. *RELEASE* — Always *EASY*. *DISENGAGE*. — Any class may be *DIFFICULT* if care must be exercised to avoid injury or damage to object.

W = Within the area of normal vision, i.e. $r = 10$ cm, $d = 40$ cm.

O = Outside the area of normal vision, i.e. $r = 10$ cm, $d = 40$ cm.

E = *EASY* to handle.

D = *DIFFICULT* to handle.

Source: Official International MTM-1 Data, © International MTM Directorate and MTM Association for Standards and Research. Tables reproduced by kind permission of the International MTM Directorate.



Standard data

Many operations in a given plant have several common elements. The element “walking”, for example, is a component of many different jobs. Diverse activities such as painting, handling or working on a site invariably involve an element of “walking”. When these activities are timed, the same common element is in fact timed again and again. The job of a work study person would therefore be made much easier if a set of data were to be available from which standard times could readily be derived for these common work elements without necessarily going into the process of timing each one. If, for instance, a standard time could be derived for the particular element “walking” and could be read directly from a table, this would not only reduce effort and cost but also lead to greater consistency in time estimation.

One can therefore see that there is an advantage in building up a **standard data** bank for various elements which occur repeatedly at the workplace. If such data existed for a wide range of elements and were reliable, there would be no need to carry out a time study for a new job. Instead, by breaking down the job into elements and referring to the data bank to derive the normal times for each element, one could calculate the total time needed to perform this new job and determine its standard time by adding the appropriate allowances in the usual way.

1. Major considerations

It is, however, difficult to visualize a situation where all the possible elements making up any and every job could be timed and stored for future retrieval. We may therefore conclude that in practice it is better to **restrict the number of jobs** for which standard data are derived — normally to one or more departments in a plant, or to all the processes involved in manufacturing a certain product. In this way the coverage becomes more manageable and less costly.

The **reliability of the data** can be increased if as many common elements as possible that are performed in the same way are grouped together for analysis, and if a sufficient amount of accumulated or collected data on each element has been analysed by a trained study person.

Reliability can be further increased by making sure that all the factors affecting a certain element have been taken into consideration. For example, the time taken to move a sheet of a given size will vary depending on whether it is a solid sheet (of metal, for instance) or a malleable one (of rubber, for

instance). The weight will also be an important factor. The time taken to move an iron sheet will be different from the time taken to move one of foam or cardboard. Again, the thickness will affect the timing in each case. Consequently, the description of the element must be as precise as possible and the various factors affecting the timing (in this case, nature of material, thickness and weight) will also have to be indicated.

Another basic consideration concerns the **source of the time data**. Should this be observed time based on stop-watch readings (what might be called "macroscopic" timing systems) or "microscopic" systems such as predetermined time standards? The first alternative may be more acceptable to the factory personnel in certain cases, and is sometimes cheaper. However, for certain elements it is not always possible to have on record enough readings to enable reliable data to be derived. Several months or even a year or more may elapse before sufficient data are accumulated in this way. The choice of a microscopic system such as MTM may make for better coverage, but its use also depends on whether sufficient experience has been acquired in using the system and on its applicability. Even in this case, one has to decide whether to use detailed systems such as MTM-1 (which can be more precise but are expensive), or MTM-2 or MTM-3 (which are less expensive but less precise).

Again, standard data have to be built up with due regard to users' needs. They are indeed invaluable for a variety of purposes, among them production planning, cost estimation, incentive payments and budgetary control. However, the "level of confidence" in the developed database which can be tolerated by those who use standard data for these purposes varies considerably: for example, the requirements for production planning allow for much greater potential deviation in the standards than the requirements for individual bonus schemes. Since one cannot produce a different set of data for each user, it is necessary to build a data system that produces the maximum benefit for each user at the same time.

2. Developing the standard data

The following steps should be taken to develop standard data:

A. Decide on coverage. As indicated above, the coverage should be restricted to one or more departments or work areas or to a limited range of processes within a plant (for example, those involved in manufacturing a specific product) in which several similar elements, performed by the same method, are involved in carrying out the jobs.

B. Break the jobs into elements, through job analysis. In this case try to identify as many elements as possible that are common to the various jobs. Let us assume, for example, that we have a worker in a fruit-packing plant who works at the end of the operation and whose job is to remove a carton of fruit from a conveyor belt, stencil the name of the customer on the carton and carry it to a nearby skid. Such an operation may be broken down into elements in various ways, but if the study person proceeds as indicated below it could be found that several of the component elements also occur elsewhere in the plant.

The suggested breakdown is:

- lifting the carton from the conveyor and positioning it on the table;
- positioning a stencil on the carton;
- applying a 10 cm brush and tar to stencil the name and address of the client;
- lifting the carton;
- walking with the carton; and
- placing it on the skid.

The elements “lifting and positioning of carton” and “walking with carton” may occur in various other jobs in the plant, although not necessarily in the same manner. Depending on the size and type of fruit, the carton may vary in size and weight. These are important considerations that will influence the time for these elements. Furthermore, in other parts of the operation the element “walking with carton” may recur but the distance covered during the walk may not be the same. These variations should not deter the work study person from collecting the necessary information for building up the standard data. This will become clear as we proceed with our step-by-step approach.

It is also useful to devise a coding system for elements so that they can be identified, categorized and retrieved easily (especially from computerized databanks). This coding should preferably be mnemonic or one that permits easy recognition and may use suffixes to indicate the value of the variables, e.g. PNT10 could indicate an element Paint an area up to 10 square metres.

For large standard data systems this coding system may need to be hierarchical. A system may consist of layers or levels of work with basic elements (or even basic motions) at the lowest level. A number of elements may be combined into an operation and a number of operations may be combined into a task. The data system maintains a specification of each element (level 1 data) together with its associated time value. The system also maintains a specification of each operation consisting of the elements that make up the operation and the frequency of each element within the operation. Similarly, the system maintains a list of all defined tasks consisting of the operations, and the corresponding frequencies, that make up each task. When a job is analysed, the work study person breaks it down into tasks. If each of these tasks is already within the data system, the time can be immediately derived by summing the time for each task. (This time is in fact the sum of all the operation times that make up the task, and each operation time is the sum of all the element times that make up the operation.) Where an element or a frequency changes, this is recorded in the system — the element description or time is changed at the elemental level and the frequency is changed at the operation level. On a computerized system, the one elemental change will be reflected in the times for all operations which make use of that element, and in all tasks which use those operations. The frequency change, however, is particular to the individual operation and thus is only reflected in those tasks which use that specific operation.

C. Decide on type of reading, i.e. whether you will use readings based on stop-watch time study (macroscopic systems) or derived from PTS systems such as MTM (microscopic systems). As explained earlier, the nature of the job and the cost of applying each system will be the major determining factors. If stop-watch time study is chosen, sufficient time must be allowed to collect the readings necessary to produce statistically reliable data.

D. Determine the factors that are likely to affect the time for each element, and classify them into major and minor factors. Let us take a simple example: the case of a worker walking. If the time for this activity is calculated, it will be found that there is always a variation in the readings. This is due to several factors, some major and others which may be considered minor. In this particular case the factors may be indicated as follows:

Activity

Restricted walking starting at dead point and ending at a dead stop

Factors influencing the time

Major

Distance covered

Minor

Physical make-up of worker

Temperature

Humidity

Lighting

External attraction

Variation due to time study person

It is clear here that the time for walking will be affected mainly by the distance covered; nevertheless, other minor factors will exert a small influence as well, and these may cause slight variations from reading to reading.

E. When using macroscopic systems, measure the time taken to perform the activity from actual observations. Here the study person can choose arbitrary distances and time the worker for each distance. If it is found that in most cases a worker walks either 10, 20, 30 or 40 metres, readings for these distances can be timed and entered in standard tables. However, this is rarely the case. A worker may walk any distance between 10 and 40 metres. The study person will then find it more appropriate to draw a curve to indicate the relationship between time and distance covered. Let us proceed with our example of walking and assume that the readings reproduced in table 25 were recorded.

It is now possible to plot base time against distance. The curve using the line of best fit will appear as shown in figure 134. For greater accuracy one may also use the method of least squares to determine the slope and the line of best fit for the curve. From the curve it will now be possible to derive standard times for values lying anywhere between 10 and 40 metres. Occasionally the relationship between the two variables may be curvilinear rather than linear; in such cases logarithmic graph paper should be used.

Table 25. Restricted walking

Distance (m)	Actual time (min.)	Rating	Base time (min.)	Average (min.)
x	a	($a \times r \Rightarrow$) r	t	y
10	0.13	85	0.1105	0.1118
	0.13	90	0.1170	
	0.13	85	0.1105	
	0.11	95	0.1045	
	0.12	90	0.1080	
	0.15	80	0.1200	
20	0.21	105	0.2205	0.2127
	0.21	105	0.2205	
	0.22	95	0.2090	
	0.22	100	0.2200	
	0.26	80	0.2080	
	0.22	90	0.1980	
30	0.29	110	0.3190	0.3034
	0.30	100	0.3000	
	0.32	90	0.2880	
	0.30	100	0.3000	
	0.30	100	0.3000	
	0.33	95	0.3135	
40	0.38	110	0.4180	0.4025
	0.37	110	0.4070	
	0.38	110	0.4180	
	0.43	90	0.3870	
	0.42	90	0.3780	
	0.37	110	0.4070	

In several cases, however, the work study person may be faced with a problem where more than one major factor affects the time of operation. Let us therefore assume that we have a case where a motor-driven circular saw is used for cross-cutting wood (of the same type). When we analyse the major and minor factors as we did in the previous example, we may reach the following conclusions:

Factors influencing the time

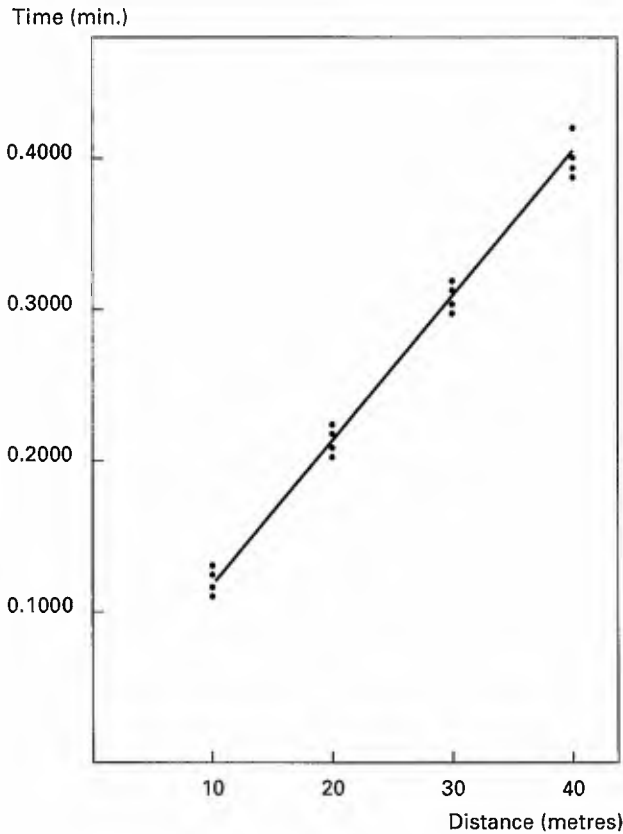
Major

Variation in the thickness of the wood
Variation in the width of the wood

Minor

Physical make-up of worker
Temperature
Humidity
Lighting
Method of holding wood
Degree of physical force applied
Machine in good working order
Experience of worker

Figure 134. Restricted walking



We are assuming here that we are dealing with skilled workers. After a period of time, it proves possible to calculate the base time for some, but not all, thicknesses and widths of wood. The results are shown in table 26.

The first step consists in plotting the time against the width of wood for each thickness (2, 4, 6, 8 cm) (figure 134). From the resulting curves the missing values in the table (say, for a thickness of 4 cm and a width of 12 cm) may be derived.

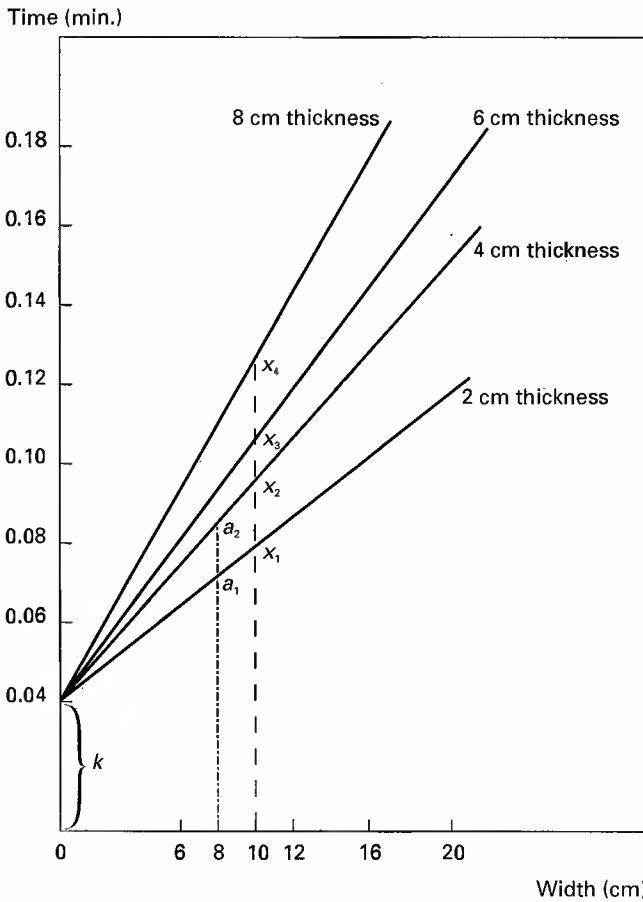
A problem arises, however, if we want to derive standard times for other thicknesses and widths, say 3 cm thick and 8 cm wide. Neither of these dimensions is represented in the table. There are two ways to solve this problem.

(1) By **calculation**. We draw a perpendicular ordinate from the point representing the required width (in this case, 8 cm) and let it intercept the appropriate lines of thickness at points a_1 and a_2 respectively (figure 135). By "appropriate" we mean the thickness curves representing the lower and upper values on either side of the desired thickness. In our example, the required thickness is 3 cm; therefore the two appropriate curves are those representing a thickness of 2 and 4 cm.

Table 26. Base times for cross-cutting wood of varying width and thickness

Thickness (cm)							
2		4		6		8	
Width (cm)	Time (min.)	Width (cm)	Time (min.)	Width (cm)	Time (min.)	Width (cm)	Time (min.)
6	0.064	6	0.074	6	0.081	6	0.093
12	0.088	12		12	0.126	12	0.146
16	0.104	16	0.130	16		16	0.181
20	0.120	20	0.160	20	0.180	20	

Figure 135. Base times for cross-cutting wood of varying width and thickness



We can then apply the following equation:

$$T = a_1 + (a_2 - a_1) f$$

where

T = time we wish to calculate;

a_1 = time at the thickness of 2 cm (lower limit curve)
(in this case it is 0.072);

a_2 = time at the thickness of 4 cm (upper limit curve)
(in this case it is 0.086);

f = a decimal fraction representing the required thickness in relation to a_2 and a_1 (in this case it is halfway between the two, or $f = 0.5$);

By applying the equation we obtain the following result:

$$T = 0.072 + 0.5 (0.086 - 0.072) = 0.079 \text{ min.}$$

(2) By **graphical factor comparison**. The first step in this method is to plot the four curves representing the various thicknesses of wood with width as the independent variable and time as the dependent variable (the curves shown in figure 135).

Looking again at table 26, we see that the data for width and time for the 2 cm thickness are complete, and that the points fit well on the curve drawn in figure 135 for that thickness. This curve is then reproduced separately and called a base curve (figure 136).

For the second step, we go back to figure 135 and choose an arbitrary point representing the width anywhere between the values of 6 and 20 cm on the horizontal axis. Let us assume that we have selected a point representing 10 cm. From this point we draw a perpendicular ordinate which will intercept the four curves at points x_1, x_2, x_3 and x_4 respectively.

The third step consists in drawing a **factor curve** from points that may be calculated as follows:

<i>Thickness:</i>	2	4	6	8
<i>Factor:</i>	$\frac{x_1}{x_1} = 1$	$\frac{x_2}{x_1}$ or $\frac{96}{80} = 1.2$	$\frac{x_3}{x_1}$ or $\frac{112}{80} = 1.4$	$\frac{x_4}{x_1}$ or $\frac{128}{80} = 1.6$

From these figures it is now possible to plot the factor curve (figure 137). The time can be readily calculated from both the base curve and the factor curve, using the following equation:

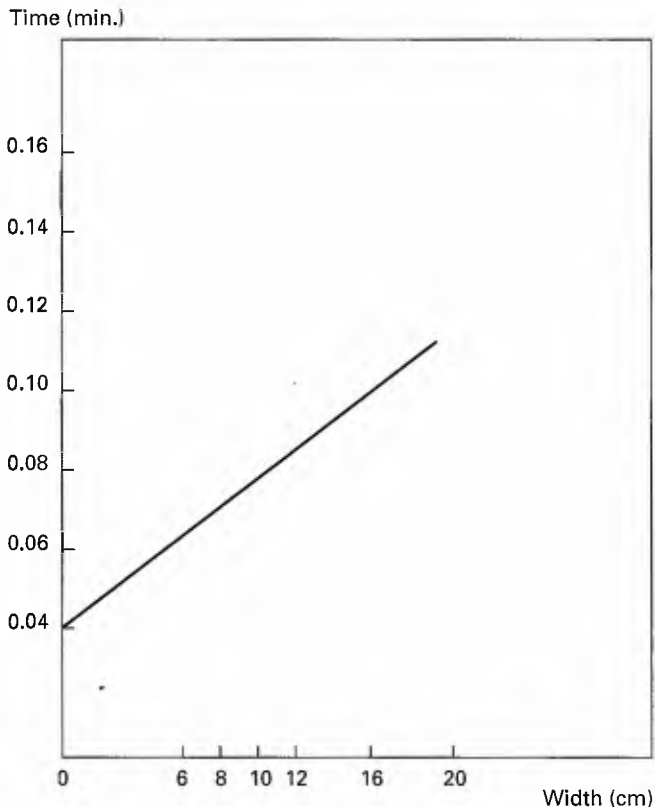
$$\text{total time} = \text{base time} \times \text{factor}$$

to calculate the time needed for cutting a piece of wood 8 cm wide by 3 cm thick:

$$T = 0.072 \times 1.1 = 0.079 \text{ min.}$$

In this case, the time needed for a width of 8 cm (read from the base curve) is multiplied by the factor for a thickness of 3 cm (read from the factor curve).

Figure 136. Base curve for cross-cutting wood of 2 cm thickness and of varying width



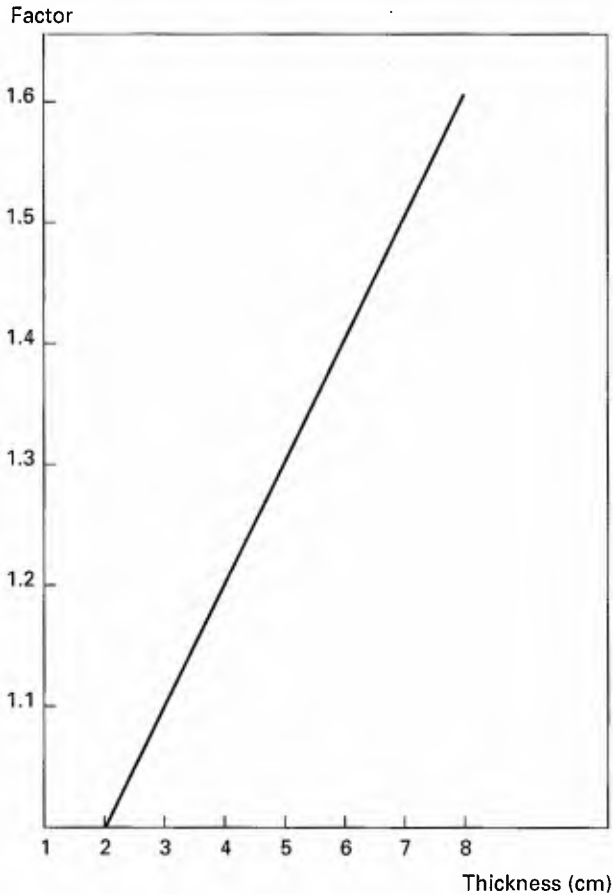
It can be seen, therefore, that the data required to derive standard times can be obtained from either tables or graphs. To these data the work study person can then add any allowances in the usual way. If a firm decides that the same allowance factor is applicable to every job in a given class of work, it can then express its standard data in terms of the standard time for each element, instead of using the normal times as we did.

A word of caution is necessary here. The data collected usually cover a certain range of readings. It is not advisable to extrapolate these data for values that fall outside this range. For example, in our previous example the readings covered pieces of wood ranging from 6 to 20 cm wide and from 2 to 8 cm thick. We know what happens within this range; but there is no way of knowing whether the same type of linear relationship will continue if we go beyond this range by exceeding the widths and thicknesses actually studied and by projecting our curves beyond the points for which we have time study data.

3. Use of PTS systems to develop standard data

The method used for developing standard data outlined above assumed that the work study person based the calculations on data derived from stop-watch time study. As was mentioned earlier, standard data may also be developed from

Figure 137. Factor curve for cross-cutting wood of varying width and thickness



PTS systems such as MTM, Work Factor, General Sewing Data (GSD) or Clerical Work Data (CWD).

In case PTS is used, the data derived for each element take into account the normal variations that are likely to arise in the execution of the job when other products, processes, equipment or materials are used. These variations result from size, capacity, method of operation, type of tool (which may be simple or elaborate, few or many) and nature of the work (which can range from jobbing or small batch work to virtually continuous production).

The use of PTS in deriving standard data is illustrated in table 27, which gives a list of the most common elements in light engineering and assembly work, with details of their possible variations. The definition of each element is also given.

Table 27. Standard data elements in light engineering and assembly work

General elements (can be used in several departments)	Possible variations	Code
<i>GET</i>	Stillage to bench Bench to tool Stillage to tool Tangled allowance Small parts to container	GSB GBT GST GTA GSP
<i>POSITION IN TOOL</i>	Easy Medium Difficult Complex	PE PM PD PC
<i>CLAMP AND UNCLAMP</i>	Fingers Toggle Slide Air-operated	CF CT CS CA
<i>OPERATE</i>	Close and open guard Foot pedal Lever Safety buttons Flypress Machine type	OCG OP OL OSB OFP OMT
<i>REMOVE FROM TOOL</i>	Automatic Easy Medium Difficult Complex Lever out component	RA RE RM RD RC RLC
<i>TURN (IN) TOOL</i>	Turn in tool Turn tool	TIT TT
<i>ASIDE</i>	Automatic Tool to bench Bench to stillage Tool to stillage	AA ATB ABS ATS
<i>MISCELLANEOUS</i>	Count parts Mark or score parts Work area to tool	MCP MSP WAT
<i>INSPECT OR CHECK</i>	Component in fixture or gauge	CCF

Element definitions

<i>GET</i>	Covers picking up and moving an object, or handful of objects, to a destination.
<i>POSITION IN TOOL</i>	Covers positioning an object, or handful of objects, in a tool fixture, etc.; or between electrodes.
<i>CLAMP AND UNCLAMP</i>	Covers all the motions necessary to close and later open a clamp of the type that operates by pressure on the object held; or to hold an object in a tool or fixture, by a clamping action of the fingers.
<i>OPERATE</i>	Covers all the time and all the manual motions necessary to: <ul style="list-style-type: none">— close and later open a guard (OCG);— grasp or contact an operating control, and later return the hand to the working area, or the foot to the ground;— operate the controls and initiate the machine cycle (OMT).
<i>REMOVE FROM TOOL</i>	Covers removing an object from a tool, fixture, etc.; or a part, component or fixture from under a drill; or from between electrodes.
<i>TURN (IN) TOOL</i>	Occurs when two "Operate" elements follow each other, and the object must be removed from the tool, turned, and repositioned in the tool; or the fixture or jig must be turned or moved, in or under the tool.
<i>ASIDE</i>	Covers moving and putting down an object or handful of objects, already held.

Word definitions

Object	Any object handled; such as parts, hand-tools, subassemblies or completed articles. Also, any jig, fixture or other holding device.
Handful	The optimum number of objects which can be conveniently picked up, moved and placed as required.
Bench	The term "bench" includes any table, tote pan or other storage area, convenient to the tool or workplace.
Stillage	A storage box or container on legs, for moving by a hand-lifting or fork-lift truck. The term "stillage" includes a pallet, the floor or any other storage device at floor level.
Tool	A general term to cover any fixture, jig, electrode press or other tool used to hold or operate on an object or objects. One tool can be positioned in another — for example, a parts-holding fixture under a drill or a welding electrode.

Figure 138 illustrates a typical operation in a light engineering plant. Many operations, including the one shown here, contain one or other of the following sequences of elements (note that other sequences are also possible):

- (a) get material; position in tool; operate machine; remove part; aside; or
- (b) get material; position in tool; position fixture in machine; operate machine; remove fixture; remove part; aside.

In figure 139, sequence (a) is shown as applied in power press work, and in figure 140 the element *TRANSPORT* has been further analysed and the distances indicated.

Figure 138. Sequence of elements in a power press operation

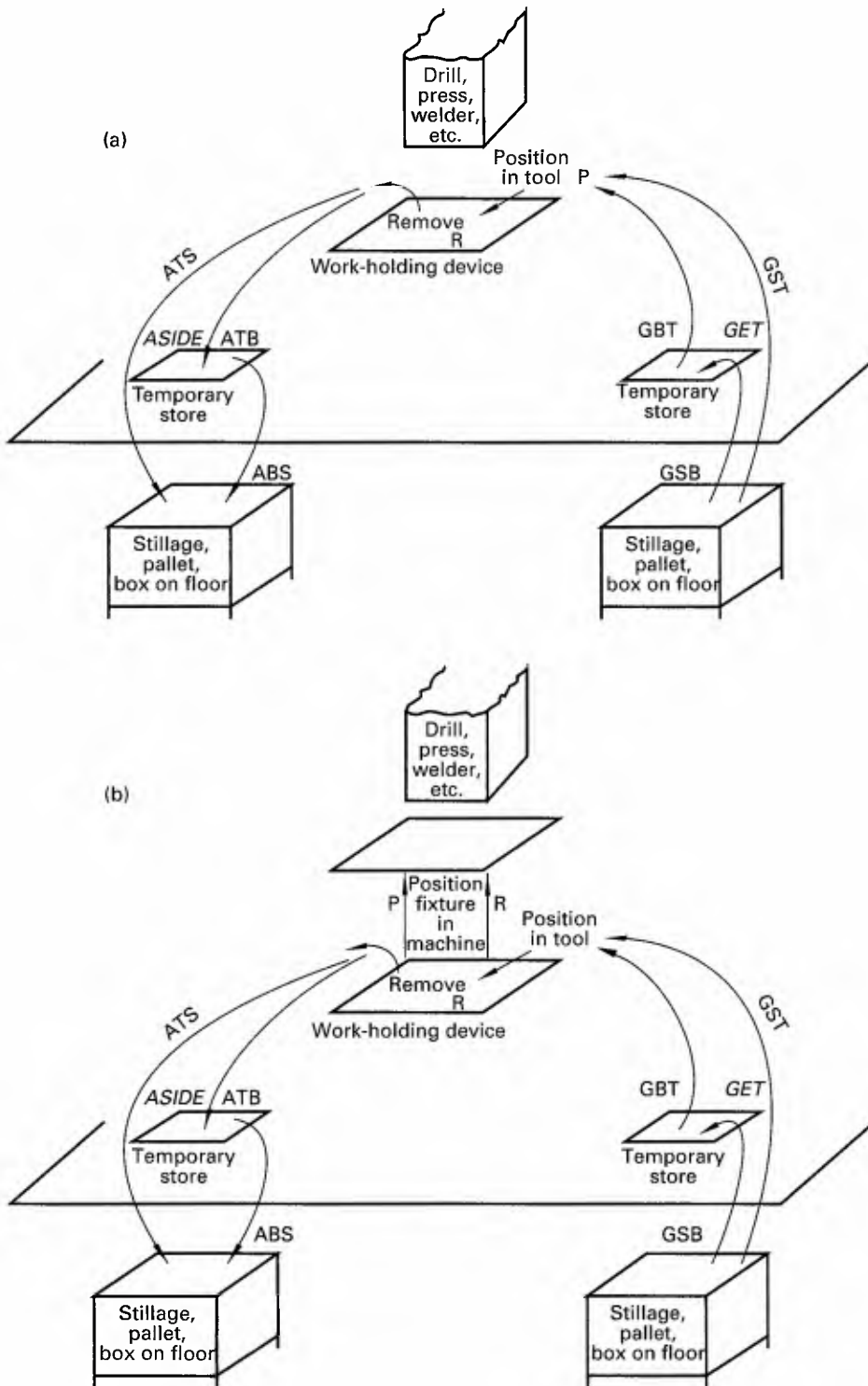


Figure 139.
Basic elements of
power press work

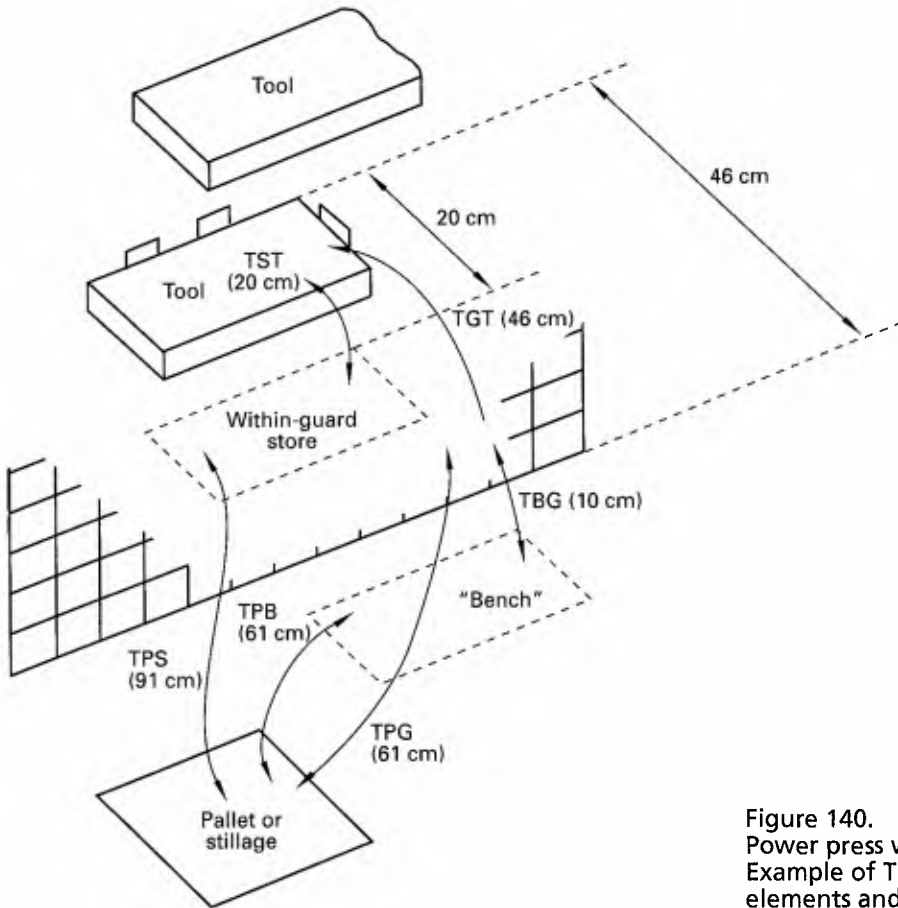
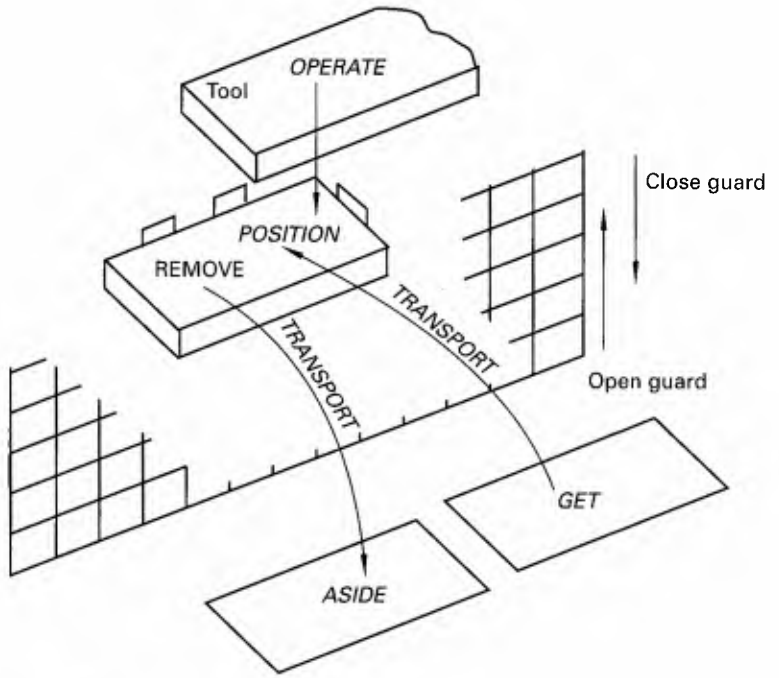


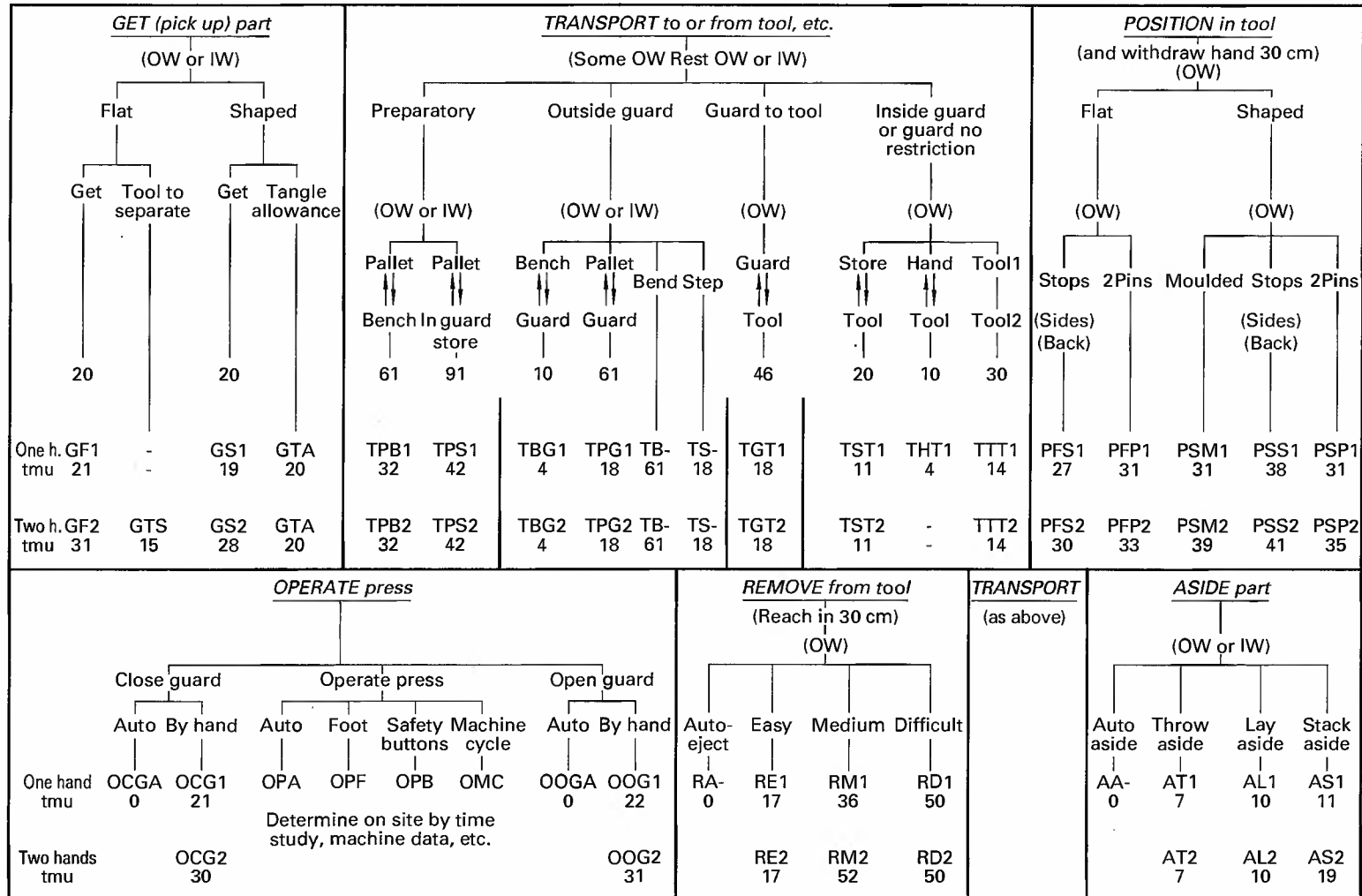
Figure 140.
Power press work:
Example of **TRANSPORT**
elements and distances

Figure 141. Power press work: Example of standard data determined by MTM-2 (tabular presentation)

Element	Code	tmu	Element	Code	tmu	Element	Code	tmu
<i>GET part</i>			<i>POSITION in tool</i>			<i>REMOVE from tool</i>		
Flat	GF1	21	<i>Flat part</i>			Auto eject	RA-	0
	GF2	31	Stops	PFS1	27	Easy	RE1	17
Use tool	GTS	15		PFS2	30		RE2	17
Shaped	GS1	19	Pins	PPF1	31	Medium	RM1	36
	GS2	28		PPF2	33	Difficult	RD1	50
Tangle, add	GTA	20	<i>Shaped part</i>				RD2	50
Weight	GW	-	Moulded	PSM1	31	Weight	GW	-
<i>TRANSPORT</i>				PSM2	39	<i>TRANSPORT (as above)</i>		
<i>To or from guard and</i>			Stops	PSS1	38	<i>ASIDE part</i>		
Bench	TBG1	4		PSS2	41	Auto aside	AA-	0
	TBG2	4	Pins	PSP1	31	Throw	AT1	7
Pallet, etc.	TPG1	18		PSP2	35		AT2	7
	TPG2	18	Weight	PW	-	Lay aside	AL1	10
Tool	TGT1	18	<i>OPERATE PRESS</i>			Stack aside	AS1	11
	TGT2	18	<i>Close guard</i>				AS2	19
Bend, add	TB-	61	Auto	OCGA	0	Weight	-	-
Step, add	TS-	18	One hand	OCG1	21			
<i>To or from tool and</i>			Two hands	OCG2	30			
Guard	TGT1	18	<i>Operate press</i>					
	TGT2	18	Auto	OPA	*			
Store	TST1	11	Foot	OPF	*			
	TST2	11	Buttons	OPB	*			
Hand	THT1	4	Machine cycle	OMC	*			
2nd tool	TTT1	14	* For each press use machine data or time study					
	TTT2	14	<i>Open guard</i>					
<i>To or from pallet and</i>			Auto	OOGA	0			
Bench	TPB1	32	One hand	OOG1	22			
	TPB2	32	Two hands	OOG2	31			
Store	TPS1	42						
	TPS2	42						
Guard	TPG1	18						
	TPG2	18						
Weight	PW	-						

Note: Last character in code indicates: 1 = one-handed; 2 = two-handed.

Figure 142. Power press work: Example of standard data determined by MTM-2 (algorithmic presentation)



To develop standard data from a PTS system, each sequence of elements is now analysed, using MTM-2, for example. It is also possible to build up from MTM-2 and other PTS systems a **data bank** for certain standard operations, with their possible variations. Standard data developed in this way may be presented either as a table (as in figure 141) or algorithmically (as in figure 142). Figure 143 reproduces a form which can then be used to record the time for a particular activity using data derived from either figure 141 or figure 142.

4. Externally sourced standard data

There are a number of standard data systems consisting of data which have been developed to represent a particular category of work — often in a particular industry. Such data are often based on PTS data, as above, but constructed to offer the higher-level data blocks for specific types of work that make the data faster and easier to apply. Examples of such systems are General Sewing Data (GSD) and Clerical Work Data (CWD).

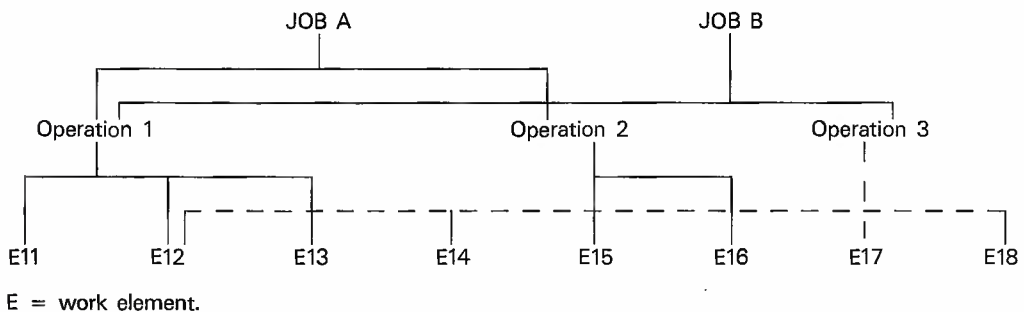
Such data systems are usually proprietary and, as a minimum, will require the practitioner to attend an authorized training course. Some systems also require the payment of a licence fee before the data can be used, either on a one-off basis or as an annual licence. Although this may be expensive it does ensure that the system developers have funding to maintain, extend and develop the system.

It is important to identify the source of the data and the way in which they have been assembled and validated. The International MTM Directorate (IMD) carries out validation of MTM-based systems but there is no independent validating body for the full range of general-purpose systems.

It is also important to validate the data in the locations and under the conditions in which they are to be applied. Data derived in one environment may not be directly transferable to another — they may require some amendment. Validation can be carried out by using the data to arrive at times for a range of jobs and comparing those times to times derived from another measurement process (such as PTS or time study). The range of jobs measured should represent the full spectrum of work to be covered in the final measurement programme, and this pilot or validation programme should include a range of operating conditions, times of day, operators, and so on. Where the results obtained from the standard data are significantly different from those obtained from the “control technique” it may be possible, by careful analysis, to identify a factor or factors that can be applied to all or some of the data to provide acceptable results. If this is the case, further studies should be taken to ensure that the conversion process remains valid over a more comprehensive range of jobs. The data can then be adjusted by the factors before being implemented as the basis of the full measurement programme.

This validation process should be carried out periodically for any standard data system (including those using data developed in-house) since the nature of jobs and the conditions under which they are performed will change over time.

Figure 144. Compilation of computerized standard data: A schematic representation



Periodic re-evaluation ensures accuracy and integrity of the data and maintains confidence in the measurement process.

5. Computerized measurement systems

The use of standard data for work measurement involves a significant amount of clerical and administrative work in maintaining the data in a form which allows particular data to be readily identified and retrieved, and in maintaining records of jobs which have been measured by the application of particular data. This is necessary so that if base data change (due to a change in method or in working conditions), jobs which have incorporated those data can be identified. This process is made easier if the data are stored in a computerized system.

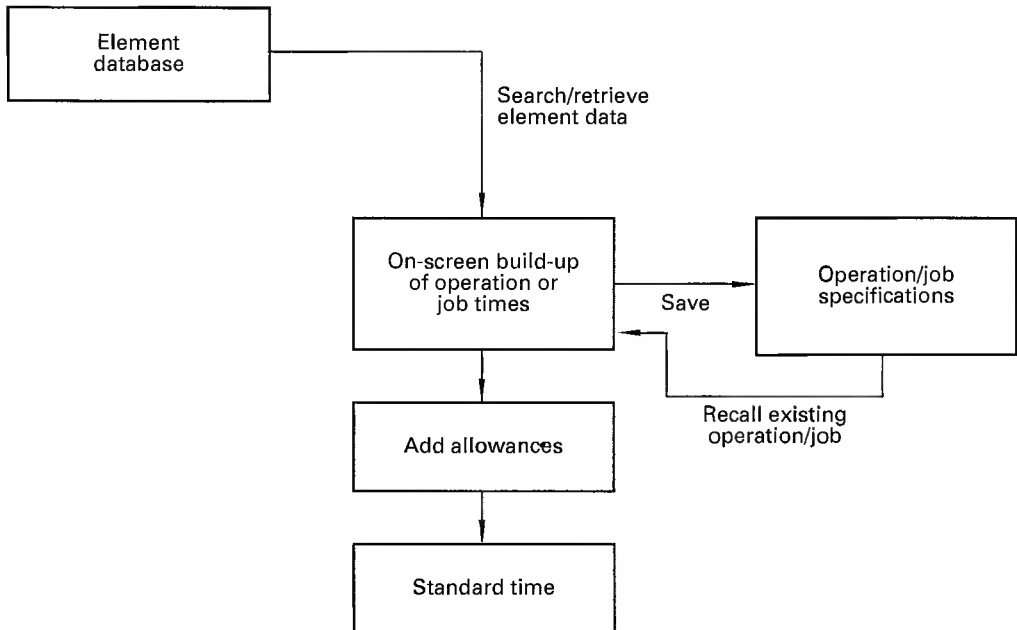
We have already made reference in Chapter 23 to the use of computers in the analysis of time study data. This is often related to the use of electronic study boards or data capture devices which together with the analysis software make up a complete electronic time study package. This is in fact a measurement system that lends itself readily to the development of computerized standard data.

Most computerized standard data make use of microcomputers but the unique part of the system is actually a software package that allows the storage and manipulation of time-based data. This data may be downloaded from electronic study devices or may be manually input. There are a number of such systems available, some being linked to particular sets of data and others being "empty shells" into which the organization can input its data from whatever source.

Many of these systems allow the application of data in a hierarchical fashion. The original standard data are stored in the system as "base data" or "elemental data". Higher-level blocks (such as operations) are then built up by combining a number of elements. The details of such operations, in terms of the elements involved and the frequency of those elements, are stored in the system. These operations can then be built into jobs in the same way. The data can thus be represented as shown in figure 144.

At any time the make-up of a particular job or operation and its standard time can be printed out, the time being calculated during the printing stage

Figure 145. Deriving a computerized standard time for an operation



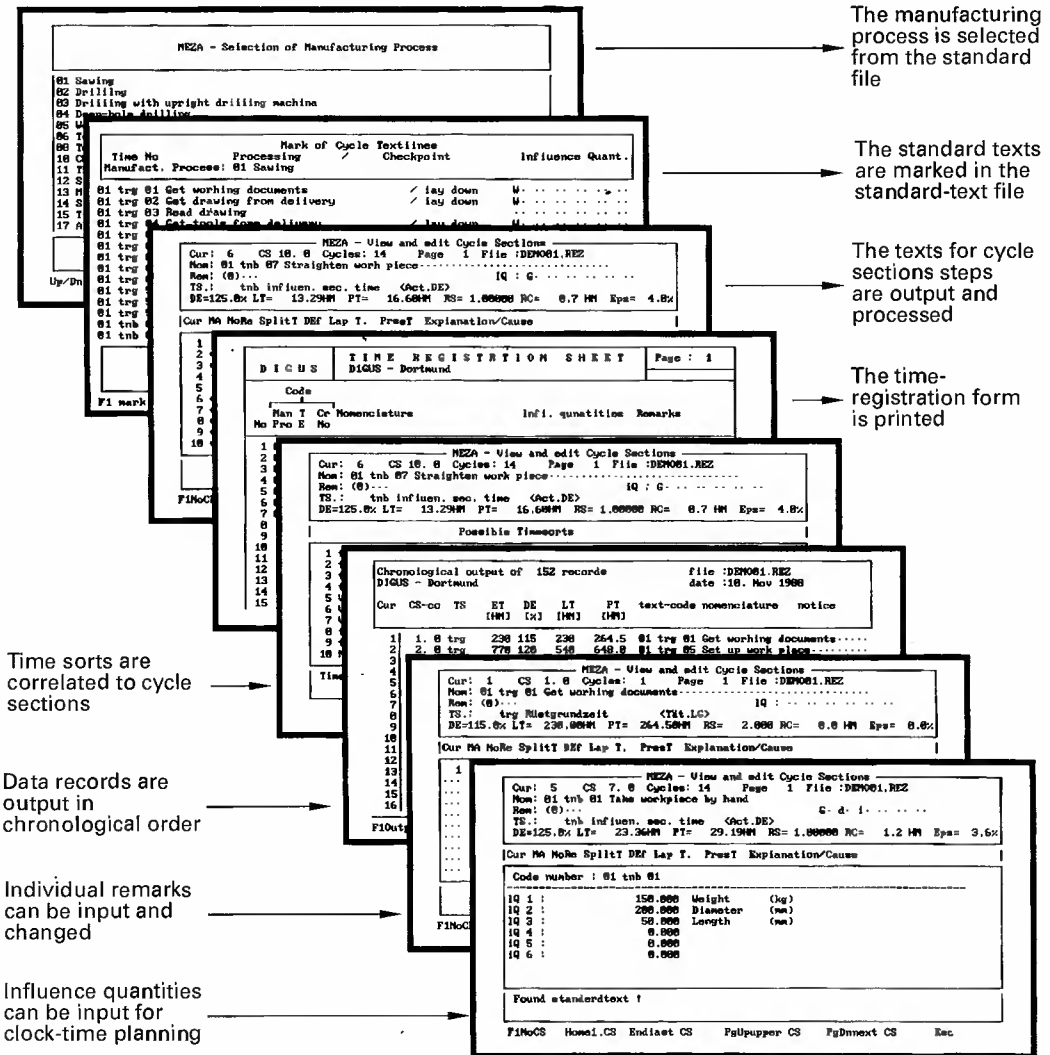
from the individual element times and frequencies, from the stored information on the various elements and cycle or operation times.

The use of such a system to develop a standard time for an operation or a job is illustrated in figure 145.

Several software packages exist for developing standard data, and for their use in deriving standard times for various operations. Examples are CPD90 from Sweden, Timebuilder from Ireland, Micromatic Methods and Measurement developed in the United States, Tectime developed in the United Kingdom, and Meza and Plazet packages from Germany. An example of the type of information that can be obtained using Meza and Plazet is shown in figures 146 and 147.

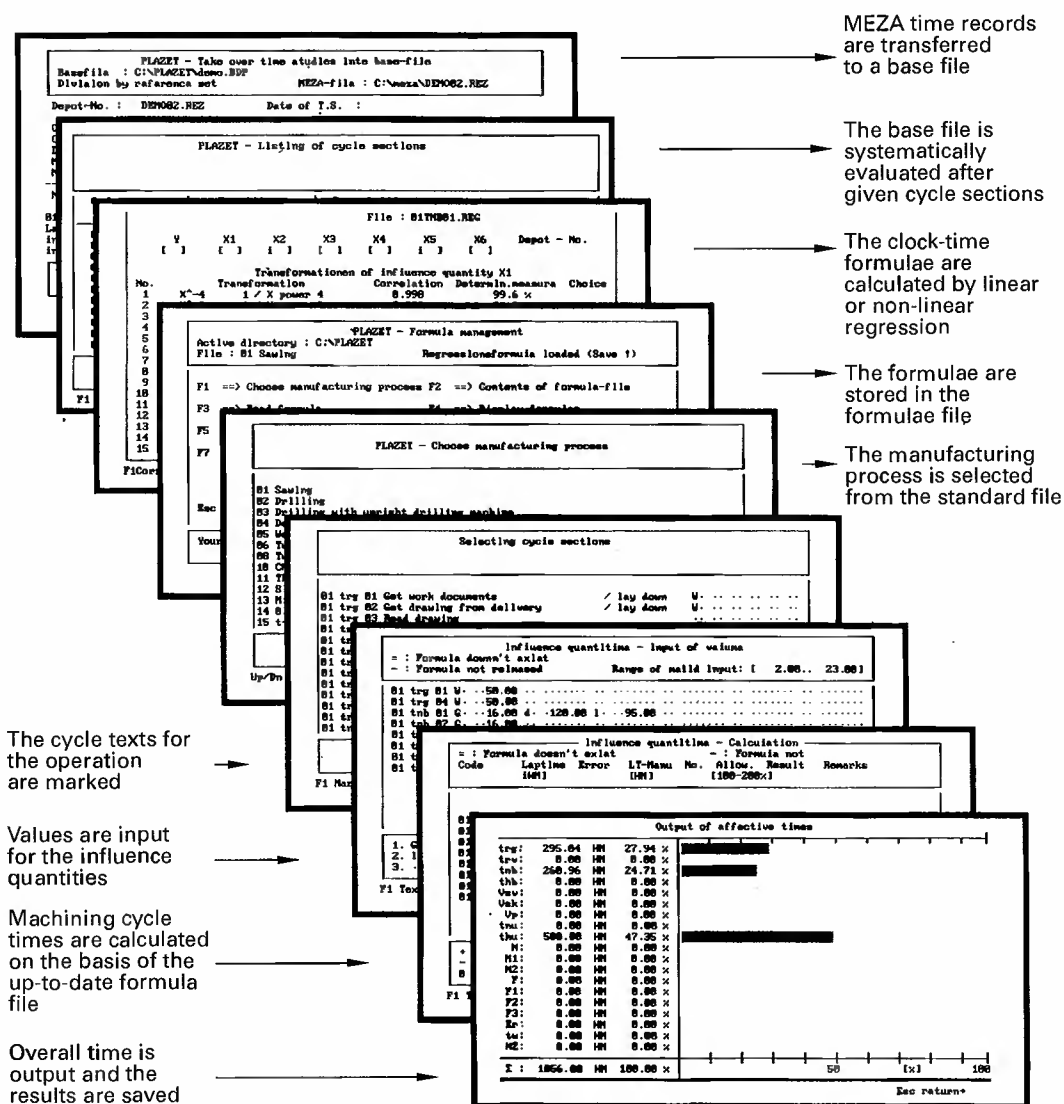
A list of computerized work measurement application systems is also available from the European Federation of Productivity Services as part of their management guide to work measurement.

Figure 146. MEZA scheme for developing standard data



Source: Reproduced by courtesy of DRIGUS GmbH, Dortmund, Germany.

Figure 147. PLAZET scheme for deriving standard times of operations



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The use of time standards

1. Definition of the work covered by time standards

When the studywork has been completed, it is important that a detailed record be made of the methods, tools and equipment used and of every feature of the operations which could possibly have a bearing on the time. This is necessary because changes in the work content of an operation affecting the time will also affect planning and costing; it is doubly important where the time standard is to be used in setting rates of pay under an incentive scheme. It is a cardinal principle of all sound incentive schemes based on time study that the time standards set should not be changed except when the work content of the job is changed, when there is a change in the organization of the work, or to correct a clerical error.

When time standards are to be used as the basis for an incentive scheme, it is usual to prepare two documents to describe and define completely the way in which time standards are compiled and the working conditions to which the standards refer. These two documents are known respectively as the **technical set-up** and the **work specification**.

The technical set-up is essentially a work study document, having no reference to rates of pay, control of workers or other matters of contract between employers and employees. It shows in summary form, in suitably presented tables and graphs, the main results of the studywork undertaken in the section and how all the time standards which have been set have been derived. It contains all the information necessary to calculate fresh time standards, should the jobs or the working conditions change, in so far as these fresh standards can be compiled from the studywork already undertaken. It is thus in effect a manual from which time standards can be built up. As explained in the previous chapter, this information may be also more conveniently stored in an information system data bank.

It will be necessary to compile a separate set-up for each technically different section of an enterprise, since the methods by which time standards are compiled will differ from section to section. Thus in a vitreous enamelling shop there would probably be one set-up for the sprayers, another for the operators of the shot-blast machines, a third for the furnace operators, and so on.

Summaries of all the data on which the technical set-up is based should be attached to it, including:

- flow process charts showing the improved methods developed;

- analysis of studies sheets;
- relaxation allowance calculation sheets;
- data from predetermined time standards (PTS);
- curves and graphs relating to standard data.

The greatest care should be taken of the technical set-up and of all the original documents attached to it, since they are essential evidence in any disputes which may arise. They are also of great value in compiling time standards for similar work in the future. Technical set-ups are normally filed in the work study department, where they are available to the management or to the workers' representatives whenever they may be needed.

2. The work specification

A work specification is a document setting out the details of an operation or job, how it is to be performed, the layout of the workplace, particulars of machines, tools and appliances to be used, and the duties and responsibilities of the worker. The standard time or allowed time assigned to the job is normally included

The work specification thus represents the basic data on which the contract between employer and employee for the operation of an incentive scheme rests.

The amount of detail necessary in a work specification varies greatly according to the nature of the operation concerned. In machine shop work in the engineering industry, where a large number of different jobs are done on machines whose methods of operation are broadly similar, general conditions governing all jobs can be established for the whole shop and only variations in detail need be specifically recorded.

On the other hand, where an operation involves a whole plant or department and will run for an indefinite period substantially unchanged, as is the case in continuous production, the work specification may be lengthy and detailed. For instance, it may include specifications for the alternatives of types of materials used.

Generally speaking, the following points should be covered by a work specification, which should, of course, embrace the standard method laid down as a result of the method study:

A. Details of the workpieces or products, including:

- drawing, specification or product number and title;
- material specification;
- sketches, where necessary, of parts or surfaces to be treated.

- B. Details of the machine or plant on which the operation is performed, including:**
- make, size or type, plant register number;
 - speeds and feeds, pulley sizes or other equivalent data;
 - jigs, tools and fixtures;
 - other equipment;
 - sketch of workplace layout (where not available on the method study).
- C. Operation number and general description of the work covered**
- D. Quality standards, including:**
- quality grade;
 - finish and/or tolerances, where applicable;
 - checking and gauging requirements, gauges and other inspection apparatus;
 - frequency of inspection;
 - action to be taken for items that fail the quality standard.
- E. Grade and sex of labour, including:**
- direct and indirect labour;
 - part-time assistance by inspectors or supervisors.
- F. Detailed description of all work involved, including:**
- repetitive elements, constant and variable;
 - occasional elements;
 - indirect work: Setting up and breaking down;
 - cleaning, greasing, etc., and frequency with which such operations are carried out.
- G. Details of time standards, including:**
- standard time for each element, job or operation, as appropriate;
 - allowed time for all indirect work, with a note on how it has been assessed;
 - percentage relaxation allowance included in each element time;
 - other allowances.
- H. Clerical procedure to be carried out by operatives in recording output and booking waiting time**
- I. Conditions under which the time standard is issued, and any special provisos**

It may be necessary to supply copies of the work specification to the management and to the departmental and shop supervisors and, in the case of specifications affecting a large number of workers, to the workers' representatives.

The manner in which the time standards are made known to the operatives depends largely on the nature of the work. If the job is one that is done only by a single worker (the one who was timed), it is usually enough for the worker to be informed by work study person, in the first instance. When work study has been accepted, workers do not usually want lengthy explanations: what they are interested in are the targets at which they must aim in order to earn a reasonable bonus. Time standards are likely to be better understood if they are put in the form "You will need to do 12 pieces an hour for time-and-a-third", or "17 hanks a shift for time-and-a-third", than in the form "13 standard minutes per piece". If anything appears to be wrong with the time standard, further details will very soon be sought. If a whole shop is on the same type of work, as is often the case in certain process industries, including textile spinning, summaries of time standards should be posted on the notice boards in the department. It may also be desirable to read relevant parts of the work specification at a departmental meeting. This will have to be done where most of the people affected by the time standards are illiterate. In batch production the standard time is generally written or printed on the work ticket, job card or process layout.

3. The standard unit of work

Standard times are generally set down in the following forms:

x minutes per piece;

y minutes per 100 (or per 1,000) pieces; or

z minutes per ton, metre, square metre, etc.

They are sometimes calculated or translated into hours. These time values represent the output at standard performance, that is, at 100 rating.

The minutes or hours allowed for any given job are not minutes or hours of continuous work. Each unit of time contains within it an element of relaxation.

The proportions of relaxation and work will vary according to the heaviness of the work. In extremely heavy, hot work such as furnace tending, the proportion of relaxation may be 50 per cent or more.

Since the standard minute is a measure of output it can be used in measuring and comparing productivity, which may be represented by the ratio:

$$\text{Performance} = \frac{\text{output of work in standard minutes}}{\text{input of labour time or machine time in clock minutes}} \times 100$$

A particular advantage of the standard minute is that it can be used to measure and compare outputs in dissimilar types of work, the accuracy of the comparison being limited by the consistency of the time standards.

4. Production planning and the utilization of plant and human resources

One of the causes of ineffective time is failing to plan the flow of work and of orders, with the result that one order does not immediately follow on another and plant and labour are not continuously employed.

In order to plan a programme of work effectively, it is necessary to know precisely:

1. What is to be made or done.
2. The quantity involved.
3. What operations are necessary to carry out the work.
4. What plant, equipment and tools are needed.
5. What types of labour are needed.
6. How long each operation may be expected to take.
7. How much plant and equipment of the types necessary are available.
8. How much labour of the types necessary is available.

The information on items 1 and 2 is generally supplied by the sales office or commercial department.

The information for determining items 3, 4 and 5 is supplied by process planning and **method study**.

The information on item 6 is supplied by **work measurement**.

The information on item 7 is supplied from plant department records or those of the department concerned.

The information on item 8 is supplied from personnel office records or those of the department concerned.

Once this information is available, it is a matter of simple arithmetic to match the requirements with the available capacity. Both the requirements and the capacity available to fulfil them must be stated in terms of time.

Requirements will be stated as:

number of operations of each type to be performed \times expected time for each operation.

This must be matched against the total time available on each type of plant and with each type of labour necessary to perform the operations.

When a programme is being planned, only the actual times which the operations may be expected to take are of interest. These will depend, among other things, on whether the general conditions in the plant — including the state of labour-management relations and the system of remuneration in use — are such that the workers are working at their best rate. Where this is the case and the work study application has had time to settle down, these times should be those of the average performance of the shop or department as given by the production records over a period. This may even apply to an individual machine or process. It is the only realistic basis for such calculations. The times are arrived at by multiplying the standard times by

100

Average performance

The plant and labour capacity available is expressed in “work-minutes” or “machine-minutes”, due regard being paid to any time it is necessary to allot for cleaning, setting up, dismantling, change-overs, repairs, and so on.

The matching of production or operational requirements to capacity in this way makes it possible to:

- show whether there is an insufficiency of any type of plant or labour likely to hold up the programme or cause bottlenecks in the course of production and, if so, its extent;
- show whether there is an excess of capacity in any type of plant or labour and its extent;
- give accurate estimates of delivery dates.

If the management can have such information, compiled from realistic standards of performance, available well before production is due to start, it can take steps to prevent hold-ups from occurring. Alternatively, it can start looking for work to fill up spare capacity. Without such standards it has no sure basis for doing either of those things.

5. Estimating production costs

The success or failure of a firm in a competitive market may depend on the accuracy with which it is able to price its products. Unless the manufacturing time of the product is accurately known, the labour cost cannot be estimated, and many indirect costs dependent on time — such as plant depreciation, fuel and power consumption, rent, and the salaries of staff and supervision — cannot be accurately determined.

If the management can rely on the accuracy of the costing, appropriate prices can be fixed. If these are below those of the firm’s competitors, the management can be happy in the knowledge that it is underselling them in safety; if they are above, the cutting of costs can be undertaken with more assurance than would otherwise be the case and with a knowledge of the margins available to be cut.

Standard and actual labour costs per 100 or per 1,000 standard minutes of production are frequently calculated each week from the weekly control statements. Since the actual labour cost per 100 standard minutes takes into account both direct and indirect labour costs, it is the more useful figure to use for estimating production costs.

As indicated in Chapter 15, the estimation of costs of special projects can be adjusted in terms of a range that varies between normal time and crash time. In this process, knowing the time it takes to perform every activity is of primordial importance in the decision-making process. Special projects are usually costly ventures and many are subject to a tendering process. Hence a proper process of estimation based on ascertained times can make the difference in obtaining an order and in making a profit.

6. Standard costing and budgetary control

Work measurement provides the basic information for setting standards of labour costs and the means of controlling them. These standards can also be used as the basis of the labour budgets for **budgetary control**; they provide certain elements of the information necessary for the production and indirect expense budgets and, related to the sales budget, indicate the plant and labour capacity likely to be available over the period of the budget.

Besides providing the standards, work measurement also provides, accurately, the actual performance figures. The need for such accurate standards cannot be overstressed. The absence of complete cost information is at the root of many poor decisions and of many failures of industrial enterprises. Labour costs will, as usual, be based on standard times, with appropriate provision being made for deviations from standard performance.

7. Incentive schemes

Direct incentive schemes based on output do not necessarily follow on an application of work measurement. There are many enterprises where time studies are made but direct incentives are not employed. One of the reasons why a good deal of attention has been paid in previous chapters to features of time study particularly related to its use in connection with incentives is that no discussion of time study would be complete without them.

The merits of work measurement as a basis for incentive schemes lie in several features inherent in the techniques, namely:

- (1) The times are generally based on direct observation and on recording by the most accurate practicable means.
- (2) Enough observations are taken of all elements of work, both repetitive and occasional, to ensure that the times finally selected to make up the standard time are truly representative and that random occurrences are taken into account.
- (3) Full records are made and retained so as to be available for examination by either management or workers, should the occasion arise.
- (4) The recorded times and associated data give a factual basis to any management-labour negotiations on performance standards, as opposed to the bargaining based on opinion which must take place when times are estimated.
- (5) Properly applied method study followed by work measurement enables management to guarantee the time standards with reasonable assurance that it is not exposing itself to the risks of perpetuating uneconomic rates.

It is important for the success of any incentive scheme that the workers should know as quickly as possible the bonus they have earned. Wherever possible, this information should be made available the day after the one to which it refers. It may be shown in money units, as a percentage of the standard performance, or as the average number of standard minutes produced per hour. In these latter ways the figures can be posted on the notice board

without workers actually seeing each other's earnings. In many firms it is a practice for operators to be acquainted with their performance. This enables them to raise any queries on the spot. When workers get used to thinking in standard minutes, they generally know at the end of each day what they have earned and tend to regard the daily figures as confirmation.

The value of this practice to an incentive scheme is as follows:

- (1) The effect of the operatives' own actions on their earnings is brought home to them while the events concerned are still fresh in their mind.
- (2) Any queries on the amount of bonus due can be taken up and corrections made, if necessary, **before** the wages are made up.
- (3) The posting of the figures daily on the notice board, where this has been agreed to by the workers and their representatives, adds interest and may stimulate a competitive spirit.
- (4) Repeated confirmation of their own calculations by management's figures, or clear explanations where they differ, tend to increase the confidence of the workers in the fairness of the system. Conversely, repeated mistakes by the wages staff can rapidly undermine their confidence.

8. Organization of an information system associated with work measurement

A full application of work measurement, when associated with an incentive scheme, has to be backed by a system of recording operatives' times and output of work. These times and output figures must then be processed at a central point, usually the accounts department, where they can be used to compile the bonus earned by each worker and provide management with compact and easily understandable statistics for the control of factory performance and costs.

Devising a system suitable for use in the organization is generally one of the functions of work study. Any such system must have certain characteristics. It should:

- provide accurate and full information;
- ensure that all the necessary information is entered as a matter of routine and transmitted with the minimum delay for processing;
- be **simple to understand and to operate** and as nearly as possible foolproof, so that all the routine work can be carried on by comparatively unskilled clerical staff;
- be economical of staff;
- be economical as to computer use or paperwork.

Working out a system to fulfil all these requirements is not easy, and a chapter could well be devoted to the subject. Space does not permit this, however, and the variety of systems for different applications is such that any set of examples given here would run the risk of being too complicated for some enterprises and insufficient for others. Comment will therefore be

Table 28. Minimum data required for work measurement and labour control records

Information	Source
1. Hours of attendance of each operative	Clock card or time sheet
2. Standard time for each operation	Job card or work study compiled standard data
3. Times of starting and finishing each operation	Job card or work sheet
4. Quantities produced	Job card or work sheet
5. Scrap or rectification: quantities and times	Scrap note or rectification slip
6. Waiting time and non-productive time sheet of actual performance	Waiting time slips or daily work sheet

confined to some general notes and to the basic data required together with their probable source.

The sheets or printouts on which output and performance information is summarized and reported to the management are known as **control statements**. In a fully developed control system there will probably be three different control statements, prepared at different intervals and for different purposes. A daily statement may be prepared, separately for each section of the organization, to indicate to the supervisor in charge of the section the results of the previous day's working. Once a week the weekly control statement will be compiled, usually on a departmental rather than a section-by-section basis. The weekly statement will go to both the supervisor and departmental heads. A single sheet frequently has space for the record of 13 weeks of work, a fresh line being used each week, so that the current week's results can be compared with those of earlier weeks during the same quarter. The control statement which goes to the top management is usually made up monthly, on either a departmental or a whole-plant basis.

In any system of recording associated with work measurement and an incentive system, the minimum data given in table 28 must be recorded and eventually transmitted for incentives and wages calculations.

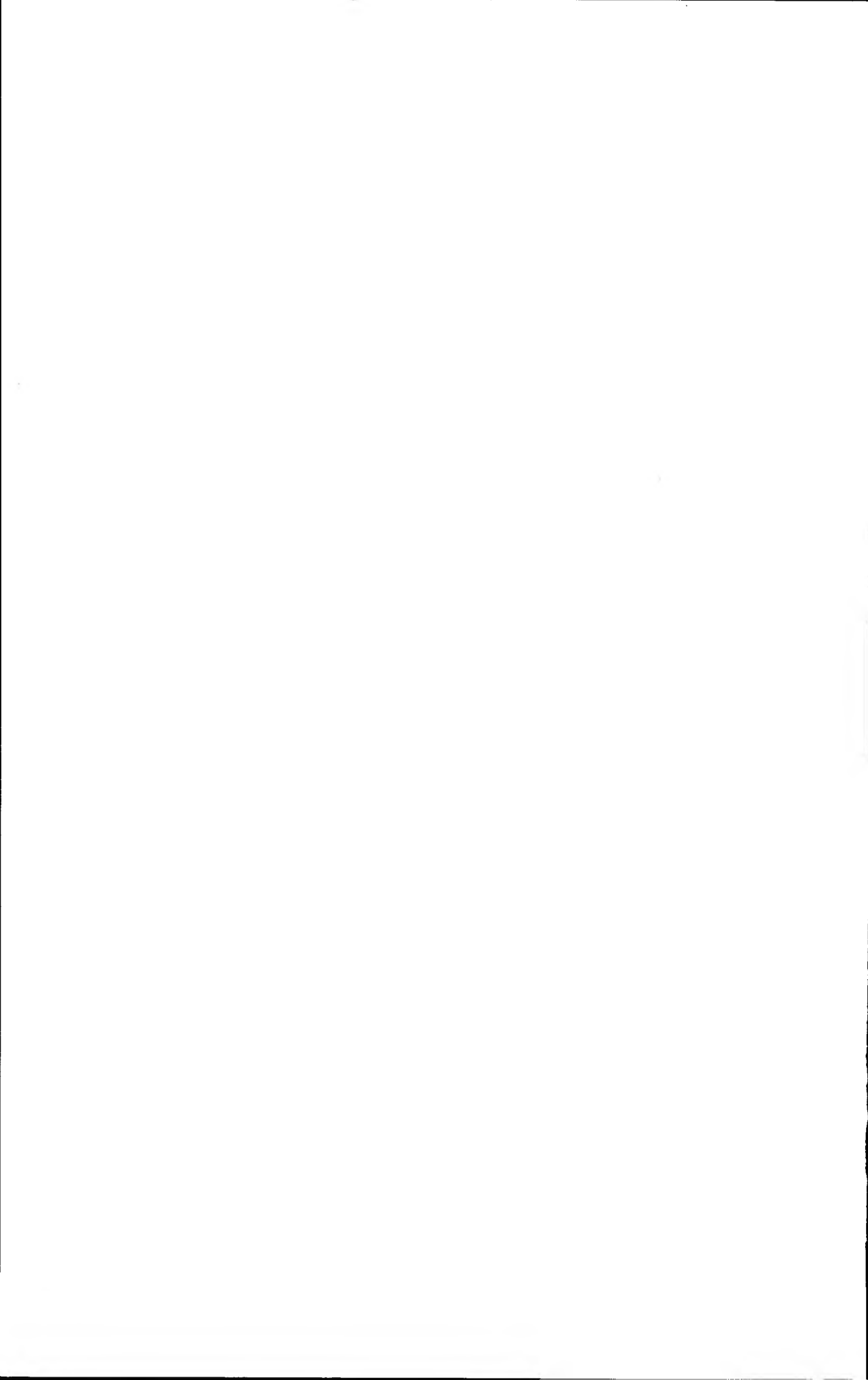
It should be noted that the rapid proliferation of mini-computers and the availability of suitable software packages have rendered the establishment of a control system quick, less cumbersome and less costly. In addition, it has also enabled management to gain an insight into ineffective times and their causes, and the productivity of various departments or of the plant as a whole.

This concludes the part of the book devoted to work measurement.



PART FIVE

**From analysis to
synthesis**



Combining methods and tasks: New forms of work organization

1. Method study and work measurement: Basic tools for job design

In the preceding chapters we have thoroughly discussed modern work study techniques. Since the introduction of these techniques at the beginning of this century, work study has become an effective tool in improving the performance of enterprises. Few developments have contributed so much towards attaining that goal. Moreover, the underlying principles of these methods will, for the foreseeable future, continue to be of immense importance in the great majority of enterprises, regardless of their size or area of economic activity.

Let us briefly summarize the basic significance of systematic work study for the development of better methods of work.

Methods: Systematic v. haphazard

The first rule of work study is that each task must be systematically analysed in advance and the ways of carrying it out must be thought through. If the task in question is to be carried out only once, perhaps this preliminary analysis is of no great importance — indeed, there might be no point in paying too much attention to it. But if the task is to be carried out repeatedly, we can easily see that much is to be gained by carefully scrutinizing the manner in which the task is executed. Every movement that can be eliminated or improved, every time span that can be shortened will produce economies — and if each task is repeated many times, as happens with mass production or long runs, the saving of even tiny movements or of a few seconds here and there can be of crucial economic importance.

It can thus readily be seen that if systematic analyses of this kind are not carried out, preferably before production is begun, inefficiency will in effect be built into the job.

Systematic analyses of the work organization which are carried out before an activity is started may thus mean considerable cost savings through the development of sound methods and working practices. However, it is important that such developments are brought out in the day-to-day activities by the people who actually perform the work using their knowledge and experience to improve working methods continuously. To bring about this situation, it is important to stimulate interest in productivity improvements among all employees, and to promote such improvements by a variety of means.

Work analysis: Step-by-step examination

An important feature of work study is therefore the systematic analysis of the job, that is the division of a task into its various component parts followed by a careful examination and discussion of each part. By thus breaking down a complex problem into its underlying elements, a clearer and more readily understandable picture of the task can be obtained, and a good method of carrying it out can be deduced.

In Chapter 7 we examined various methods of breaking down work processes into small parts. In the same chapter we went over the questioning technique — a method of questioning everything that is done and taking nothing for granted, with the aim of finding new alternatives, new combinations and new ideas.

Pre-set times for various movements

One of the most important features of modern work study is that it is possible to fix in advance, with moderate margins of error, the times necessary to carry out different movements. There are many different methods of doing this, ranging from summary estimates to highly refined PTS systems. One point that these methods have in common, however, is that they all contain a more or less established method of determining, on the basis of the characteristics of the work in question, the “normal” time that a task should require.

This process of pre-setting times for various tasks is of overwhelming importance in production management. Most importantly, it makes it possible to test alternative methods and combinations of methods of performing a certain job and to determine which alternative is the most time-saving. Furthermore, with the help of these systematic time guidelines, it becomes feasible to distribute work assignments among different individuals and groups in order to plan production more efficiently and to construct a foundation for discussing production-linked wages and similar incentives.

Again, this is an element of modern work study that is virtually indispensable in normal industrial activities. Without the help of work study methods and systematic time formulae, the determination of guidelines would be pure guesswork.

The latest role of work study: From analysis to synthesis

So far we have discussed the basic role of work study in the design of individual jobs and of work organization. Before we go into more detail, it should be emphasized that the development of method study and work measurement has been continuous, so that it is now possible to apply work study to any kind of activity. Furthermore, the workers' understanding of and active involvement in work study has increased rapidly. Over the past few years we have seen many examples of companies providing extensive training in work analysis, job simplification and work study methods, so that in their work all employees will be able to employ systematic methods to improve productivity.

With this point clear in our minds, let us now turn to the question of how the basic “building blocks” of method study and work measurement can be put together in designing jobs, and how work organization can best be shaped in other respects. We shall divide this discussion into four parts, corresponding to four organizational levels:

- Design of individual work roles.
- Design of group work in production.
- Design of product-oriented organizations.
- Design of enterprise-oriented organizations.

A detailed examination of these topics falls outside the scope of this introductory book, and we shall limit ourselves here to a discussion of some of their basic features.

2. Design of individual work roles

Guidelines in the design of jobs: Some examples

In putting together an individual work role with the help of the fundamental building blocks we have been discussing (that is, the component parts of each task and the description of methods), we may adopt a number of criteria as guidelines for satisfactory job design.

Most important are the economic aspects. With the help of systematic work study the component parts of a task are put together in such a way that as little time as possible is required to carry it out. In this book we have so far confined our discussion to this point.

However, the design of individual work roles is too complex to be effected with the aid of a single criterion — that is, what appears on paper to be the shortest time needed to carry out a task. In practice, numerous different factors must be considered.

Some of these are purely practical considerations, such as the need for different types of machinery, the nature of the different components of each job, and so on. For example, if it takes ten minutes to carry out a particular component part of the task and if this component part is repeated 1,000 times within a 50-person work group, it is easy to see that the results of this study must be combined with other information about the work situation in order to arrive at a reasonable division of the task among the various members of the group. This example is given merely to indicate the problem, which we shall not examine here. There is, however, one special group of factors that we must look at more closely: namely, the worker's needs, preferences, experience of the work, and reaction to different kinds of work organization. This is a new and important dimension, since it implies the need to adapt work design to the individual's wishes and capacities, to create jobs in industry that offer a reasonable challenge, and to provide the worker with the chance of a working climate that offers some degree of satisfaction. The reader will no doubt recall that this point was made earlier, in Chapter 4. Here we can identify three important factors that can lead to increased job satisfaction:

- A moderate amount of variety in the work done.
- Decoupling of worker/machine systems, that is, freedom from being tied to a machine during the entire working day.
- The opportunity to integrate various service and auxiliary tasks into a production job.

These three topics will be treated separately below.

Variety at work

If work is to be done well, there must be a reasonable correlation between the job and the person doing that job. A job that consists of only a few simple movements and takes only a few seconds to do can certainly be easy to learn. At first sight, it may seem that this is an efficient way of organizing the work. But this type of job is hardly efficient from a more practical viewpoint. It will rapidly become monotonous and tiring, and such extreme specialization requires long runs, plus a degree of structural stability and production volume that is not often found in reality. It is much better to create work roles that display a reasonable amount of variety, that require something from the worker in terms of learning and that are adapted to reality in terms of the true length of runs, a stable product mix and infrequent production disturbances.

There is no complete, clear answer to the question of how a task cycle that gives just the right amount of variety should be designed. However, a study of the following factors offers some guidance in bringing about improvements:

- the basic structure of the technical system;
- the pattern of the physical load;
- the information content of the task;
- the balance between physical and intellectual task components;
- the demand for learning and the need for individual development opportunities.

In many production technologies the basic structure of the technical system is an important determining factor. By way of example, we can consider final assembly in a car factory. In such systems, the content of an individual operative's work cycle is often determined by the technical system. If 500 cars are to be assembled in 500 minutes, the work cycle at each individual workstation must be one minute long. The most usual arrangement in European and American car factories has been to allocate a work volume of approximately one minute to each workstation, and to have one assembly worker at each station. With such an arrangement, each individual at the allotted workstation will perform assembly work equivalent to approximately one minute, and this will be repeated over and over again a few hundred times a day. To ensure that everyone will have time for a complete work cycle each time, it is impossible to allot a volume of work to each station equivalent to a full minute, and a safety margin of 10-15 per cent is often allowed. Since the assembly line runs at a fixed speed, any operation which is not completed at a particular workstation will result in quality defects in the finished car.

In Japanese car factories (as well as in transplants in Europe and the United States) a rather different work organization has been put into practice at these machine-controlled assembly lines. In these plants, a type of group organization is employed in such a way that a group of assembly workers is jointly responsible for one part of the assembly work, and that within such a group one particular assembly worker accompanies the car along a number of following workstations. This lengthens the job cycle despite the fact that the technical system keeps the material moving at a certain rate. In these Japanese assembly plants, it is also normal for each worker to be able to stop the whole of the assembly system by pressing a "red button" if something goes wrong.

Assembly lines in car factories and other similar production systems for assembly in long series are an area where the choice of work organization has often been discussed, and where a variety of different solutions has been tested. However, as always, the best solution in each individual case will depend on the specific circumstances at that particular plant.

However, the fixed-speed assembly line is not the only technological system that affects the time cycle. Short-cycle worker/machine operations, such as those carried out with eccentric shaft presses, offer another example of the need to reshape the entire technical system in order to apply time cycles that are of a comfortable length for the operative. This also will be discussed later.

It should be emphasized that variety in the time cycle is primarily a subjective concept and therefore cannot be precisely defined, either technically or mathematically. However, it is more or less closely related to other factors such as:

- length of the time cycle;
- size of the run;
- frequency of recurrence of a product (that is, the time that passes before the same product is worked on again);
- amount and distribution, in repetitive jobs, of non-repetitive tasks;
- differences in work structure and job content between different series.

Example. In an enterprise manufacturing electrical circuit breakers, two alternatives for the organization of the work were identified. The first would require that assembly be done in four separate jobs, each carried out at a specially built and specially equipped workstation. At the last of these workstations the assembly work is completed and a control check is made. In this type of arrangement the cycles are about 10 seconds in length. Variations within cycles are virtually non-existent.

The second alternative would require that the entire circuit breaker assembly be done at each of the workstations (i.e. one job at each workstation). In order to arrive at this solution, the materials supply system would have to be completely reorganized. By planning the work in this way the cycle is lengthened to 40 seconds. In addition, opportunities for varying the cycles increase markedly.

After an analysis of the practical consequences of the two choices at the workplace, the second alternative was chosen. The decision is significant, since

it exemplifies the efforts that have been made in recent years to limit monotony in jobs and to achieve a practical balance of working conditions.

One important point in an analysis of this kind is the fact that people are different. At any one time the people at the same workplace will present quite different characteristics. And if we study the same person at different times during his or her working life, we shall find significant differences in performance. This is an important, indeed fundamental element in the design of individual work roles. Jobs should be varied, and should present different degrees of complexity to those who execute them. Thus people can find a work role and a level of difficulty that match their own aptitudes and preferences. In addition, an individual can begin working in a certain job that has a certain level of difficulty, and can then move steadily to more challenging jobs as he or she develops further.

Decoupling worker/machine systems

The rigidity of the links on a worker in a worker/machine system may be due to several factors. The person can be tied to the workplace in a geographical sense — it may be impossible to be absent from the station for even a short time. The worker can also be tied by the method — it may be impossible to vary the order in which operations are carried out. And there can also be a restriction in terms of time — it may be necessary to carry out certain operations at fixed times.

The degree of rigidity with which the worker is tied can be “planned” — that is, the operative and the machine are consciously and deliberately tied together in a worker/machine system — but in many cases the rigidity is quite “unplanned”. In some cases this unplanned rigidity arises from a fault in the technical system; the operational stability of the machines may be so poor that the machines must be continuously tended, usually with only simple movements. Unplanned rigidity can, however, be reduced through the use of more operationally reliable technology.

Three different types of solution may be offered for this problem of rigid worker/machine links:

- complete decoupling through increased mechanization;
- use of technical auxiliary equipment to free the operative from the machine;
- decoupling through contact and cooperation among operatives.

Let us examine more closely each of these three choices.

Complete decoupling through mechanization

Decoupling of this kind requires heavy capital investment. Therefore, production processes that are to be handled in this way must be characterized by mass production, extremely short cycles and severe rigidity and monotony. In such cases mechanization means the complete elimination of all human intervention.

However, new technology has markedly increased the scope for what may be automated. It is, in particular, the much improved resetting features of machines and handling equipment which have made it possible to employ

automated solutions, even for short series production. In many cases, it might be said that it has become possible to employ mass production methods on a small scale.

One example of this is the industrial robot. Automated handling of workpieces in production equipment at earlier stages of industrial development took the form of advanced mechanical systems which had been designed specifically for the production equipment and the products that were to be handled. These installations were unable to cope with variations in products, and the high cost of such installations made very long series necessary. The industrial robot, on the other hand, is a flexible piece of equipment for handling tasks, and it can be reprogrammed relatively easily and quickly for new movements, new objects or new grips. Thus, production equipment served by an industrial robot can deal with considerable variations within a product range, and the series length for each variation within the range need not be especially great.

The industrial robot has therefore opened up promising new automation potential, both within production (such as grinding, polishing and spot-welding) and for materials handling. In the same way, modern information technology has influenced the development of production and handling equipment within many areas, and the potential for automation of working tasks in mixed production has greatly increased. In general, this development has meant that the role of the worker is becoming more and more supervisory in character.

Even the actual assembly work, which is perhaps the most difficult area, has to a certain extent been mechanized. To date, this is mostly a matter of certain simple assembly tasks, such as positioning and tightening of screws. However, developments are progressing relatively rapidly, and new opportunities are constantly being opened up as a result of technological advances. "Seeing" robots, which are now being brought into use in industrial applications, are expanding greatly the potential areas of use since the objects which are to be handled no longer need to be positioned in exactly the same location each time; the robot can "see" where the object is.

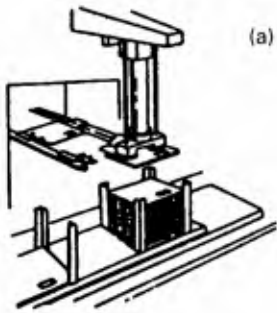
Technical auxiliary equipment for the operator

This principle can be put into effect by establishing **buffers** and **magazines** in an integrated worker/machine system in order to reduce dependence relationships between workers and machines. (A buffer is a waiting point located between two consecutive operations in the production flow; a magazine is a point of accumulation located within an operation and providing automatic feeding of material to the machine.) The key is to create processes that can accept variations in the speed at which different sections of the line move.

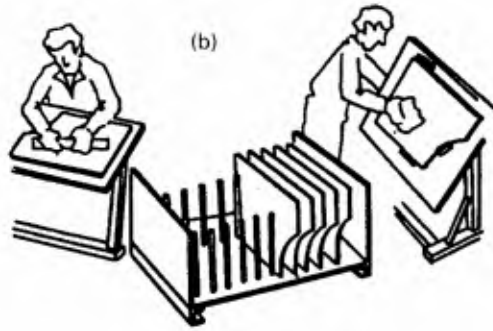
Both buffers and magazines are characterized by an "accumulation of products for continued processing" which can be completely identical in their technical design.

Since buffers and magazines are placed at different points in the worker/machine system, their characteristics as accumulators of time are influenced by different types of time gaps in the process (figure 148).

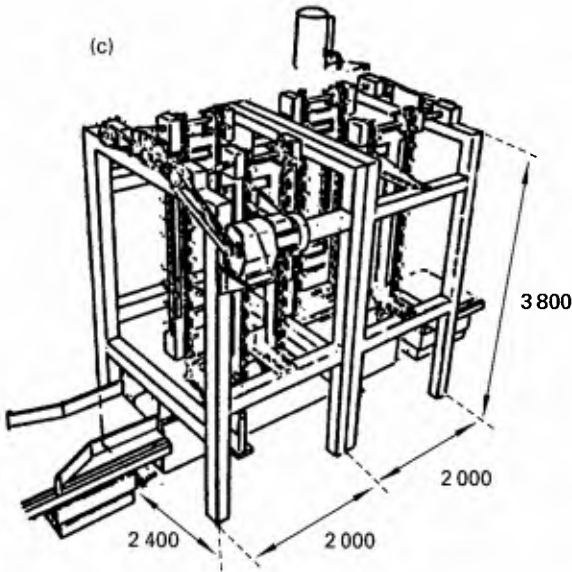
Figure 148. Some examples of the building of buffer stock in manufacturing operations



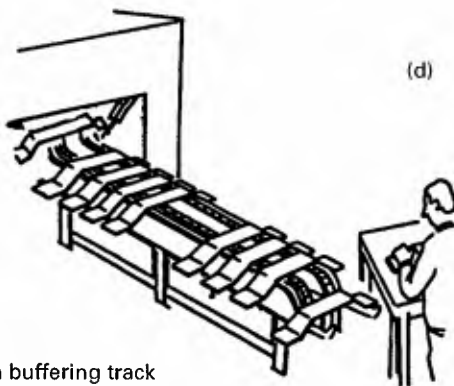
Sketch of a typical magazine



Sketch of a workstation with a simple sliding rack or storage space



Sketch of a high-stacking machine used as a buffer



Sketch of a buffering track

A buffer makes it possible to accumulate:

- the waiting times created when two operatives on opposite sides of the buffer work at different speeds; and
- the waiting times created because the quantities of work done at two stations are not absolutely identical.

A magazine makes it possible to accumulate:

- waiting times created because an operative works at a different speed from the overall speed of the technical process; and
- waiting times created because an operative is forced to wait while a machine does its part of the work.

Decoupling through contact and cooperation

Finally, decoupling can be achieved if, through job rotation and mutual cooperation and in agreement with management, workers are able to interchange tasks and assignments.

Integration of production and auxiliary tasks

In the design of individual work roles it can often be advantageous to include various service and auxiliary tasks in production jobs. This leads to greater variety for the individual in his or her job.

Auxiliary tasks that are most often combined in this way are:

- maintenance of machines and tools;
- setting-up of machines;
- handling of materials near the workstation;
- inventory work;
- quality control.

Let us discuss some of these auxiliary tasks further.

When we speak of maintenance in production positions, we are referring to measures that can be taken to reduce the number and extent of production errors. Maintenance can include a regular inspection of the system in order to find errors and take remedial measures. Maintenance can also include repairs of parts so as to make it possible to achieve the established precision norms required in production. In addition, it can include a statistical follow-up in order to improve the capacity utilization of equipment.

The possibility of including machine setting-up and similar preparatory functions in the ordinary operative's role depends on a number of factors, among which are the following:

- degree of difficulty and time available for the setting-up operation;
- frequency of setting-up operations;
- degree of rigidity in other production tasks;
- need for special auxiliary equipment to undertake this work.

Example. A metalworking enterprise conducts its operations with the help of advanced computer-controlled equipment. In one department operatives were trained to programme the computer equipment themselves. They were

thus able to handle the traditional job as well as the programming of the machine tool's computer equipment. They therefore work both as programmers and as machine operators. This example shows that even moderately difficult and specialized tasks can sometimes be integrated into a normal production job.

Regarding the possible integration of material-handling work near the workstation, the following factors are some of the more decisive:

- character of the product;
- volume of materials to be handled;
- design of the transport system;
- degree of rigidity in the production operation.

Quality activities can also be integrated to a varying extent in the production process. This applies to both inspection and measurement tasks, as well as action to correct any faulty products that might be produced. Recently in industry, and as mentioned in Chapter 13, we have seen a dramatic upswing in interest in developing quality-consciousness on the part of all employees in the production organization and in involving all employees in efforts to produce fault-free products directly in the production organization. Known as zero-defect strategies, these are an important aspect of current management strategies. This development affects the work organization in that the separate quality organization which used to be responsible for quality inspection after production and correction of faults is now tending to become smaller and quality work is instead being integrated into production.

These are some examples showing how direct production jobs can be supplemented with various auxiliary and service tasks. There are no simple, standard solutions in this area; each case must be examined in the light of its special characteristics. However, the guiding principle in making these decisions is that a practical and smoothly functioning arrangement must be feasible, that jobs can be broadened sufficiently to include everyday variations and that they must not be excessively monotonous.

3. Design of group work in production

Advantages of group work

Once individual jobs have been designed, the next logical step is to coordinate these roles. One method of coordination that has attracted increasing interest in recent years is the tying together of individual jobs into work groups. Organizational descriptions of a complete work group specify which roles are included in the group and the principles according to which these roles should be coordinated. Group work in production can have many advantages. Here we shall touch only on some of the more important of them.

The most important advantage is the way in which objectives are established and the results measured. In this connection it must be borne in mind that it is much easier to formulate appropriate objectives for a group than for an individual job.

Another advantage is that the leeway for variations in the individual's activities increases and that a stronger sense of participation in the larger process can be experienced than when each person is tied to a limited individual task. People working in a group have a better chance to cooperate continuously in improving methods and eliminating unnecessary work. Attitudes can change as team spirit develops.

A further merit of group organization is that the organization's capacity to adapt itself to change increases. An enterprise is in a state of continuous change. The management alone cannot completely control, manage and follow up this process of adaptation to change; the organization itself must possess a strong built-in capacity for self-adaptation.

These are some of the most important reasons why ideas of group work in production have been gaining ground in the design of work organization. But group work is not suitable everywhere. In certain types of production system it is an excellent concept, while in others it is completely unworkable. Let us look at some models of production systems and see how group work might fit with specific working conditions.¹

Seven production system models: Where does group work fit?

We shall divide these production systems schematically into seven main types, and then use this classification to discuss where group production is most suitable as an organizational concept. We may refer to these seven models as follows:

- The machine-paced line.
- The worker-paced line.
- The automated process.
- The concentrated operation.
- The diversified line group.
- The service group.
- The construction group.

Let us study briefly the requisite characteristics for group work in each of these categories.

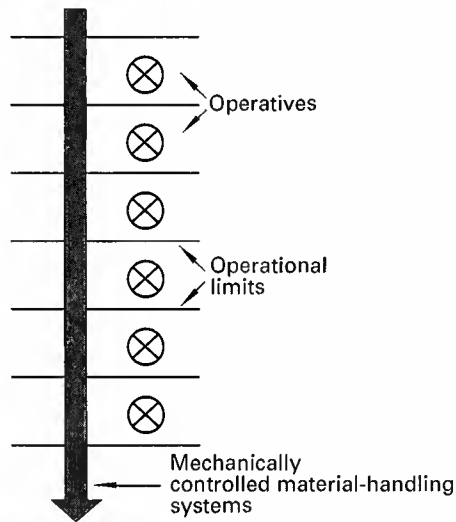
The machine-paced line

This type of arrangement is most often found in situations where material handling is an important factor and where the material-handling function occupies a dominant role. The classical example of this type is the motor car factory's final assembly on a fixed-speed assembly line.

In this type of production system a high degree of mechanized handling is chosen (figure 149). The flow of materials and the organization of work are therefore completely under the control of the technical system. Until only a few

¹ These models are taken from Hans Lindestad and Jan-Peder Norstedt: *Autonomous groups and payment by result* (Stockholm, Swedish Employers' Confederation, 1973). For further details see also George Kanawaty (ed.): *Managing and developing new forms of work organisation* (Geneva, ILO, 2nd ed., 1981).

Figure 149. Machine-paced line



years ago this was the only assembly arrangement used in situations where a high volume of materials was the rule.

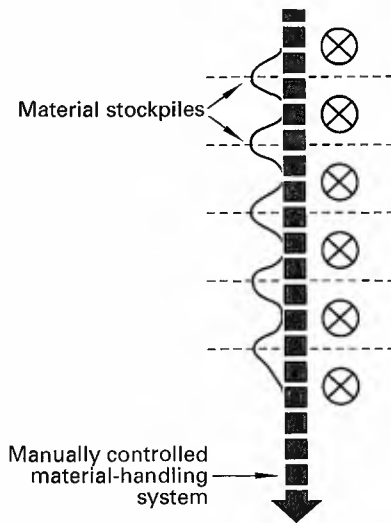
The disadvantage of this system is that the individual's work role tends to be strictly limited and the pace of the work is in all essentials controlled by the technical system. The most important disadvantage of such production systems is the way in which the operatives experience their work. Other disadvantages include the extreme sensitivity of such production lines to disturbances. A promising approach to overcoming this sensitivity can be seen in those methods, often applied in Japan, which permit any operative to stop the assembly line. Experience shows that the number of times these systems are stopped is still low. Since everyone is aware of the drastic effects of stopping the entire system, they do everything within their power to avoid having to use their "red button".

But production systems of this type nevertheless always remain sensitive to disturbances. These production chains are only as strong as their weakest link, and it requires only a small influenza epidemic in the region where the factory is located to upset the whole system. Moreover, it is difficult to make changes in such production lines.

The advantages are short through-put times, the efficient utilization of space, machines and auxiliary equipment and, consequently, the efficient operation that is achieved through the extreme division of work. This far-reaching specialization also makes it worthwhile to push the development of methods and hand tools as far as possible. Specialization also creates the best possible conditions for automation of tasks, whereas a work organization in which the work is more varied, on the other hand, makes automation more difficult.

During recent years a considerable number of attempts to "loosen up" the assembly line have been made with the help of different innovative arrangements — a point to which we shall return later.

Figure 150. Worker-paced line



The worker-paced line

If we imagine an assembly line from which we have removed the mechanized control and flow speed and introduced some inventories between workstations, we have a type of functional arrangement that is common in many companies (in the clothing and metalworking industries, for example) and which is illustrated in figure 150.

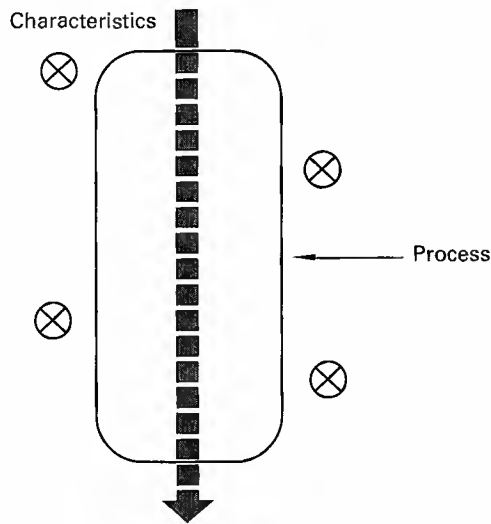
In this sort of production system the control is less rigorous and the existence of buffers makes it possible to adapt the individual work pace in a completely different way from work on an assembly line. In such a system work organization based on production groups is an excellent arrangement. Within a group made up of individual work roles, operatives can help each other, take care of work disturbances, even out peaks and valleys of work flows and strive for a good common work result. However, it is necessary to be aware of the risk of the volume of work-in-progress increasing so that the overall financial equation is less favourable.

The automated process

If it were possible to mechanize all the manually executed tasks on a conventional assembly line, the result would be a kind of process line where the individual's work would be concerned primarily with supervision and control. Process lines of this type are extensively used, particularly in the steel, chemicals, and paper and pulp industries (figure 151).

On a process line the possibilities of creating meaningful group work are often excellent. Operatives rely greatly on one another and possess a common goal. Working together to attain this goal is a clear-cut necessity. One factor that may sometimes make group cooperation difficult is an excessive distance between group members. A key question in this type of production system is the relationship of direct production tasks and maintenance tasks executed in the work organization. The higher the degree of mechanization, the fewer

Figure 151. Automated process



production workers there are; but the number of maintenance workers normally increases at almost the same rate as the number of production workers decreases.

Functional layout

A constant element in the three types of system that we have discussed up to now is the grouping together of production equipment along the production flow so that different types of machines are placed in the correct order along the direction of flow. However, if we group the machines in such a way that all machines of a certain type are concentrated in one department, all machines of another type in another department, and so on, we obtain a concentration of each type of operation in one place (this is the "functional layout" referred to earlier in the book), as illustrated by figure 152. In this layout the product to be worked is sent through the various departments in turn — the drilling department, the turning department, the milling department, and so forth.

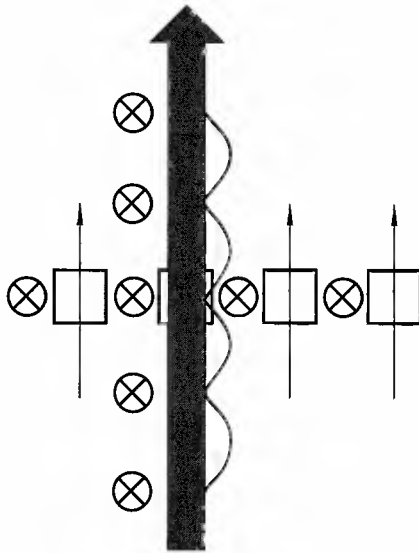
This type of concentrated operation often occurs in batch production, where series are short and the products varied.

In this type of production system it is extremely difficult to organize meaningful group work. In everyday reality each individual is bound to his or her own individual job and workstation. Genuine group work with spontaneous interaction between different roles and role occupants is virtually impossible to bring about. For several decades, this work organization represented the dominating approach to mixed production with moderately long series. More recently, however, it has become less common, often being replaced by product- and flow-oriented organizational systems.

The diversified line group

In many cases the conditions affecting production are such that neither highly developed line grouping nor an advanced degree of operation grouping is

Figure 152. Concentrated operation



suitable. Instead, an intermediate type is chosen — what we may call the “diversified line group”. Production is concentrated in an arrangement that is primarily flow oriented, but in order that it may carry out many combinations of tasks, some critical operational stages are repeated two or more times. In this way a system is obtained that can, with a high degree of efficiency, combine the capacity of the flow group to accept and channel a large volume of materials with the capacity of the functional layout to execute all conceivable production assignments.

In this type of production system, group work is often an excellent organizational concept. With this arrangement the division of work between various individuals must be adapted continuously to varying conditions. But this cannot be done entirely by management, and a substantial proportion must occur spontaneously at the initiative of the members of the group. In a group organization the capacity for such spontaneous self-adaptation can gradually be generated.

The service group

Conditions within service-producing organizations differ in several respects from the types of activity discussed earlier. Various forms of services are produced in large sectors, such as commerce, transport, hotels and restaurants, and motor vehicle repair shops. But service functions also occur in manufacturing industry, a good example being repair and maintenance activities.

The service functions of a production unit must be highly adaptable to varying demands. Generally, the tasks to be done vary in nature. The workload is uneven and it is difficult to plan the work in detail.

Group organization is a good concept in this type of situation also. The work group can itself handle much of the variation that shows up in the inflow of tasks, in routine work planning and in other circumstances that tend to vary.

The construction group

For the final type in our classification, let us see how construction operations are carried out. In this case the product itself is the centre for the whole organization, which is built up around the construction object itself. Work organizations of this type are also found in industry, for example in manufacturing very large products (e.g. turbines, ships, process machinery).

In production work of this type, group work is not only a good idea: it is the only conceivable type of work organization. Moreover, the work is varied, and the spontaneous adaptation of the division of work and planning is such an essential feature that flexible group organization is the only possible solution.

We have now briefly examined the possibilities of group work in different types of production systems. We have seen that group work is more suitable in some cases than in others.

One of the lines of development that has been particularly advocated in discussions about group work in production is the degree to which groups can be organized along the direction of production flow. Grouping of this type makes it possible to direct the group's interests and strivings toward a good common production result. We might look rather more closely at the possibilities of organizing such groups, either in assembly work or in machine shops. Our purpose in taking up these examples for special discussion is not to provide ready-made solutions but to point out a line of development that nowadays is assuming particular importance.

Flow groups in assembly work: Some trends and examples

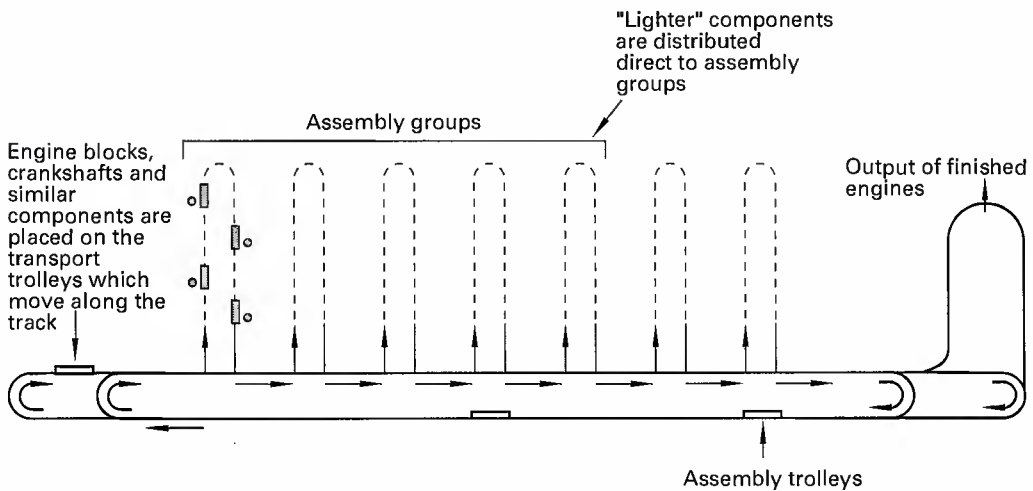
In assembly work, flow groups have always been the most natural arrangement. Let us take final assembly of a motor car, for example. When this arrangement was first conceived it was quite natural to introduce an assembly system that moved beside a materials inventory, with the different components being assembled on the car as it moved past. This is an extreme example of flow orientation in assembly work. The flow of materials was completely decisive in arranging the work.

But an arrangement of this type can also have its disadvantages. The work is strictly controlled and the cycle time is normally very short. However, especially in Japanese companies, there are countless examples of group organizations where the group members move with their work along the production line to overcome this disadvantage.

At subsequent stages of development, efforts were made to introduce buffers in the production line in order to create greater freedom in different parts of the production system. This placed new demands on the system, and various technical solutions were advocated to separate the different links in the chain from each other.

With reference to our previous discussion of different production system models, we may say that the introduction of buffer arrangements in motor car assembly changes the production system from a "machine-paced line" to a "worker-paced line". The following is an example from a newly constructed motor car engine factory.

Figure 153. Assembly of motor car engines



Assembly of motor car engines

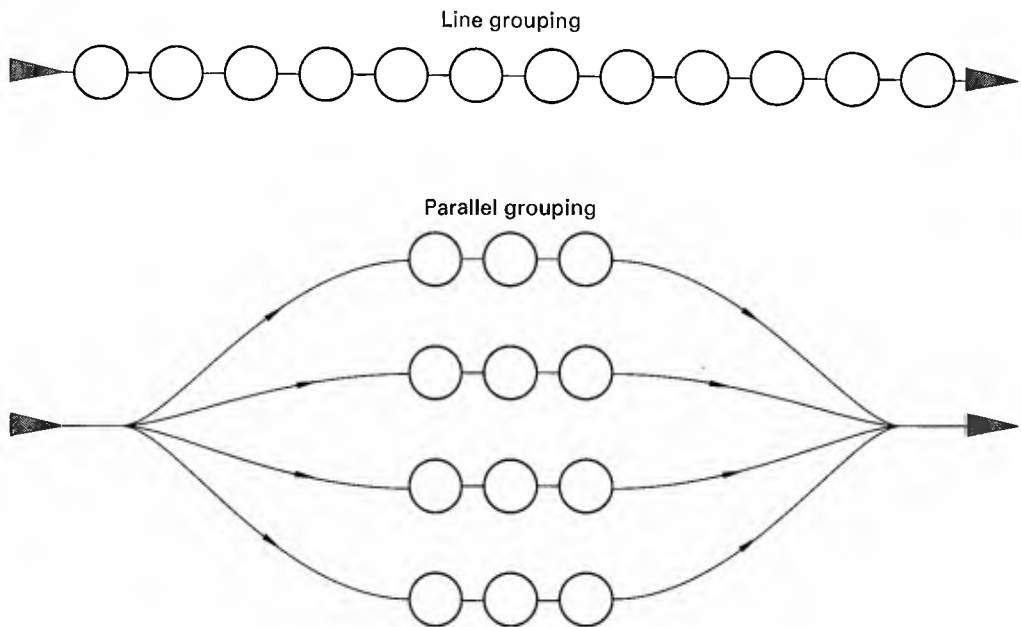
The assembly process can be summarized as follows. Seven assembly groups are organized beside an automatic transport track loop. Except for certain steps which are handled before the loop stage, complete engines are assembled in each group (figure 153).

Up to six engines can be assembled at the same time within each production group. During the assembly itself there is no mechanized control of the flow as in a moving assembly line. Engines are moved manually while being assembled. When an engine has been completely assembled in a group, it is transported automatically to a testing station which is common to all groups. At the same time it is automatically registered that an engine has left the group and a new assembly trolley is moved forward to that group on the transport track.

The advantages and disadvantages of this type of assembly process, as compared with the traditional assembly line, are as follows:

- (1) This arrangement is more flexible and less susceptible to interruptions and fluctuations in the production flow.
- (2) It offers good possibilities for job expansion and a more stimulating kind of group work. Each of the small loops contains a production group, a "gang" whose members cooperate closely in everyday tasks and themselves take care of such chores as the adaptation of work to changing conditions. One of the seven groups is a training group. In this group there is a fairly strict and extensive division of tasks based on detailed instructions. In the other groups the division of work is made on the basis of the abilities of individual members. There is therefore an opportunity to adapt the design of jobs within the group to the workers' knowledge and experience.
- (3) It is not necessary to carry out an extensive and costly reconstruction of the line every time the production volume has to be increased or

Figure 154. Line grouping and parallel grouping



decreased. Capacity can be expanded to a certain extent by varying the numbers of members in the groups, up to six. Further increases in capacity can be achieved by increasing the number of groups.

- (4) Job design is better adapted to the individual and should therefore lead to better recruiting possibilities, reduced personnel turnover and less absenteeism.
- (5) The new arrangement requires greater floor space and higher goods-in-process inventories than a moving assembly line.
- (6) Capital investment is somewhat higher for the new arrangement.
- (7) Work efficiency is lower than on a conventional assembly line because of the lower degree of specialization and the fragmentation of work segments.

This example illustrates not only how buffer arrangements can be introduced between different jobs and different capacities for work of different individuals but also how different parts of an assembly line — or an entire line — can be rearranged in a parallel pattern. The assembly of the engines is carried out at a number of stations, with an entire engine being assembled at each station.

The nature of parallel production operations is made clear in figure 154.

The most important advantages offered by the parallel arrangement of an assembly operation (or parts of an assembly operation) are as follows:

- (1) **Production reliability** — it is naturally less likely that several subsystems will all be simultaneously affected by disturbances than that one large system will be so affected.

- (2) **Flexibility** — it is easier to handle different product models, as well as changes in production volume, in a parallel system.
- (3) **Work content and work organization** — the possibility of creating tasks with a richer content, and of finding natural dividing lines between groups, is considerably greater. Opportunities for production groups to accept responsibility for quality and the division of work, for example, are also greater. But parallelization of assembly work is always accompanied by a need for larger factory premises, by more work-in-progress and a lower systems level since the same work has to be divided among several workstations.

Flow-oriented machine groups in batch production

In a traditional layout in batch production, machines and personnel are grouped in departments, with each department carrying out its own separate function. For example, one department may handle turning, another drilling, a third milling, and so on. The advantage of this arrangement is that it results in great flexibility and a high degree of utilization of machine capacity. A major disadvantage is that the volume of goods-in-process, and therefore the amount of working capital tied up in these goods, is always substantial. Moreover, the work in a plant of this kind is highly fragmented. It is difficult for an individual or a group of individuals to see the connection between their own work roles and the overall activity of the company. It is therefore difficult for individuals and groups to participate actively in work planning and in attaining the established goals of the company.

During recent years, interest has grown in finding ways of grouping machinery and equipment around flow-oriented groups in batch production, that is, groups formed around the manufacture of entire products or complex product components. We shall discuss these trends briefly here.

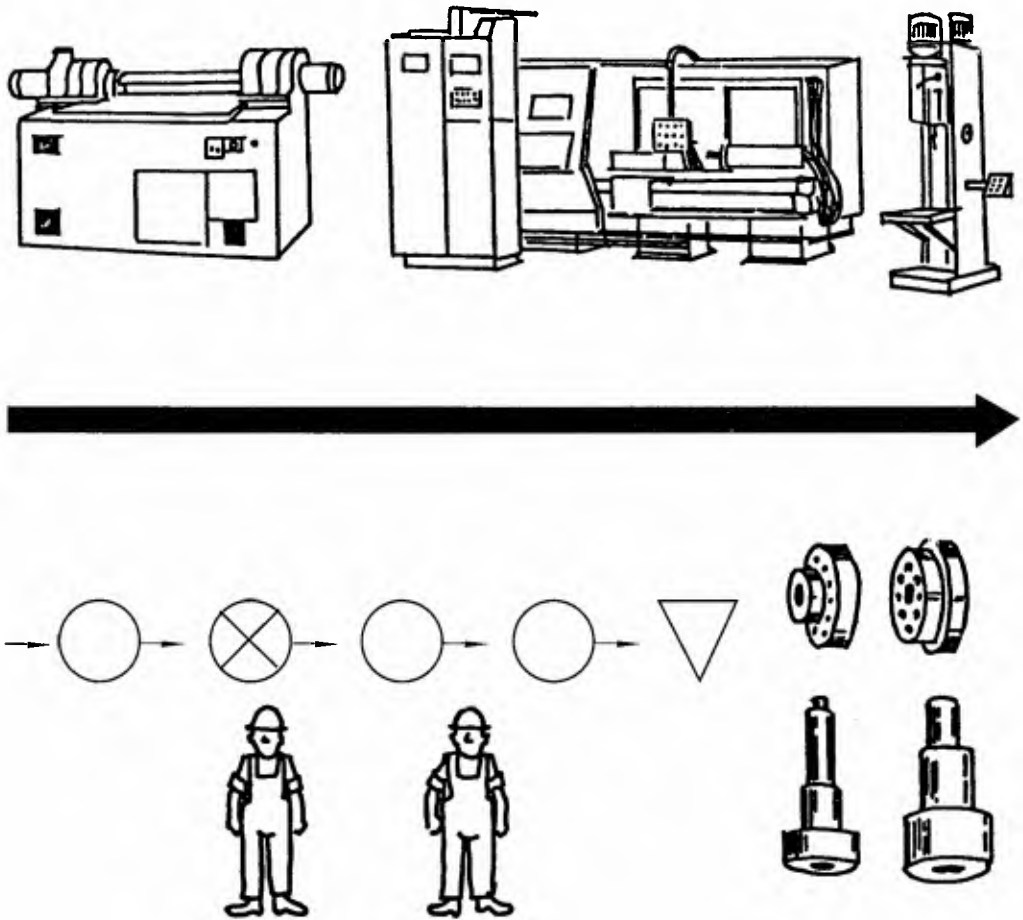
What is a **flow-oriented group**? Figure 155 illustrates the basic principle.

With the help of a standard classification method, we have selected an assortment of different components, such as axles and flanges. In each of these groups there are subgroups that resemble each other as regards the types of work required. Machines, personnel and other resources needed for the components — from metal supplies to finished parts — are collected in one unit. Through the choice of suitable components, methods and equipment we can create a simple flow pattern.

With this manufacturing arrangement through-put times, and therefore also the working capital tied up in the system, can both be reduced. Production can be carried out with a minimum of supplies of materials on hand — this applies particularly to the workstations themselves. The lower the supply of materials on hand, the shorter and surer the through-put times become.

In a functional organization, each operative's task at an individual machine and the job planned for the machine are fixed in advance. A flow-oriented group is a machine group for the finished manufacture of a mix of components. It contains more machines or workstations than there are operatives, and each operative should preferably master several types of job. This means that all the members of the group must be able to work relatively

Figure 155. Schematic diagram of a flow-oriented group



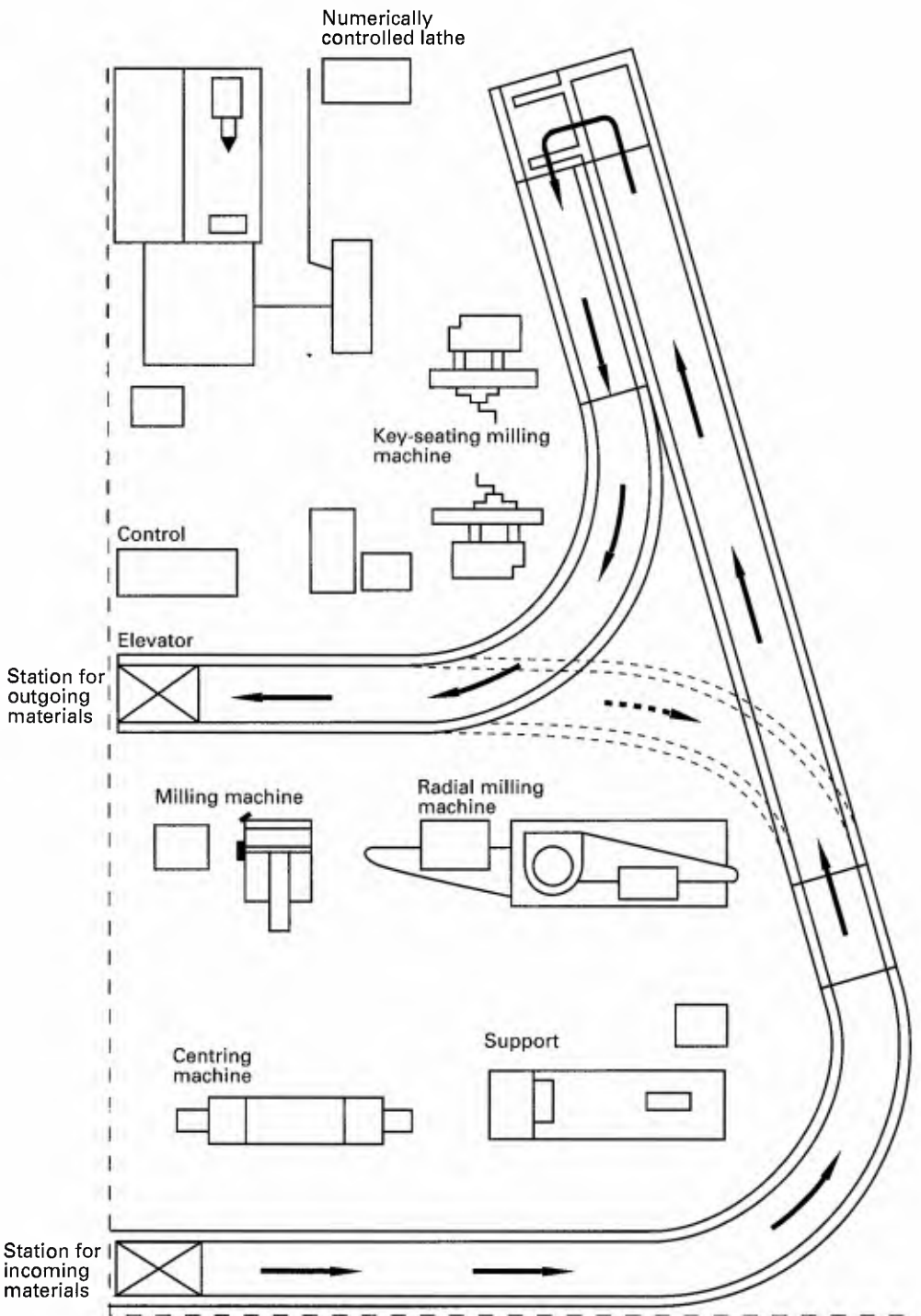
independently. The group members themselves have the responsibility for dividing the work between them and seeing that material flows through the group as it should. Thus the work of a flow group relies heavily on teamwork and cooperation.

Unlike a functional grouping of machines, a flow group makes heavy demands on individuals. But a flow group also makes possible the creation of more attractive work roles for group members, because:

- they have a better overall view of their contribution to the larger production process;
- they have more variety in their work because they can move between various tasks;
- they have the chance of being trained for new jobs;
- they have increased contact with their colleagues at work as well as with the management.

Example. In figure 156 a flow group has been created for the manufacture of pump axles in a metalworking company. In this group approximately

Figure 156. Flow group for the manufacture of pump axles



150 types of axle are produced; however, these are based on about ten general methods, of which the most widely used account for about 65 articles.

The simplest components are manufactured from pre-cut metal pieces during a single trip through the group. The most complicated components must go through the group three times. Operatives can easily return parts to the incoming station with the help of roller conveyor tracks. Two people work in this group; their work is delineated by the shape of the conveyor.

However, flow-oriented manufacturing in short series requires certain definite conditions and cannot be used in all situations. For example, a systematic structuring of the product mix must be made, to make it possible to channel certain main types of product in a homogeneous flow. Moreover, production must be of such a nature that an "unbroken flow principle" can be applied. If it is necessary to break the material flow within the flow group at a certain operational step and to send components outside the group for working, the planning will naturally become substantially more complicated.

A key issue in the formation of flow-oriented groups is the degree of utilization of equipment that can be attained, especially in the case of more expensive production machinery. Here it is necessary to weigh machine costs against the costs of tying up capital in everyday work. Recently, the clear trend is towards a recognition of the fact that tying up capital in goods-in-process inventories has reached such proportions that the order of priorities has had to be modified in favour of the use of flow groups.

A further factor of decisive importance is of course the stability of the product mix. Flow grouping of machinery has to be based on the assumption that it is possible to foresee that a certain product or product component will be manufactured in a certain form and according to certain methods. In cases where there is some uncertainty about these factors, flow grouping is not possible.

In conclusion, we may again emphasize the fact that, in batch production, there are often excellent reasons for choosing flow grouping of machinery and operatives rather than functional grouping. The main reasons are that, in practice, functional grouping is difficult to cope with from an administrative point of view, that substantial amounts of goods-in-process tie up considerable working capital and that jobs in a functional shop tend to be boring and monotonous for workers.

4. Design of product-oriented organizations

The company within the company

The concept of product-oriented organizations as a method of structuring production in batch manufacturing is becoming increasingly common. The conventional method of organizing production of this type has been in functional shops or departments, that is, where machines with similar functions are grouped together.

In this arrangement, precisely the opposite direction is taken. A product-oriented organization may be defined as a production unit which is organized and equipped in such a way that it can independently manufacture a certain finished product or family of products. To put it another way, the aim is to group together, physically as well as administratively, the entire production chain for a specific product or group of products.

With reference to the previous discussion of flow groups in batch production, we can say that this is an organizational solution which follows the same principle not only as regards production but also at the organizational level. A product-oriented organization is a larger unit than a flow group, manufactures more complex products or product components and can consist of several flow groups.

A product-oriented organization should be able to function rather as a company within a company. This means that it must occupy an independent position vis-à-vis its environment. Complete manufacturing resources should be found so that the complete manufacturing chain can be handled from beginning to end for a certain product or product component. It should also have its own administrative resources and its own operating services, such as maintenance, material handling, and so on.

By locating complete manufacturing resources within the plant so that the entire production chain can be held together in one place, there is very little dependence on other units and the coordination of products can be taken care of within the organization. In this way a simple planning process and short throughput times can be attained. The unit can also be truly independent with regard to other working areas in the immediate vicinity.

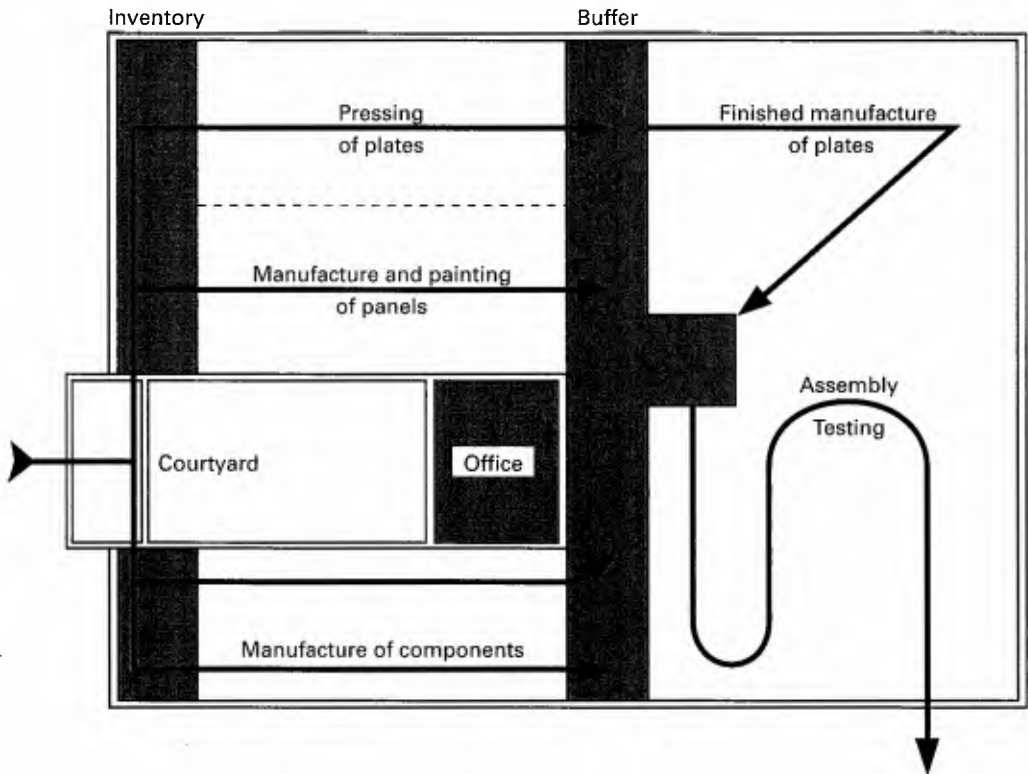
If this method is to work properly, however, all the machinery necessary to carry out the complete production operation must be available. In general, the capacity of utilization of most machines will be lower than in a functional shop. The possible machine utilization will thus be a key factor in examining the feasibility of this organizational concept, and should be weighed against its other advantages, especially as regards lower working capital tied up in inventories and simpler administration.

Flow patterns in a product-oriented organization: An example

By definition, the product-oriented organization refers to a certain flow of production. Within the unit itself, however, this flow can be more or less divided, and machine grouping can vary from very pronounced line grouping to a more operationally grouped functional arrangement. Let us look at two examples of the organization of a product shop.

In the first example, a heat exchanger unit, a systematic attempt has been made to build the production structure on the basis of flow groups. It proved possible to do so for the main part of the manufacturing process despite the fact that it is heavily influenced by customer orders and that batches are small. Figure 157 shows how an attempt was made to come as near as possible to a "straight-line" arrangement. This simplifies material handling and gives all operatives a good overall view of the manufacturing process.

Figure 157. Layout for a heat exchanger unit



In our second example, relating to the manufacture of electric motors, figure 158 shows a product-oriented organization consisting of a number of flow groups in which different components are manufactured. Among the principles on which the arrangement was based are the following:

- manufacture of components in units from raw materials, each in its own component flow or flow group;
- coordination of component flow directly with the main flow without material buffers or interim inventories;
- completion of main flow with delivery of finished motors.

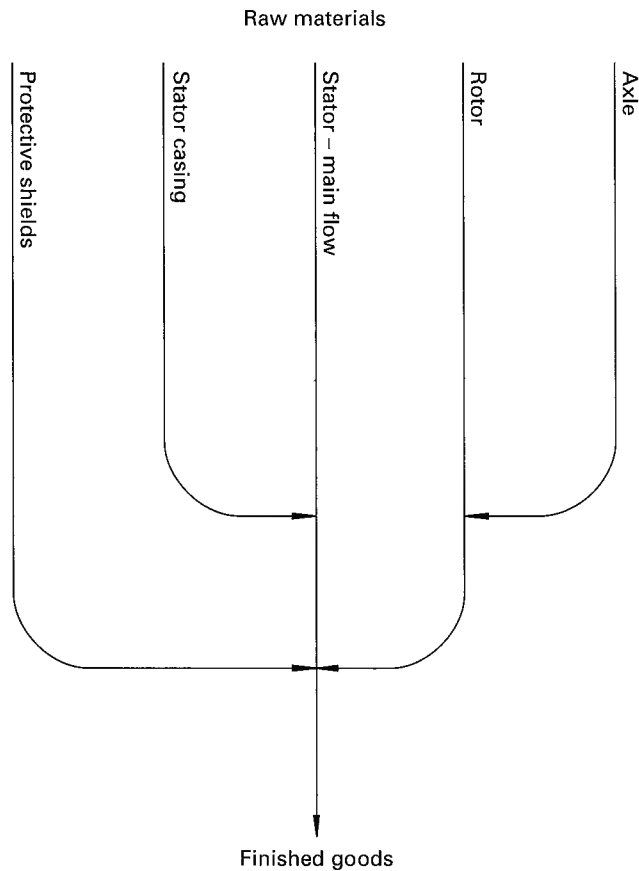
This arrangement of the flow means that the quantity of goods-in-process is very small, and the throughput times from the first operation to the finished motor is only two or three days. Furthermore, no interim inventories are needed for assembly.

5. Design of enterprise-oriented organizations

We have now examined how on the basis of the methods analyses and work measurement of work study we can design jobs for individuals and teamwork in production, and how an entire production system consisting of several production groups can be organized.

The production system is in its turn part of a larger system, an enterprise system.

Figure 158. Manufacture of electric motors



Here we will discuss three subsystems within the enterprise system which are all of importance to the work organization of the production system:

- system for product design;
- system for subcontractors and suppliers;
- system for marketing, sales and customer contact.

These three components in the enterprise system are closely connected to the production system, first because they affect the conditions of the work organization in the production system, and second because different work organization alters the conditions affecting these subsystems. In the following section we intend to examine these subsystems and their relationship to the work organization.

Product design and its relationship with the work organization in the production system

Work organization in the production system is determined to a great extent by the design of the product to be manufactured in the system. If the views and experiences of production are taken into account when the product design is

established, this will influence the conditions affecting the way the work can be organized. And, conversely, experience and views from product use can affect the methods of working and judgements in the production system. It is therefore important to ensure that product design and the work organization in production interact effectively and work closely together.

Here we examine two aspects of product design which have attracted considerable attention in recent years:

- design for manufacturing;
- modularization of complex products.

Design for manufacturing

As explained earlier, product design is always an important consideration in production planning. It has always been part of the preparation and work planning for industrial production to try to take account of production. For example, attempts have always been made to select those qualities which not only satisfy the product requirement, but are also suitable from the point of view of machining and processing. Selection of materials can affect the work organization in such areas as which machine in a processing group should be used, for example.

Recently, more and more attention has been devoted to how complex products should be designed to make production and assembly easier. An example of this may be taken from the car industry where in recent years attempts have been made to adapt the design of the car so that the assembly work can be organized in a more efficient manner. By adopting this approach, some Japanese car manufacturers have been able to improve the organizational efficiency of their assembly plants by changing the sequence of the operations involved and by modifying the assembly work, for example, to include more pre-assembly of components. In many of these cases, a more production-friendly car design has turned out to be an important factor influencing the design of the work organization in the car factory.

Modularization of complex products

In principle, modularization means that a large number of different products can be offered to the customer by combining a limited number of standardized modules in different ways. Modularization was referred to briefly in Chapter 12. As explained earlier, modularization is a means of meeting widely varying customer demands in a way that enables the manufacturer to improve production efficiency at low cost. An example may be drawn from the industry that manufactures prefabricated houses; modularization has been pushed a long way in the companies' efforts to offer a wide range of choices to the customer within the framework of relatively standardized production. Wall units, roof designs, kitchen modules, bathroom modules, garage modules — these are all examples of structural units which help individual customers to design their own dream house. But for the manufacturer, modularization means that effective production groups can be built up which can specialize in the production of a certain type of module at low cost by using efficient methods. Each team can also be given responsibility for checking the quality of its own

output and, where necessary, carrying out tests of the various systems. A further consequence of specialization is that highly advanced tools and mechanical aids can be used.

If product design were not modularized in this way, production of a house would largely become a matter of handcraft. In the past, these houses were of course often built on site by a team of building workers who demarcated their tasks in accordance with the strict craft traditions of earlier times (and it could take months before the house was built).

With today's production methods, the house can largely be produced indoors in factories where the work environment is satisfactory. The houses are then transported in building blocks to the site and erected so quickly that they can be roofed over in a day or two, or even within hours.

A second example comes from the electrical engineering industry. One product is an electric control box where circuit breakers, relays, measuring devices and components for adjusting, measuring and controlling electrical installations, for example in an industrial enterprise, are all kept together. These control boxes used to be manufactured according to the specifications laid down by an individual customer in a specific situation. The manufacturer produced what the customer wanted and the result was a wide variety of different products which were manufactured in the relatively old-fashioned craft tradition. With modularization, however, it became possible to offer customers almost the same freedom of choice as in the past, but at considerably lower cost since production could now be organized using efficient production groups, each producing its own type of module. Another advantage of this arrangement was that delivery dates were reduced from several months to a few days.

Both these factors, design for manufacturing and modularization, are examples of situations where close interaction between production and product design is important as a means of creating conditions that will improve the efficiency of the work organization.

Suppliers and their relationship with organization of the production system

By suppliers here is meant all the external companies which are responsible for the supply of raw materials, input items and other externally produced components for the enterprise's activities. This subsystem is of great importance to the efficiency of the enterprise system. In recent years, industrial enterprises have begun to increase their use of subcontractors in order to concentrate on their own core operations. Consequently, the interaction with subcontractors is assuming growing importance.

In this context we will limit ourselves to discussing the relationship of subcontractors to production.

Subcontractors and just-in-time strategies

As explained in Chapter 16, one of the most dramatic changes in industrial production organization in recent years is the remarkable reduction in the volume of goods-in-process. This reduction is of great financial significance to

the overall financial result of production. The efforts to have as narrow a supply of materials as possible begin during the first operation in a production chain and then spread throughout the entire production system.

The basic idea is that the materials to be used in a production system should arrive just in time and the quantities supplied should be limited in size.

The application of just-in-time methods of inventory control was extended to build a completely new type of relation with suppliers as indicated in Chapter 16. As a result the system of work organization and production planning of the core company became more closely linked to the production system of the supplier. By effective coordination of these systems and by jointly utilizing the skills, knowledge and experience available on both sides, both products and production systems can be further developed.

Marketing/sales systems and their links with the work organization

Two particular aspects of this part of the commercial system will be considered here:

- customization of products;
- integration of the customer into the production system.

Customer-specific products

In many areas of industrial production earlier methods of mass producing standardized products have been replaced by production of versions specifically designed for the customer. Even in the car industry much of the manufacturing is of specific cars for given customers in accordance with specifications drawn up by this customer. Of course, these specifications are composed of a number of standardized model and equipment options, but the combination as such is specific to the customer. This was also made possible by the adoption of the just-in-time methods mentioned above. Consequently, delivery dates for a customer-specific car could in fact be reduced to a few weeks.

The customer-specific production naturally brings new and difficult demands within both the organization of production systems and the sales organization.

The organization of production has to be able to make reliable forecasts of the mix of different models and equipment options, and it should be able to revise these plans at frequent intervals. Within the framework of these plans it must also be capable of producing a mixture of models on the same production line.

Corresponding demands are made on the ability of the sales organization, when a model or equipment mix which has been expected in production deviates noticeably from the actual sales mix, to respond actively and attempt to influence sales so that they do not deviate too far from the model mix that the production organization is capable of producing.

Customization of products has therefore brought noticeably more rigorous demands on the interaction between the production organization and sales organizations. This is the case in many different industrial production contexts,

not only those producing capital goods and consumer goods but also in the production of services.

Integration of the customer into the production system

As a result of the introduction of customer-specific production discussed above, it may be said that the sale to the customer is the first stage in a just-in-time system. When the special product required by the customer is being delivered, the sale often includes an offer of service, and sometimes also guarantee commitments, by which is meant that the supplier undertakes to put right any faults which may arise during a particular period after delivery. As a result of such service and guarantee commitments, conditions are also created for more long-term and systematic contact with the customer. It immediately becomes possible to follow up the extent to which the product delivered functions and whether or not the customer is satisfied. The impulses obtained in this way can be fed back to product design for future product generations and to the production system in order to improve its results.

At present manufacturing enterprises and service companies are engaged in systematic programmes to create long-term, stable customer relationships. The customer should become an integrated part of the suppliers' own enterprise system, and by responding to the customer's wishes within a long-term, close relationship, the supplier hopes to be able to ensure that the customer stays within the "family" and does not look for other suppliers.

Both these factors which affect the marketing and sale of companies' products are consequently highly dependent on the work organization of the production system. They therefore represent a further expression of the growing need to integrate the various components and subsystems within the enterprise system.

The work organization in the production system, which in this context in the main focus of our interest, is, as we have seen, affected in many ways by considerations relating to other parts of the enterprise system.

6. Criteria of good work organization: Some concluding remarks

Effectiveness

The first and most fundamental criterion of good work organization is, of course, that it should be effective — that the use of resources should be maximized and that the largest possible output should be obtained from the smallest possible input. The various chapters of this book have dealt extensively with this criterion, because this factor will always be of fundamental significance — in all types of technology, in all stages of development and at every workplace.

Naturally, there are situations in which considerations other than those of a purely economic nature are of paramount importance. If, for example, there are evident safety or health risks at a workplace, and if additional investment is required to eliminate them, the appropriate steps to do so must be taken even if

it is not possible to point to any demonstrable economic profitability resulting directly from such measures. This is an example of how economic considerations (at least in the short term) have to give way to other factors.

In this financial analysis it is also important to take into account not only such yardsticks as those that measure production per hour worked. As we have mentioned in our earlier analysis, there are many other factors which may be of great importance, indeed, even greater than labour productivity. One example of this is the gains that can be achieved by adopting just-in-time strategies and reducing the volume of goods-in-process between workstations in a production chain. Such an arrangement leads, first, to significantly lower capital costs as one result of the reduction in goods-in-process and, second, to shorter delivery times. This factor is hard to measure in financial terms, but is none the less important to the competitive ability of the company.

To sum up, economic considerations must inevitably be of fundamental importance in the choice of a suitable form of work organization. The organizational principles and solutions that result both in increased effectiveness and in better jobs for the workers are naturally to be preferred.

Autonomy of small systems

Even if economic considerations are of fundamental significance and must be carefully analysed in each individual case, there are several rules of thumb, or general lines of thinking, for the construction of a good production system — guidelines that have become increasingly important during recent years in the development of new forms of work organization but in which precise calculations of short-term profitability are difficult, if not impossible. Nevertheless, there has been so much emphasis on these guidelines that we take special note of them here; but we must also stress that they stand somewhat apart from the basic economic factors.

The first of these criteria for constructing good production systems is **the search for greater independence for small systems** in company organization. By this we mean production systems that consist of moderately large production units and can function with a relatively high degree of independence within the larger company. The underlying intention is to create a production arrangement that emphasizes local independence within smaller units. Breaking down the company into these smaller units reduces the need for coordination, and therefore management problems too become simpler to deal with.

The decentralization that results from this type of production arrangement is also of great value in stimulating local initiative and in increasing the ability to adapt to the changing conditions and needs that arise in different parts of the company. It has also been shown that workers are often more satisfied and more involved in their work if they are members of smaller and more independent production units.

If we wish to create production systems based on this principle, four points are particularly significant:

- the possibility of dividing up larger systems into smaller systems;

- the possibility of arranging finished manufacturing units into smaller units so that the need for contacts with adjacent units is reduced;
- the possibility of arranging for self-sufficiency as regards production resources, operational service, and so on;
- the possibility of arranging for less direct management control from high levels, so that the independence of the smaller units is not eroded too much by control from the upper levels of the hierarchy.

Stability of the production system

One further rule of thumb or criterion of a good production system which has received increasing interest in recent years is the desire to arrange for stable production activity with a minimum of disturbance. The following requirements in particular arise in this connection:

- a simple flow pattern, so that as far as possible the workers have an overall view and it becomes easier to plan the work;
- an operationally reliable technology with an optimum level of mechanization, so that technical disturbances are held within reasonable limits;
- a disturbance-resistant work arrangement, so that all production stages that are critical for production are organized in parallel and those that are particularly sensitive to disturbance are surrounded with buffers of different kinds.

Attractive jobs

It is important to be able to offer people jobs that they find attractive and in which they can feel personally involved. Personal aspirations vary from individual to individual and from situation to situation, and depend not only on a person's ambitions and desires but also on his or her abilities, knowledge and capacity to develop. A production organization must therefore offer a variety of jobs, so that the desires of as many people as possible can be satisfied and so that a particular individual can progress from simple jobs to more complex work roles.

Among the factors that should be considered in any endeavour to create sufficiently attractive jobs are the following:

- (1) The creation of jobs with different degrees of difficulty through flow orientation, different degrees of subdivision of work and different degrees of integration of auxiliary tasks. Variations of this kind make it possible to offer to different individuals at different times jobs that correspond to their abilities and wishes.
- (2) The creation of individual jobs and group arrangements that bring about a degree of independence in work, through finished manufacturing of entire products, self-sufficiency of production service functions and buffering vis-à-vis adjacent systems. This independence is of value both in terms of the production results obtained and for the way the work is experienced by individuals in the group.

- (3) The design of a work organization that is suitable for teamwork, as a result of flow grouping and similar arrangements that are compatible not only with more attractive jobs and work situations but also with greater efficiency.
- (4) Provision of overall views from inside the organization. In order for people to find their work attractive, they must also be able to view the larger context of which their work is a part. It is also important that they should be involved, if possible, in the design of the work and be able to feel some sense of “belonging” with their group of fellow workers and with the overall production process in which they perform their function.

Good working environments

An important criterion of a good job is the quality of the working environment. In Chapter 5 we indicated the basic factors that have to be considered with respect to safety at the workplace.

In addition, however, a working environment should also be pleasant to work in — in other words, it should be so designed that it becomes easier to adopt ergonomically correct working positions.

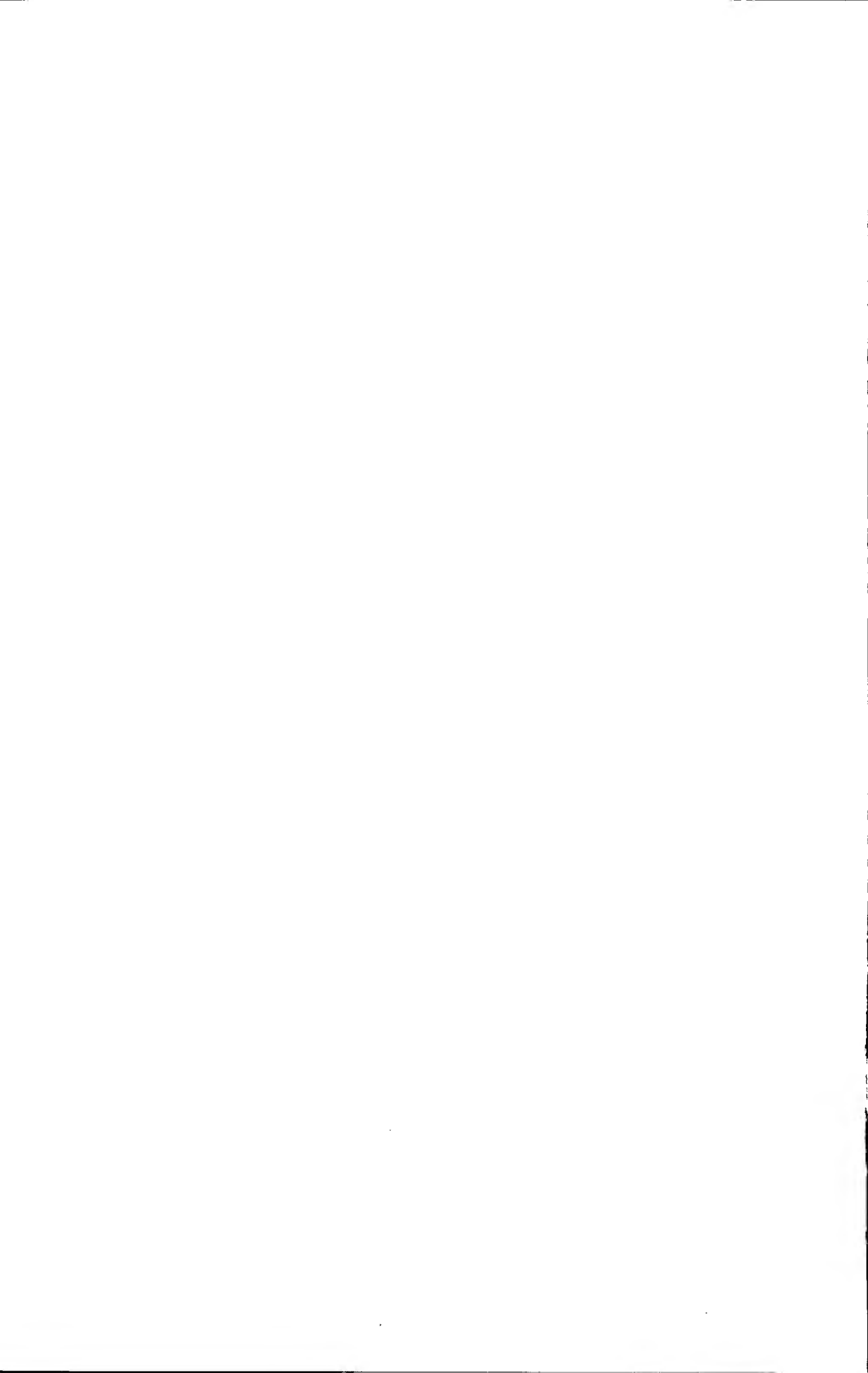
Conclusion

We have briefly touched on some of the trends leading towards new forms of work organization. We have given some principles and general guidelines. We have provided some examples and emphasized certain current lines of development. Finally, we have given some criteria to be borne in mind when designing good working environments.

It is important, however, to stress the fact that there are no standard solutions to these problems. Our aim has been merely to put forward a few ideas, tendencies and general indications of solutions to problems. It must be remembered that the best solution to a problem can be found only in the specific circumstances of the particular case — when the actual conditions are known, when local values are considered and when the persons involved are able to find their own solutions.

PART SIX

Appendices



Glossary of terms used

Activity sampling See *Work sampling*.

Basic time The time for carrying out an element of work at standard rating, i.e.:

$$\frac{\text{observed time} \times \text{observed rating}}{\text{standard rating}}$$

Break point The instant at which one element in a work cycle ends and another begins.

Check time The time intervals between the start of a time study and the start of the first element observed, and between the finish of the last element observed and the finish of the study.

Contingency allowance A small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays, the precise measurement of which is uneconomical because of their infrequent or irregular occurrence.

Cumulative timing See *Timing*.

Cycle time The total time taken to complete the elements constituting the work cycle.

Elapsed time The total time from the start to the finish of a time study.

Element A distinct part of a specified job selected for convenience of observation, measurement and analysis.

Constant element An element for which the basic time remains constant whenever it is performed.

Foreign element An element observed during a study which, after analysis, is not found to be a necessary part of the job.

Governing element An element occupying a longer time than that of any other element which is being performed concurrently.

Machine element An element automatically performed by a power-driven machine (or process).

Manual element An element performed by a worker.

Occasional element An element which does not occur in every work cycle of the job, but which may occur at regular or irregular intervals.

Repetitive element An element which occurs in every work cycle of the job.

Variable element An element for which the basic time varies in relation to some characteristics of the product, equipment or process, e.g. dimensions, weight, quality, etc.

Extension The calculation of basic time from observed time.

Fatigue allowance A subdivision of the relaxation allowance intended to cater for the physiological and psychological effects of carrying out specified work under specified conditions.

Fixture A less accurate device than a jig for holding parts which would otherwise have to be held in one hand while the other worked on them.

Flow diagram A diagram or model, substantially to scale, which shows the location of specific activities carried out and the routes followed by workers, materials or equipment in their execution.

Flow process chart A process chart setting out the sequence of the flow of a product or a procedure by recording all events under review using the appropriate process chart symbols.

Equipment type A flow process chart which records how the equipment is used.

Worker type A flow process chart which records what the worker does.

Material type A flow process chart which records how material is handled or treated.

Flyback timing See *Timing*.

Idle time That part of attendance time when the worker has work available but for various reasons does not do it.

Ineffective time That portion of the elapsed time, excluding the check time, spent on any activity which is not a specified part of a job.

Inside work Elements which can be performed by a worker within the machine- (or process-) controlled time.

Inspection Indicates an inspection for quality and/or check for quantity.

Interference allowance An allowance of time for production unavoidably lost through synchronization of stoppages on two or more machines (or processes) attended by one worker. Similar circumstances arise in teamwork.

Interference time The time when the machine (or process) is idle awaiting attention, while the worker attends to another machine (or process). Similar circumstances arise in teamwork.

Jig Holds parts in an exact position and guides the tool that works on them.

Job breakdown A listing of the content of a job by elements.

Load factor The proportion of the overall cycle time required by the worker to carry out the necessary work at standard performance, during a machine- (or process-) controlled cycle.

Machine ancillary time The time when a machine is temporarily out of productive use owing to change-overs, setting, cleaning, etc.

Machine available time The time during which a machine could work based on attendance time — i.e. working day or week plus overtime.

Machine capacity The potential volume of a machine, usually expressed in physical units capable of being produced in any convenient unit of time, e.g. tons per week, pieces per hour, etc.

Machine-controlled time The time taken to complete that part of the work cycle which is determined only by technical factors peculiar to the machine.

Machine down time The time during which a machine cannot be operated on production or ancillary work owing to breakdown, maintenance requirements, or for other similar reasons.

Machine effective utilization index

The ratio of: Machine running time at standard
to: Machine available time.

Machine efficiency index

The ratio of: Machine running time at standard
to: Machine running time.

Machine-hour The running of a machine or piece of plant for one hour.

Machine idle time The time during which a machine is available for production or ancillary work but is not used owing to shortage of work, materials or workers including the time that the plant is out of balance.

Machine interference The queuing of machines (or processes) for attention — e.g. when one worker is responsible for attending to more than one machine. Similar circumstances arise in teamwork where random delays at any point may affect the output of the team.

- Machine maximum time** The maximum possible time during which a machine or group of machines could work within a given period, e.g. 168 hours in one week or 24 hours in one day.
- Machine running time** The time during which a machine is actually operating, i.e. the machine available time less any machine down time, machine idle time or machine ancillary time.
- Machine running time at standard** The running time that should be incurred in producing the output if the machine is working under optimum conditions.
- Machine utilization index**
The ratio of: Machine running time
to: Machine available time.
- Method study** The systematic recording and critical examination of ways of doing things in order to make improvements.
- Methods-time measurement (MTM)** A system of predetermined time standards (q.v.).
- Multiple activity chart** A chart on which the activities of more than one subject (worker, machine or item of equipment) are each recorded on a common time scale to show their interrelationship.
- Multiple machine work** Work which requires the worker to attend two or more machines (of similar or different kinds) running simultaneously.
- Observed time** The time taken to perform an element or combination of elements obtained by means of direct measurement.
- Operation** Indicates the main steps in a process, method or procedure. Usually the part, material or product concerned is modified or changed during the operation.
- Outline process chart** A process chart giving an overall picture by recording in sequence only the main operations and inspections.
- Outside work** Elements which must necessarily be performed by a worker outside the machine- (or process-) controlled time.
- Permanent storage** Controlled storage in which material is received into or issued from a store under some form of authorization, or an item is retained for reference purposes.
- Personal needs allowance** A subdivision of the relaxation allowance intended to cater for attention to personal needs.
- Plant and machine control** The procedures and means by which efficiency and utilization of units of plant and machinery are planned and checked.
- Policy allowance** An increment, other than bonus increment, applied to standard time (or to some constituent part of it, e.g. work content) to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstances.
- Predetermined time standards (PTS)** A work measurement technique whereby times established for basic human motions (classified according to the nature of the motion and the conditions under which it is made) are used to build up the time for a job at a defined level of performance.
- Primary questions** The first stage of the questioning technique, which queries the fundamental purpose, place, sequence, person and means of every activity recorded, and seeks a reason for each reply.
- Principles of motion economy** Characteristics which, when incorporated in the methods adopted, make for easier working.
- Process charts** Charts in which a sequence of events is portrayed diagrammatically by means of a set of process chart symbols to help a person to visualize a process as a means of examining and improving it.
- Process-controlled time** The time taken to complete that part of the work cycle which is determined only by technical factors peculiar to the process.
- Qualified worker** One who is accepted as having the necessary physical attributes, who possesses the required intelligence and education, and who has acquired the necessary

skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity and quality.

Questioning technique The means by which the critical examination is conducted, each activity being subjected in turn to a systematic and progressive series of questions.

Random observation method See *Work sampling*.

Rating

- (1) The assessment of the worker's rate of working relative to the observer's concept of the rate corresponding to standard pace.
- (2) The numerical value or symbol used to denote the rate of working:
 - (a) loose rating: an inaccurate rating which is too high;
 - (b) tight rating: an inaccurate rating which is too low;
 - (c) inconsistent ratings: a mixture of loose, tight and accurate ratings;
 - (d) flat ratings: A set of ratings in which the observer has underestimated the variations in the worker's rate of working;
 - (e) steep ratings: A set of ratings in which the observer has overestimated the variations in the worker's rate of working.

Rating scale The series of numerical indices given to various rates of working. The scale is linear.

Ratio-delay study See *Work sampling*.

Relaxation allowance An addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of the allowance will depend on the nature of the job.

Representative worker A worker whose skill and performance is the average of a group under consideration. He or she is not necessarily a qualified worker.

Restricted work Work in which the output of the worker is limited by factors outside his or her control.

Secondary questions The second stage of the questioning technique, during which the answers to the primary questions are subjected to further query to determine whether possible alternatives of place, sequence, persons and/or means are practicable and preferable as a means of improvement upon the existing method.

Selected time The time chosen as being representative of a group of times for an element or group of elements. These times may be either observed or basic and should be denoted as selected observed or selected basic times.

Setting-up time The time required to prepare a machine for work. It includes the removal of tools used for the previous tasks, any necessary cleaning of the machine, and the fixing of tools and fixtures for the new job.

Standard data Tables and formulae derived from the analysis of accumulated work measurement data, arranged in a form suitable for building up standard times, machine process times, etc., by synthesis.

Standard performance The rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift, provided that they know and adhere to the specified method and provided that they are motivated to apply themselves to their work. This performance is denoted as 100 on the standard rating and performance scales.

Standard time The total time in which a job should be completed at standard performance, i.e. work content, contingency allowance for delay, unoccupied time and interference allowance, where applicable.

String diagram A scale plan or model on which a thread is used to trace and measure the path of workers, material or equipment during a specified sequence of events.

Temporary storage or delay A delay in the sequence of events, for example, work waiting between consecutive operations, or any object laid aside temporarily without record until required.

- Time study** A work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.
- Timing** The practice of observing and recording, by the use of a watch or other device, the time taken to complete each element. Three alternative methods of timing with a stop-watch are:
- Cumulative timing** A method in which the hands of the stop-watch are allowed to continue to move without returning them to zero at the end of each element, the time for each element being obtained subsequently by subtraction.
- Differential timing** A method for obtaining the time of one or more small elements. Elements are timed in groups, first including and then excluding each small element, the time for each element being obtained subsequently by subtraction.
- Flyback timing** A method in which the hands of the stop-watch are returned to zero at the end of each element and are allowed to restart immediately, the time for the element being obtained directly.
- Tool allowance** An allowance of time, which may be included in a standard time, to cover adjustment and maintenance of tools.
- Transport** The movement of workers, materials or equipment from place to place.
- Travel chart** A tabular record for presenting quantitative data about the movements of workers, materials or equipment between any number of places over any given period of time.
- Two-handed process chart** A process chart in which the activities of a worker's hands (or limbs) are recorded in their relationship to one another.
- Unoccupied time** The periods during machine- (or process-) controlled time when a worker is engaged neither on inside work nor in taking authorized rest, the time for carrying out the work being calculated at a defined performance.
- Unoccupied time allowance** An allowance made to a worker when there is unoccupied time during machine- (or process-) controlled time.
- Unrestricted work** Work in which the output of the worker is limited only by factors within the control of the worker.
- Work content** Basic time + relaxation allowance + any allowance for additional work — e.g. that part of contingency allowance which represents work.
- Work cycle** The sequence of elements which are required to perform a job or yield a unit of production. The sequence may sometimes include occasional elements.
- Work factor** A system of predetermined time standards (q.v.).
- Work-hour** The labour of one person for one hour.
- Work measurement** The application of techniques designed to establish the time for a qualified worker to carry out a task at a defined rate of working.
- Work sampling** A method of finding the percentage occurrence of a certain activity by statistical sampling and random observations. (Work sampling is also known as ratio-delay study; observation ratio study; snap-reading method; random observation method; and activity sampling.)
- Work specification** A document setting out the details of an operation or job, how it is to be performed, the layout of the workplace, particulars of machines, tools and appliances to be used, and the duties and responsibilities of the worker. The standard time or allowed time assigned to the job is normally included.
- Work study** The systematic examination of the methods of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out.
- Workplace layout** A convenient term used to describe the space and the arrangement of facilities and conditions provided for a worker in the performance of a specified job.



Check-list of useful questions in developing a new method of work

Most of the questions listed below apply generally to method study investigations. They amplify the questioning procedure described in Chapter 7 and may be of service in suggesting to study persons aspects of the method which might otherwise be overlooked. The questions are listed under the following headings:

- | | |
|------------------------------|-----------------------|
| A. Operations | F. Materials handling |
| B. Products and parts design | G. Work organization |
| C. Quality requirements | H. Working conditions |
| D. Materials utilization | I. Job enrichment |
| E. Workplace layout | |

A. Operations

1. What is the purpose of the operation?
2. Is the result obtained by the operation necessary? If so, what makes it necessary?
3. Is the operation necessary because the previous operation was not performed correctly?
4. Is the operation instituted to correct a condition that has now been corrected otherwise?
5. If the operation is being carried out to improve appearance, does the additional cost give extra saleability?
6. Can the purpose of the operation be obtained in another way?
7. Is the operation being performed to satisfy the requirements of all users of the product, or is it made necessary by the requirements of one or two customers only?
8. Does a subsequent operation eliminate the necessity for this operation?
9. Was the operation established to reduce the cost of a previous operation, or a subsequent operation?
10. Would adding a further operation make other operations easier to perform?
11. Is there another way to perform the operation and maintain the same or even better results?
12. Have conditions changed since the operation was added to the process?
13. Could the operation be combined with a previous or a subsequent operation?
14. Can the operation analysed be combined with another operation? Can it be eliminated?
15. Can it be broken up and the various parts of the operation added to other operations?
16. Can a part of the operation being performed be completed more effectively as a separate operation?
17. Is the sequence of operations the best possible or would changing the sequence improve the operation?
18. Could the operation be done in another department to save the cost of handling?
19. If the operation is changed, what effect will it have on the other operations? On the finished product?

20. If a different method of producing the part can be used, will it justify all the work and activity involved?
21. Can the operation and inspection be combined?

B. Products and parts design

1. Can the design be changed to simplify or eliminate the operation?
2. Can the number of component parts be reduced?
3. Can certain component parts be standardized?
4. Can a standard part be substituted by another cheaper or better material?
5. Has Pareto analysis been used to detect the products or parts that are most valuable?

C. Quality requirements

1. Has an agreement been reached by all concerned as to what constitutes acceptable quality?
2. What are the inspection requirements for this operation?
3. Can the operative inspect his or her own work?
4. Are tolerance and other standards appropriate?
5. Can standards be raised to improve quality without unnecessary cost?
6. Will lowering standards reduce cost considerably?
7. Can the finished quality of the product be improved in any way above the present standard?
8. Can the quality be improved by using new processes?
9. Are the same standards necessary for all customers?
10. Will change in standards and inspection requirements increase or decrease the defective work and expense in the operation, shop or field?
11. What are the main causes of rejections for the part?
12. Would a change in the composition of a product render it less susceptible to quality variances?

D. Materials utilization

1. Is the material being used really suitable for the job?
2. Could a less expensive material be substituted and still do the job?
3. Could a lighter-gauge material be used?
4. Is the material purchased in a condition suitable for use?
5. Could the supplier perform additional work on the material that would improve usage and decrease waste?
6. Is the material sufficiently clean?
7. Is the material bought in amounts and sizes that give the greatest utilization and limit scrap, offcuts and short ends?
8. Is the material used to the best possible advantage during cutting, processing?
9. Are indirect materials used in connection with the process — oils, water, acids, paint, gas, compressed air, electricity — suitable, and is their use controlled and economized?
10. How does the cost of material compare with the cost of labour?
11. Can the design be changed to eliminate excessive loss and scrap material?
12. Can the number of materials used be reduced by standardization?
13. Can the part be made from scrap material or offcuts?
14. Can the scrap be salvaged for further processing?
15. Can the scrap be sorted out for sales at higher price?
16. Is the supplier of the material performing operations on it which are not necessary for the process?
17. Is the material supplied of consistent quality?

18. Could a more careful inspection of incoming materials decrease difficulties now being encountered in processing?
19. Is the material free from sharp edges and burrs?
20. What effect does storage have on material?
21. Could sampling inspection combined with supplier rating reduce inspection costs and delays?
22. Could the part be made more economically from offcuts in some other gauge of material?

E. Workplace layout

1. Does the plant layout aid efficient material handling?
2. Does the plant layout allow efficient maintenance?
3. Does the plant layout provide adequate safety?
4. Is the plant layout suitable for appropriate sequencing of operation? Can parts of an intermittent operation be changed to a line operation layout for major products or parts?
5. Does the plant layout help social interaction between the operatives?
6. Are materials conveniently placed at the workplace?
7. Are tools pre-positioned to save mental delay?
8. Are suitable jigs and fixtures available at the workplace to facilitate work, particularly in assembly operations?
9. Are adequate working surfaces provided for subsidiary operations, e.g. inspection and deburring?
10. Are facilities provided for the removal and storage of scrap and waste?
11. Is adequate provision made for the comfort of the operative, e.g. fan, duckboard or chairs?
12. Is the lighting adequate for the job?
13. Has provision been made for the storage of tools and gauges?
14. Has provision been made for the storage of the operatives' personal belongings?

F. Materials handling

1. Is the time spent in bringing material to the workstation and in removing it large in proportion to the time used to handle it at the workstation?
2. If not, could material handling be done by the operatives to provide a rest through change of occupation?
3. Should hand, electric or fork-lift trucks, or conveyors or chutes be used?
4. Should special racks, containers or pallets be designed to permit the handling of material with ease and without damage?
5. Where should incoming and outgoing materials be located in the work area?
6. Can material be dispatched from a central point by means of a conveyor?
7. Is the size of the container suitable for the amount of material transported?
8. Can a container be designed to make material more accessible?
9. Could a container be placed at the workstation without removing the material?
10. If an overhead travelling crane is used, is the service prompt and accurate?
11. Can gravity be utilized by starting the first operation at a higher level, and using suitable chutes or conveyors?
12. Are truck loading and unloading stations located appropriately?
13. Would a turntable eliminate walking?
14. Can incoming raw material be delivered at the first workstation to save double handling?
15. Could operations be combined at one workstation to save double handling?
16. Would a container of standard size eliminate weighing?

17. Are containers uniform to permit stacking and eliminate excessive use of floor space?
18. Could material be bought in a more convenient size for handling?
19. Would signals, i.e. lights, bells, etc., notifying workers that more material is required, save delay?
20. Can the location of stores and stockpiles be altered to reduce handling and transport?

G. Work organization

1. How is the job assigned to the operative?
2. Are things so well controlled that the operative is never without a job to do?
3. How is the operative given instructions?
4. How is material obtained?
5. How are drawings and tools issued?
6. Is there a control on time? If so, how are the starting and finishing times of the job checked?
7. Are there many possibilities for delays at the drawing-room, tool-room and store-room?
8. Is the material properly positioned?
9. If the operation is being performed continually, how much time is wasted at the start and end of the shift by preliminary operations and cleaning up?
10. What clerical work is required from operatives for filling in time cards, material requisitions and the like? Can some of these operations be computerized?
11. How is defective work handled?
12. How is the issue and servicing of tools organized?
13. Are adequate records kept on the performance of operatives?
14. Are new employees properly introduced to their surroundings and do they receive sufficient instruction?
15. When workers do not reach a standard of performance, are the details investigated?
16. Are suggestions from workers encouraged?
17. Do the workers really understand the incentive plan under which they work?

H. Working conditions

1. Is the lighting even and sufficient at all times?
2. Has glare been eliminated from the workplace?
3. Is the proper temperature for comfort provided at all times? If not, can fans or heaters be used?
4. Would installation of air-conditioning equipment be justified?
5. Can noise levels be reduced?
6. Can fumes, smoke and dirt be removed by exhaust systems?
7. If concrete floors are used, are duckboards or matting provided to make standing more comfortable?
8. Can a chair be provided?
9. Are drinking fountains with cool water provided and are they located nearby?
10. Has due consideration been given to safety factors?
11. Is the floor safe, smooth but not slippery?
12. Has the operative been taught to work safely?
13. Is the clothing suitable from a safety standpoint?
14. Does the plant present a neat and orderly appearance at all times?
15. How thoroughly is the workplace cleaned?
16. Is the plant unduly cold in winter, or stuffy in summer, especially on the first morning of the week?
17. Are dangerous processes adequately guarded?

I. Job enrichment

1. Is the job boring or monotonous?
2. Can the operation be made more interesting?
3. Can the operation be combined with previous or subsequent operations to enlarge it?
4. What is the cycle time?
5. Can the operative do his or her own setting?
6. Can the operative do his or her own inspection?
7. Can the operative deburr his or her own work?
8. Can the operative service his or her own tools?
9. Can the operative be given a batch of tasks and do his or her own scheduling?
10. Can the operative make the complete part?
11. Is job rotation possible and desirable?
12. Can group work be encouraged?
13. Are flexible working hours possible and desirable?
14. Can buffer stock be provided to allow variations in work pace?
15. Does the operative receive regular information about his or her performance?



Example of tables used to calculate relaxation allowances

This appendix is based on information supplied by Peter Steele and Partners (United Kingdom). Similar tables have been developed by various institutions such as REFA (Germany) and by other consulting firms.

Relaxation allowances may be determined by means of the tables of comparative strains and the points conversion table reproduced in this appendix. The analysis should proceed as follows:

- (1) For the element of work under consideration, determine the severity of the strain imposed under each subheading of the table of strains below, by reference to the tables of comparative strains.
- (2) Allocate points as indicated and determine the total points for the strains imposed by the performance of the element of work.
- (3) Read off from the points conversion table the appropriate relaxation allowance.

Table 1. Points allocated for various strains: Summary

Type of strain	Severity		
	Low	Medium	High
A. Physical strains resulting from nature of work			
1. Average force exerted	0-85	0-113	0-149
2. Posture	0-5	6-11	12-16
3. Vibration	0-4	5-10	11-15
4. Short cycle	0-3	4-6	7-10
5. Restrictive clothing	0-4	5-12	13-20
B. Mental strains			
1. Concentration/anxiety	0-4	5-10	11-16
2. Monotony	0-2	3-7	8-10
3. Eye strain	0-5	6-11	12-20
4. Noise	0-2	3-7	8-10
C. Physical or mental strains resulting from nature of working conditions			
1. Temperature			
Low humidity	0-5	6-11	12-16
Medium humidity	0-5	6-14	15-26
High humidity	0-6	7-17	18-36

Type of strain	Severity		
	Low	Medium	High
2. Ventilation	0-3	4-9	10-15
3. Fumes	0-3	4-8	9-12
4. Dust	0-3	4-8	9-12
5. Dirt	0-2	3-6	7-10
6. Wet	0-2	3-6	7-10

Note: Allocate points for each strain independently, irrespective of what has been allowed for other strains. If any strain occurs for only a proportion of the time, allocate a similar proportion of the points:

e.g. High concentration: 16 points, 25 per cent of the time;
 Low concentration: 4 points, 75 per cent of the time.
 Allocate $16 \times 0.25 = 4$ points plus $4 \times 0.75 = 3$ points, which gives a total of $4 + 3 = 7$ points.

Tables of comparative strains

A. Physical strains resulting from the nature of the work

1. AVERAGE FORCE EXERTED (FACTOR A.1)

Consider the whole of the element or period for which the relaxation allowance is required and determine the **average** force exerted.

Example:

Lift and carry a weight of 40 lb. (time 12 seconds) and return empty-handed (time 8 seconds). In this example, if the relaxation allowance is to apply to the full 20 seconds, the "average force exerted" should be calculated as follows:

$$\left(40 \times \frac{12}{20}\right) + \left(0 \times \frac{8}{20}\right) = 24 \text{ lb.}$$

The number of points allocated for the average force exerted will depend upon the type of stress involved. Stresses are classified as follows:

- (a) Medium stress
 - (i) where the work is primarily concerned with carrying or supporting loads;
 - (ii) shovelling, swinging hammers and other rhythmical movements.
 This category covers most operations.
- (b) Low stress
 - (i) where the weight of the body is transferred in order to exert force, e.g. foot-pedal operation, pressing an article, with the body, against a buff;
 - (ii) supporting or carrying well-balanced loads strapped to the body or hung from the shoulders; arms and hands free.
- (c) High stress
 - (i) where the work is primarily concerned with lifting;
 - (ii) exerting the force by continued use of certain muscles of fingers and arms;
 - (iii) lifting or supporting loads in awkward attitudes, manipulation of heavy weights into awkward positions;
 - (iv) operations in hot conditions, hot metalworking, etc.

Relaxation allowances should be awarded in this category only after every endeavour has been made to improve facilities which will make the physical task lighter.

Table II. Medium stress: Points for average force exerted

lb.	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	3	6	8	10	12	14
10	15	16	17	18	19	20	21	22	23	24
20	25	26	27	28	29	30	31	32	32	33
30	34	35	36	37	38	39	39	40	41	41
40	42	43	44	45	46	46	47	48	49	50
50	50	51	51	52	53	54	54	55	56	56
60	57	58	59	59	60	61	61	62	63	64
70	64	65	65	66	67	68	69	70	70	71
80	72	72	72	73	73	74	74	75	76	76
90	77	78	79	79	80	80	81	82	82	83
100	84	85	86	86	87	88	88	88	89	90
110	91	92	93	94	95	95	96	96	97	97
120	97	98	98	98	99	99	99	100	100	100
130	101	101	102	102	103	104	105	106	107	108
140	109	109	109	110	110	111	112	112	112	113

Table III. Low stress: Points for average force exerted

lb.	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	3	6	7	8	9	10
10	11	12	13	14	14	15	16	16	17	18
20	19	19	20	21	22	22	23	23	24	25
30	26	26	27	27	28	28	29	30	31	31
40	32	32	33	34	34	35	35	36	36	37
50	38	38	39	39	40	41	41	42	42	43
60	43	43	44	44	45	46	46	47	47	48
70	48	49	50	50	50	51	51	52	52	53
80	54	54	54	55	55	56	56	57	58	58
90	58	59	59	60	60	60	61	62	62	63
100	63	63	64	65	65	66	66	66	67	67
110	68	68	68	69	69	70	71	71	71	72
120	72	73	73	73	74	74	75	75	76	76
130	77	77	77	78	78	78	79	80	80	81
140	81	82	82	82	83	83	84	84	84	85

Table IV. High stress: Points for average force exerted

lb.	0	1	2	3	3-4	4	5	6	7	8	9
0	0	0	0	3	6	8	11	13	15	17	18
10	20	21	22	24		25	27	28	29	30	32
20	33	34	35	37		38	39	40	41	43	44
30	45	46	47	48		49	50	51	52	54	55
40	56	57	58	59		60	61	62	63	64	65
50	66	67	68	69		70	71	72	73	74	75
60	76	76	77	78		79	80	81	82	83	84
70	85	86	87	88		88	89	90	91	92	93
80	94	94	95	96		97	98	99	100	101	101
90	102	103	104	105		105	106	107	108	109	110
100	110	111	112	113		114	115	115	116	117	118
110	119	119	120	121		122	123	124	124	125	126
120	127	128	128	129		130	130	131	132	133	134
130	135	136	136	137		137	138	139	140	141	142
140	142	143	143	144		145	146	147	148	148	149

A study should be made of the elements in relation to low, medium and high stress conditions. The points to be allocated, according to the type of stress and the average force applied, are set out in tables II to IV.

Example: If the weight carried is 25 lb.:

- (i) determine the type of the stress involved (medium, low or high);
- (ii) in the left-hand column of the table for the type of stress (tables II, III or IV), find the line for 20 lb.;
- (iii) on this line, move across the table to the right, to column 5;
- (iv) read off the points allocation for 25 lb. carried, which is:
table II, medium stress: 30 points;
table III, low stress: 22 points;
table IV, high stress: 39 points.

2. POSTURE (FACTOR A.2)

Consider whether the worker is sitting, standing, stooping or in a cramped position and whether a load is handled easily or awkwardly.

	Points
Sitting easily	0
Sitting awkwardly, or mixture of sitting and standing	2
Standing or walking freely	4
Ascending or descending stairs unladen	5
Standing or walking with a load	6
Climbing up or down ladders, or some bending, lifting, stretching or throwing	8
Awkward lifting, shovelling ballast to container	10
Constant bending, lifting, stretching or throwing	12
Coalmining with pickaxes, lying in a low seam	16

3. VIBRATION (FACTOR A.3)

Consider the impact of the vibration on the body, limbs or hands and the addition to mental effort due to it, or to a series of jars or shocks.

	<i>Points</i>
Shovelling light materials	1
Power sewing-machine	} 2
Power press or guillotine if operative is holding the material	
Cross-cut sawing	
Shovelling ballast	} 4
Portable power drill operated by one hand	
Pickaxing	6
Power drill (two hands)	8
Road drill on concrete	15

4. SHORT CYCLE (HIGHLY REPETITIVE) (FACTOR A.4)

In highly repetitive work, if a series of very short elements form a cycle which is continuously repeated for a long period, award points as indicated below, to compensate for the lack of opportunity to vary the muscles used during the work.

<i>Average cycle time (centiminutes)</i>	<i>Points</i>
16-17	1
15	2
13-14	3
12	4
10-11	5
8-9	6
7	7
6	8
5	9
Less than 5	10

5. RESTRICTIVE CLOTHING (FACTOR A.5)

Consider the weight of the protective clothing in relation to effort and movement. Consider also whether ventilation and breathing are affected.

	<i>Points</i>
Thin rubber (surgeon's) gloves	1
Household rubber gloves	} 2
Rubber boots	
Grinder's goggles	3
Industrial rubber or leather gloves	5
Face mask (e.g. for paint-spraying)	8
Asbestos suit or tarpaulin coat	15
Restrictive protective clothing and respirator	20

B. Mental strains

1. CONCENTRATION/ANXIETY (FACTOR B.1)

Consider what would happen if the operative relaxed attention, the responsibility carried, the need for exact timing of movements, and the accuracy or precision required.

	<i>Points</i>	
Routine simple assembly	}	0
Shovelling ballast		
Routine packing, labourer washing vehicles	}	1
Wheeling trolley down clear gangway		
Feed press tool; hand clear of press	}	2
Topping up battery		
Painting walls		3
Assembling small and simple batches, performed without much thinking	}	4
Sewing-machine work, automatically guided		
Assembling warehouse orders by trolley	}	5
Simple inspection		
Load/unload press tool, hand feed into machine	}	6
Spray-painting metalwork		
Adding up figures	}	7
Inspecting detailed components		
Buffing and polishing		8
Guiding work by hand on sewing-machine	}	10
Packing assorted chocolates, memorizing pattern and selecting accordingly		
Assembly work too complex to become automatic		
Welding parts held in jig		
Driving a motor bus in heavy traffic or fog	}	15
Marking out in detail with high accuracy		

2. MONOTONY (FACTOR B.2)

Consider the degree of mental stimulation and if there is companionship, competitive spirit, music, etc.

	<i>Points</i>	
Two workers on jobbing work	0	
Cleaning own shoes for half an hour on one's own	3	
Operative on repetitive work	}	5
Operative working alone on non-repetitive work		
Routine inspection		6
Adding similar columns of figures		8
One operative working alone on highly repetitive work		11

3. EYE STRAIN (FACTOR B.3)

Consider the lighting conditions, glare, flicker, illumination, colour and closeness of work and for how long the strain is endured.

	<i>Points</i>
Normal factory work	0
Inspection of easily visible faults	} 2
Sorting distinctively coloured articles by colour	
Factory work in poor lighting	
Intermittent inspection for detailed faults	} 4
Grading apples	
Reading a newspaper in a motor bus	8
Arc-welding using mask	} 10
Continuous visual inspection, e.g. cloth from a loom	
Engraving using an eyeglass	14

4. NOISE (FACTOR B.4)

Consider whether the noise affects concentration, is a steady hum or a background noise, is regular or occurs unexpectedly, is irritating or soothing. (Noise has been described as "a loud sound made by somebody else".)

	<i>Points</i>
Work in a quiet office, no distracting noise	} 0
Light assembly factory	
Work in a city office with continual traffic noise outside	1
Light machine shop	} 2
Office or assembly shop where noise is a distraction	
Woodworking machine shop	4
Operating steam hammer in forge	5
Rivetting in a shipyard	9
Road drilling	10

C. Physical or mental strains resulting from the nature of the working conditions

1. TEMPERATURE AND HUMIDITY (FACTOR C.1)

Consider the general conditions of atmospheric temperature and humidity and classify as indicated below. Select points according to average temperature within the ranges shown.

Humidity (per cent)	Temperature		
	Up to 75°F	76° to 90°F	Over 90°F
Up to 75	0	6-9	12-16
76-85	1-3	8-12	15-26
Over 85	4.6	12-17	20-36

2. VENTILATION (FACTOR C.2)

Consider the quality and freshness of the air and its circulation by air-conditioning or natural draught.

	<i>Points</i>	
Offices	}	0
Factories with "office-type" conditions		
Workshop with reasonable ventilation but some draught		1
Draughty workshops		3
Working in sewer		14

3. FUMES (FACTOR C.3)

Consider the nature and concentration of the fumes; whether toxic or injurious to health; irritating to eyes, noise, throat or skin; disagreeable odour.

	<i>Points</i>	
Lathe turning with coolants	0	
Emulsion paint	}	1
Gas cutting		
Soldering with resin		
Motor vehicle exhaust in small commercial garage		5
Cellulose painting		6
Moulder procuring metal and filling mould		10

4. DUST (FACTOR C.4)

Consider the volume and nature of the dust.

	<i>Points</i>	
Office	}	0
Normal light assembly operations		
Press shop		
Grinding or buffing operations with good extraction		1
Sawing wood		2
Emptying ashes		4
Linishing weld		6
Running coke from hoppers into skips or trucks		10
Unloading cement		11
Demolishing building		12

5. DIRT (FACTOR C.5)

Consider the nature of the work and the general discomfort caused by its dirty nature. This allowance covers "washing time" where this is paid for (i.e. where operatives are allowed three minutes or five minutes for washing, etc.). Do **not** allow both points and time.

	<i>Points</i>
Office work	
Normal assembly operations	0
Office duplicators	1
Refuse collection	2
Stripping internal combustion engine	4
Work under old motor vehicle	5
Unloading bags of cement	7
Coalminer	
Chimney-sweep with brushes	10

6. WET (FACTOR C.6)

Consider the cumulative effect of exposure to this condition over a long period.

	<i>Points</i>
Normal factory operations	0
Outdoor workers, e.g. letter carrier	1
Working continuously in the damp	2
Rubbing down walls with wet pumice block	4
Continuous handling of wet articles	5
Laundry wash-house, wet work, steamy, floor running with water, hands wet	10

Points conversion table

Table V. Percentage relaxation allowance for total points allocated

Points	0	1	2	3	4	5	6	7	8	9
0	10	10	10	10	10	10	10	11	11	11
10	11	11	11	11	11	12	12	12	12	12
20	13	13	13	13	14	14	14	14	15	15
30	15	16	16	16	17	17	17	18	18	18
40	19	19	20	20	21	21	22	22	23	23
50	24	24	25	26	26	27	27	28	28	29
60	30	30	31	32	32	33	34	34	35	36
70	37	37	38	39	40	40	41	42	43	44
80	45	46	47	48	48	49	50	51	52	53
90	54	55	56	57	58	59	60	61	62	63
100	64	65	66	68	69	70	71	72	73	74
110	75	77	78	79	80	82	83	84	85	87

Points	0	1	2	3	4	5	6	7	8	9
120	88	89	91	92	93	95	96	97	99	100
130	101	103	105	106	107	109	110	112	113	115
140	116	118	119	121	122	123	125	126	128	130

Example: If the total number of points allocated for the various strains is 37:

- (i) in the left-hand column of table V, find the line for 30;
- (ii) on this line, move across the table to the right, to column 7;
- (iii) read off the relaxation allowance for 37 points, which is 18 per cent.

Examples of calculation of relaxation allowances

1. *Power press operation.* As press guard opens automatically, reach in with left hand, grasp piece-part, and disengage it. With left hand move piece-part to tote bin, while right hand places new blank in press tool. Withdraw right hand, while left hand closes guard. Operate press with foot. Simultaneously, with right hand reach to tote bin, grasp blank and orient it in hand, move blank near guard and wait for guard to open.

On 20-ton press. Maximum reach 50 cm (20 in.). Posture somewhat unnatural; seated at machine. Noisy department, adequate lighting.

2. *Carry 50 lb. sack up stairs.* Lift sack on to bench 90 cm (3 ft.) high; transfer to shoulder, carry up stairs, drop sack on floor. Dusty conditions.

3. *Pack chocolates* in three layers of 4 lb. box, according to pattern for each layer, average 160 chocolates. Operative sits in front of straight shelves bearing 11 kinds of chocolates in trays or tins; must pack the chocolates according to a memorized pattern for each layer. Air-conditioned, good light.

Table VI. Calculation of relaxation allowances: Examples

Type of strain	Job					
	Power press operation		Carrying 50 lb. sack		Packing chocolates	
	Stress	Points	Stress	Points	Stress	Points
A. Physical strains						
1. Average force (lb.)	—	—	M	50	—	—
2. Posture	L	4	M	6	L	2
3. Vibration	L	2	L	—	—	—
4. Short cycle	H	10	L	—	—	—
5. Restrictive clothing	—	—	—	—	—	—
B. Mental strains						
1. Concentration/anxiety	M	6	L	1	H	10
2. Monotony	M	6	L	1	L	2
3. Eye strain	L	3	—	—	L	2
4. Noise	M	4	L	—	L	1
C. Working conditions						
1. Temperature/humidity	—	—	L/L	1	L/L	3
2. Ventilation	—	—	—	—	—	—
3. Fumes	—	—	—	—	—	—
4. Dust	—	—	H	9	—	—
5. Dirt	M	3	L	—	—	—
6. Wet	—	—	L	—	—	—
Total points	38		68		20	
Relaxation allowance, including tea breaks (per cent)	18		35		13	

APPENDIX 4

Conversion factors

(1)	(2)	To convert column (1) into column (2), multiply by
<i>Length</i>		
Inches	Feet	0.083
Inches	Centimetres	2.54
Feet	Yards	0.333
Feet	Metres	0.305
Yards	Feet	3
Yards	Metres	0.914
Poles	Yards	5.502
Poles	Metres	5.029
Furlongs	Miles	0.125
Furlongs	Kilometres	0.201
Miles	Yards	1760
Miles	Kilometres	1.609
Fathoms	Feet	6
Fathoms	Metres	1.829
Centimetres	Inches	0.394
Metres	Feet	3.281
Metres	Yards	1.094
Metres	Poles	0.199
Metres	Fathoms	0.547
Kilometres	Furlongs	4.975
Kilometres	Miles	0.621
<i>Area</i>		
Square inches	Square feet	0.0069
Square inches	Square centimetres	6.452
Square feet	Square yards	0.111
Square feet	Square metres	0.093
Square yards	Square feet	9
Square yards	Square metres	0.836

(1)	(2)	To convert column (1) into column (2), multiply by
Acres	Square feet	43560
Acres	Square miles	0.0016
Acres	Square metres	4047
Acres	Hectares	0.405
Square miles	Square feet	27878400
Square miles	Square kilometres	2.59
Square miles	Hectares	259.2
Square miles	Acres	640
Square centimetres	Square inches	0.155
Square metres	Square feet	10754
Square metres	Square yards	1.196
Square metres	Acres	0.0025
Square kilometres	Hectares	100
Square kilometres	Acres	247.105
Square kilometres	Square miles	0.386
Hectares	Acres	2.471
Hectares	Square kilometres	10 ²
Hectares	Square miles	0.0039
<i>Volume</i>		
Cubic inches	Cubic feet	5.787 x 10 ⁻⁴
Cubic inches	Cubic centimetres	16.387
Cubic feet	Cubic yards	0.037
Cubic feet	Cubic metres	0.028
Cubic yards	Cubic feet	27
Cubic yards	Cubic metres	0.765
Cubic centimetres	Cubic feet	3.53 x 10 ⁻⁵
Cubic centimetres	Cubic inches	0.061
Cubic metres	Cubic yards	1.308
Cubic metres	Cubic feet	35.315
<i>Liquid measure</i>		
Fluid ounces (Imperial)	Fluid ounces (US)	0.961
Fluid ounces (Imperial)	Mililitres	28.413
Fluid ounces (US)	Fluid ounces (Imperial)	1.041
Fluid ounces (US)	Mililitres	29.574
Pints (Imperial)	Pints (US)	1.201
Pints (Imperial)	Quarts	0.5
Pints (Imperial)	Gallons (Imperial)	0.125
Pints (Imperial)	Litres	0.568

(1)	(2)	To convert column (1) into column (2), multiply by
Pints (US)	Pints (Imperial)	0.833
Pints (US)	Litres	0.473
Gills	Pints	0.25
Gills	Litres	0.142
Gallons (Imperial)	Gallons (US)	1.201
Gallons (Imperial)	Litres	4.546
Gallons (US)	Gallons (Imperial)	0.833
Gallons (US)	Litres	3.785
Cubic centimetres	Litres	10 ⁻³
Litres	Pints (Imperial)	1.760
Litres	Pints (US)	2.113
<i>Weight</i>		
Grains (avdp.)	Grains (troy)	1.003
	Grams	0.0648
Grains (troy)	Grains (avdp.)	0.996
	Grams	0.0648
Pennyweight (troy)	Grains (troy)	24
	Grams	1.555
Ounces (avdp.)	Ounces (troy)	0.9115
	Pounds	0.0625
	Grams	28.35
Ounces (troy)	Ounces (avdp.)	1.097
	Grams	31.104
Pounds (avdp.)	Pounds (troy)	1.215
	Ounces (avdp.)	16
	Kilograms	0.454
Pounds (troy)	Pounds (avdp.)	0.823
	Ounces (troy)	12
	Kilograms	0.373
Stones	Pounds (avdp.)	14
	Grams	6350.297
Tons (short)	Pounds (avdp.)	2000
	Kilograms	907.185
Tons (long)	Pounds (avdp.)	2240
	Kilograms	1016.047
Grams	Ounces (avdp.)	0.035
	Ounces (troy)	0.032
Kilograms	Pounds (avdp.)	2.205
	Tons (short)	0.0011
	Tons (long)	0.00098



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