Macmillan Handbooks in Industrial Management

A. W. Pemberton

Plant Layout and Materials Handling

Introduction to the Series

The six books comprising the Macmillan 'Handbooks in Industrial Management' series were from the outset planned as an entity, and together they cover comprehensively yet concisely the varied aspects of knowledge required by those who manage a modern factory or plant. At the same time, care has been taken to ensure that each volume shall be complete in itself, and carry sufficient basic management theory for a proper understanding of its specific subject.

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It is expected that many practising works managers and mature students will wish to have the whole set on their shelves, but that others will welcome the opportunity of buying single volumes to meet their particular needs.

Thanks are due to the authors for the enthusiasm with which they have joined in the enterprise, and to members of the staff of the Institution of Works Managers for practical support on many occasions.

J. EKINS

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Plant Layout and Materials Handling

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Foreword

In the world of modern industry, it becomes increasingly necessary for managers to be aware not only of the fundamental principles of good management, but also of the latest techniques necessary for putting those principles into practice.

Works managers in particular, because of the salient position which they hold in the management structure of modern industry and their responsibility for translating policy into execution, must be both educated in sound theory and trained in modern methods.

This series of eight books has been designed to provide the basis of that education and to supplement essential experience.

I welcome the opportunity the Institution of Works Managers has been given to sponsor this venture and commend the books to all present and future managers in industry.

RICHARD MARSH
Chairman, British Rail
President, Institution of Works Managers

Preface and Acknowledgements

This book is not intended to be an exhaustive treatise on layout and handling, neither does it propound any new theories or techniques. No attempt is made to describe the different types of materials handling equipment and their uses: there are plenty of publications where this kind of information can be obtained.

The author's intention has been to produce a working handbook for any member of management who shoulders the responsibility for a task in the field of layout and handling. The person concerned may be from line management, administration or advisory services, and he may be working in any industry, but the problems and difficulties which he will encounter are of much the same nature throughout. This is particularly so in relation to building structures, and problems of siting and planning.

The book tries to relate to British practice; readers from other countries may find this parochial, but the main motivation for writing it was the lack of direct information on layout available to the British reader. Many American books deal adequately with the methodology and techniques, but the application is vastly different between the U.S.A. and the U.K.

The book tries to reflect experience, both my own and that of many colleagues and friends in industry and the unions. If it helps to smooth the path of anyone who has set foot upon the uphill and often rough road which leads from an existing to a proposed layout, it will have been worth while. For readers who require more detail on specific subjects, particularly those with a technical content, the bibliography should go some way towards satisfying this.

I should like to thank all those friends and colleagues who have borne with me during the gestation period of this book, with particular thanks to Alan Fields, whose book on method study is referred to, and to Brian Toyn, whose help and experience have been drawn upon in relation to network analysis.

A. W. P.

1 | Introduction

Before looking in detail at the techniques of materials handling and plant layout, it is necessary to consider what area is covered by these terms, and where they fit into the pattern of general management. Although the two terms are often considered and used independently of each other, in practice the matters covered are so closely related that it is impossible, for example, to lay out a workshop without considering in great detail the system of handling material that will operate therein.

MATERIALS HANDLING

The term 'materials handling' itself requires defining, if only because the phrase usually conjures up visions of fork-lift trucks (FLTs), conveyors and other pieces of expensive hardware. If we regard it as a series of related techniques with a particular objective, we are much more likely to find it meaningful than if we consider it as the application of equipment to problems of work movement. Materials handling endeavours to do for the flow of materials through an organisation what work study does for the various jobs that make up the production processes. By examining each movement, and considering in detail the requirements for the move, the necessity for it, and the amounts and sizes of material to be moved, we obtain a detailed picture of the handling which is taking place throughout the processes, and are thus in a position to consider whether any of these moves can be eliminated, combined with some other move or processes, or simplified. To those readers who are already conversant with the tenets of work study, this last sentence will have a familiar ring.

MECHANICAL HANDLING

Some confusion arises through the frequent use of the term 'mechanical handling' as a substitute for 'materials handling'. Mechanical handling simply means the use of mechanical devices in handling materials, and is not concerned with the necessity for their use. The term, if used at all, should be applied with caution: mechanical handling is always expensive and the first objective of anyone working in the materials handling field should be to eliminate as much unnecessary handling as possible, and only to mechanise when this is financially rewarding in terms of overall cost reduction.

PLANT LAYOUT

'Plant layout' is a term which covers a great deal more than the simple process of laying out machinery, being concerned with the relationship of processes to each other, overall factory design and layout, the calculation of manning and planning data, and the evaluation of machine capabilities for production. It is a complex activity, calling for considerable amounts of accurate data over a wide range of activities before the outlines of a new layout can begin to take shape. Much of the planning activities call for a considerable knowledge of the product and its various production processes, and a continual liaison with works management, production engineering and production control is required for success.

Both materials handling and plant layout have one enormous disadvantage compared with many other management tools: it is very seldom possible to have a 'dry run' or experimental set-up in these fields. Materials handling equipment is expensive and bulky, plant layout requires a considerable capital outlay in cash and manpower to achieve: both have to be considered together. So it is absolutely essential to try to be as near as possible to 'right first time' before the plan is transferred from paper to hardware.

SPECIALIST OR NON-SPECIALIST?

Contrary to the view taken by many consultants, neither materials handling nor plant layout can be described as a specialist activity, at least in the medium to small firm (2,000 to 200 employees). That is to say, there is unlikely to be anyone whose entire work falls into these categories, but more likely some member of management will have acquired or received specialised knowledge in these areas. In the larger firm, and particularly those where frequent layouts and changes are necessary for the continuance of production due to changes of product (i.e. the motor industry), the plant layout function is often performed by a specialised group, who are basically draughtsmen and who work in close liaison with production engineers. However, this seldom produces the best work, since the layout group members are often denied access to the shop floor, and are working in a theoretical vacuum for most of the time.

In most firms the work study department, in conjunction with the works management, the production engineering, function or both, are often jointly responsible for the preparation of layout plans; the materials handling aspect is usually covered by the work study department working with the works engineering function. It cannot be too highly stressed that successful layout and handling can be attained only through the fullest co-operation of all the 'management services' division and the works line management. Proper defining of objectives and placement of responsibilities must be carried out long before any actual plans are conceived, otherwise disagreements in these areas will lead to disputes and delays.

It is also essential to keep the shop-floor employees abreast of any plans for alteration of their environment. Today, when the slightest suspicion of management's motives for a particular course of action can lead to labour unrest, we must take steps to see that everyone concerned is informed. Even without this incentive, it can be appreciated that no one likes to feel that he may be uprooted from his place of work, and the whole workplace changed, without some warning and explanation. (Compare the situation with some of those apocryphal stories which have emerged from the U.S.A., about a manager arriving one morning to discover his desk is now in a smaller office, with only one telephone. In subsequent weeks other changes are made, until the victim finds himself without a job – or an explanation!)

AVOIDING THE OBVIOUS REASON

Before going on to describe the techniques and concepts behind materials handling and plant layout, it is necessary to emphasise the importance of not accepting the obvious reason for the existence of a problem, particularly in the field of materials handling. Many works difficulties look as though they are prima facie materials handling problems: large amounts of work-in-progress; delays in the raw materials stores; difficulties with internal transport; dispatch and delivery to customers.

Materials handling may well help to solve such problems, but in many cases the basic difficulty is caused by failures in other functions, such as production control, stock control, etc., and these must be examined first if they appear to have any bearing on the problem.

PROBLEMS AND THEIR INVESTIGATION

Dealing with the industrial problem is in no way different from examining any other kind of difficulty whether scientific, social or environmental. The approach to the problem is made from an often loosely formulated hypothesis that some improvement is possible, and that the direction of such an improvement can be seen.

In order to prove a hypothesis, it is necessary to collect evidence about the problem, and to analyse in considerable detail; using the information gained, the hypothesis can then be fitted into the material and an attempt made to see whether, in fact, it is workable. The resolution of the problem then consists, usually, of a series of adjustments to the original situation to bring about the best obtainable result in the circumstances. Such adjustments can range from minor alterations to the existing set-up, to a completely new approach which has been exposed by examining the evidence produced by the investigation.

This way of approaching a problem, sometimes called the epistemological method, is the basis of work study. So it follows that one of the key techniques is to be found here, and some basic knowledge of both method study and work measurement (the two main branches of work study) is essential to anyone working in plant layout and materials handling.

AREA OF KNOWLEDGE REQUIRED BY THE INVESTIGATOR

Apart from the techniques of work study, which give the investigator the tools to carry out a systematic inquiry into all aspects of the layout and handling problem, it is necessary to know something about several fields of activity which have a wide bearing on the layout of industrial plant. Some of these will be treated more fully later in this book, so it will only be necessary to summarise at this point.

Firstly, it should be understood that no one could be expected to comprehend the full body of knowledge in all these fields: each has its own techniques and specialists. But the investigator must know the basics, and he must know where to get more detailed information, from whom, and to be able to evaluate it.

1. *Costing*

Since all industrial activity must eventually be profitable, a knowledge of how the costing system works is essential. Note that, for the individual investigator, the requirement is knowledge of the costing system that he is working in and not the overall study of cost accounting. In other words, he must know how to evaluate any expenditure or savings from improvements, in terms that his own cost department understand.

2. *Buildings*

Most handling and layout problems occur in relation to buildings, hence their shape, size and construction have a very strong bearing on any proposals. (For example, it is not easy to install a heavy-duty overhead conveyor if the buildings have a lightweight concrete shell roof.) Heights, roofs, floors and services are all matters which impinge directly on layout.

3. *Product*

No one can attempt to investigate a problem unless he is conversant with all aspects of the product under review. A thorough understanding of its nature, characteristics, materials required, processes through which it passes, and its form, condition and handling characteristics at every stage of manufacture must be known. The more sophisticated the product, the more comprehensive the knowledge required. (For example, if the layout of a chemical plant is being considered, it is probably essential for the engineer concerned to have chemical knowledge in the relevant field.)

4. *Manufacturing Equipment*

This is the plant or machinery in or on which the product is made. Again, detailed knowledge of the working parts may not be required, but the part it plays in producing the product must be understood, as well as the machinery's requirements in terms of services, i.e. electricity, compressed air, etc. Some knowledge of its construction is helpful, in order that an assessment can be made of the difficulties of installing or moving it, or whether it is liable to damage if moved by unskilled labour. It is difficult to define just how much knowledge is required here, as plant goes all the way from heavy rolling mills to sewing machines, and obviously, in many cases, the works engineers will be the only persons with detailed information.

5. *Production and Stock Control*

As in costing, it is here only necessary to have an understanding of the objectives of these systems, but a much more detailed knowledge is required of the particular systems in use in the investigator's organisation. As mentioned earlier, many handling problems have their roots in production control, and matters such as shop and machine loading, progress stores and methods of ordering raw materials have direct effects on layout and handling.

6. *Factory Safety and the Factories Act*

Anyone working in the layout field must have a working knowledge of the Factories Act, particularly as it relates to operator safety and the legal requirements of the employer. Unfortunately, it is only too easy to neglect some not very obvious point and so perhaps involve an organisation in litigation or, at the worst, hold up production while modifications are made as well. Again, knowledge to legal standards is not required, but such matters as machine guarding in relation to conveyors, etc., what constitutes the difference between a goods and a passenger lift, the scale of toilet accommodation for workers, and so on. H.M. Stationery Office publish a small but comprehensive guide to the Factories Act.[1]

Fire and building regulations both have bearings on layout; the latter is obtainable in booklet form,[2] and for fire regulations all that is needed is good liaison with the local fire service head.

If the body of information suggested above seems heavy, it is put forward as the minimum necessary for someone who is going to carry out major layouts, or who may be employed full-time on such activities. Minor works may not require such comprehensive coverage, although the more general knowledge of the organisation held, the better the final result is likely to be. Looked at from the point of view of the works management staff, there is very little

[1] *The Factories Act: A Short Guide* (HMSO).
[2] *The Building Regulations, 1965* (HMSO).

referred to above which such men would not regard as essential to their own job. One of the reasons why plant layout can usually be more successfully carried out by the organisation's own staff, given proper training, can now be seen: no outside party is likely to have as much detailed knowledge of the company's internal affairs or product manufacture.

MATERIALS HANDLING EQUIPMENT

No mention has been made in the foregoing of the knowledge which may be required regarding specialised items of equipment in the materials handling field. The reason for this omission is that for most organisations only a limited knowledge will be required: it is not necessary for the person making the investigation to have a comprehensive knowledge of all the available equipment, or the dimensions and characteristics of the different items. Such a level of knowledge is only likely to be necessary for a specialist adviser either in a very large organisation or working as a consultant.

As will be shown in later chapters, analytical methods will be described which will enable the investigator to specify in some detail the type and capacity of any materials handling equipment which may be required for a particular application. The details relating to these limited items are obviously well within the compass of knowledge of an investigator with some engineering or general management capability.

PATTERN OF THE INVESTIGATION

Whether the investigation is related to materials handling, to plant layout or, more usually, to both, the overall approach to the problem follows this pattern:

Select the area or job to be studied, defining as far as possible the limits of the investigation, and allocating responsibilities for action.

Survey the selected area, taking in the major existing difficulties, and making an assessment of the possible improvement.

Record all the relevant information that can be obtained from the existing situation, going into as great a depth as possible, and taking care to make a note of all possible side-issues.

Examine the recorded information thoroughly, using the full questioning technique (see p. 102) and making every effort to exhaust all the possible sources of information.

Develop a proposed layout, system or method, taking into account the real needs and objectives of the situation, and exploring the cost-effectiveness of all possible alternatives.

Prepare a drawn-up detailed plan of the new layout or system, using whatever visualisation techniques are appropriate to the scale of the project, and discuss this in detail with those persons who are going to be concerned in operating the new set-up. Prepare and circulate a written report on the project at this stage, which should give estimates of the cost.

Install the new system, working together with those people or departments who carry the responsibility for the physical installation, together with the works management.

Maintain the new system in accordance with the agreed plan. Responsibility for this stage must be clearly defined. Who is responsible for seeing that the agreed set-up continues to function? Settle any queries which arise and be prepared to accept minor adjustments if necessary.

Throughout the investigation, continuous feedback of information will be required, and the investigating team will have to be given authority and access to the areas under investigation. No successful investigation can be carried through unless it takes place on the factory floor, and with constant liaison with the works staff. At each stage of the investigation it will be necessary to keep in contact with the supervision to ensure that nothing is being generated which cannot subsequently be put into operation.

There are many reasons why a change of layout may be required, and it is worth while to consider some of these in detail. From so doing, an indication can be given of the different scales of layout planning which may be required, running from the construction of a new factory and the subsequent installation of all types of plant, to a simple readjustment within the existing layout to accommodate a new process or method.

THE NEW FACTORY

This is at the same time the most rewarding and the most testing situation that can face the layout planner, particularly if there is no history of previous operations of the type to be installed (this is a situation that the average layout planner or materials handling adviser may meet only once or twice in the whole of his career). With such an important step to take, even a small amount of help can be better than none, and the most crucial point that can be made is to get into the planning of the project at the earliest possible stage, preferably long before the architect has been briefed.

One of the most hallowed tenets of the plant layout faith is the 'green field approach'. By this is meant that in planning a new layout one should always make the first attempt on the basis that there will be no structural limitations placed on the layout; modifications of this ideal layout are then made to fit it into the required or existing area or building. Although this is theoretically possible, and indeed should be used by anyone new to the field, it can nevertheless waste a tremendous amount of time in circumstances where the areas available are predetermined. In the case of a new building, however, this practice should always be followed, and wherever possible the building should be regarded as a covering shell for the activities, and tailored accordingly, rather than, as so often happens, the layout having to be distorted to fit a previously designed box. Fortunately, numerous architects and civil engineers concerned with industrial building are now firmly on the side of the layout planner, and in some cases would hesitate to design a building unless they had full details of the operations and processes which were to be carried out therein. There are still, however, far too many cases where the architect happens to be acquainted with some member of the board, and gets inadequately briefed for the work. These, too, are usually the cases where the works staff and layout planners have little say in the general design of the building.

MANUFACTURE OF NEW PRODUCTS

This is the situation where a firm has decided to bring out a new product or range of products not previously manufactured or, at the most, only in pilot quantities. The new production may be carried out in a new factory, in a rented or hired building, or in the existing factory. The major difficulty here is usually lack of data on the manufacture of the new product. If, of course, it is a development of something already existing, then some extrapolation from current methods is possible. For a totally new product, however, some experience must be gained on an experimental basis in order to acquire planning data for layout.

EXPANSION OF EXISTING BUSINESS

This is the most usual case for demanding a new layout, and fortunately the one usually providing the simpler task. Unless drastic changes in production methods are likely (see below), much of the existing information can be used in planning. This is not to say that it should be accepted in its entirety: the existing methods must be carefully examined to ensure that such changes as can offer improvement in handling and layout are made or planned before finalisation. This is often an opportunity to put into practice many ideas which will have been gained or suggested as a result of operating experience, and the fullest consultation with the operating staff should take place. As before, layouts for this cause may be in new buildings, existing buildings or other accommodation.

ADJUSTMENTS WITHIN EXISTING MANUFACTURE

Following closely on the above, but probably on a smaller scale, this is the commonest cause for re-layout and, paradoxically, sometimes the case where most difficulty is experienced. Nearly always in these situations, everyone is hoping to squeeze the traditional quart out of a pint pot, and the layout planner is given very little latitude. Despite these limitations, the planner is often in a better position actually to prepare the changes than in any other case. The methods and operations are probably unchanged, there will almost certainly be a wealth of available data which can be used without a great deal of manipulation, and the working environment, although perhaps restrictive, is well known to both operators and planners. This situation is one that calls for juggling with limited space together with immense tact in dealing with supervision, who will almost certainly have their own fixed ideas on what could and should be done.

TECHNICAL PROGRESS

One of the more usual causes for a new layout is the advent of changes in technology of manufacture. While these are slower and less frequent in the older and heavier industries (although often far more sweeping when they do occur!), in the lighter end of manufacturing the rate of technological change may be very high. One has only to look at the electronics industry to see that in a few years it has gone from valves and chassis to transistors and printed circuit boards, and is now entering the integrated circuit era. This has meant tremendous changes in production methods and layout, and the same is true for many other industries. Again, as considered under 'New Products', many of the production methods may be experimental or previously unknown, and layout has to proceed hand in hand with development.

TYPES OF MANUFACTURE

One of the earliest concepts of the plant layout field is that of the 'production classification'. This usually refers to grouping the different basic methods under three headings, and listing their advantages and disadvantages. The usual grouping is:

1. *Fixed Position or Unit Manufacture*
This is where the article being produced is large, heavy and relatively immovable, e.g. ships, alternators, turbines, aircraft, where the product remains in one fixed position during its manufacture, and parts or assemblies made elsewhere in the organisation are brought together and assembled at this point.

2. *Batch Production*
Often dignified with the title 'group technology', this means bringing together all machinery of a particular function or process, and progressing the work in batches through each function in turn. Most general engineering production falls into this class, together with such products as plastics, some types of furniture, and many others.

3. *Line or Mass Production*
This is when the product is of such a nature or is made in such quantities that a separate processing line can be set up for each product or group of products, and the work progresses down the line of processes, often mechanically, passing through the various stages of manufacture and finally emerging as a completed item. Such

a system lends itself to steady production rates and large quantities of relatively similar articles, such as radio and TV sets, refrigerators, cars, etc.

The use of this classification is very limited. Listing the advantages and disadvantages of one system against the other **can only be meaningful if there is a possibility of changing from one type of system to the other.** So that it is meaningless to say that 'mass production is more efficient (or less flexible) than batch production', unless it is possible to evaluate the costs of either system for an identical product and quantity. Methods for identifying the situations where there is a possibility of change will be found in later chapters. Generally, things are seldom as clear-cut as these classifications would imply: most firms using mass production techniques have elsewhere a series of batch processes producing parts and sub-assemblies; many batch producers use a small production line for final assembly.

When a layout is to be made, the existing production methods and quantities will need to be evaluated and examined: the quantities and speed of production will be thrown up in the calculations made. The choice of type of manufacture (if there is a choice) has to be made at this time, and the assessment has to be made, as always, on the grounds of lowest cost of manufacture per unit.

In later chapters of this book, an attempt is made to show the development of a layout from the initial brief through to the installation of the required plant and its successful operation. Not all the possible cases are covered, but hopefully enough is shown to help the ordinary works executive or management services specialist over a few of the hurdles that he will undoubtedly face.

2 Investigational Methods: Work Study

Since investigations into materials handling and layout situations are usually concerned with industrial processes or movement of materials in connection therewith, and since work study is a widely accepted set of tools for analysing industrial problems, it will come as no surprise to find that it forms the basis of methodical investigations in these areas.

In any trade or profession it is necessary for the practitioner to know how to use the tools of his trade, whether these be physical objects or routines for recalling and applying areas of knowledge.

Similarly, in carrying out an investigation in any field of activity, the primary requirement is to extract the maximum amount of useful information with the minimum expenditure of effort.

Anyone who is formally appointed to carry out materials handling and layout investigations must have a working knowledge of the uses and applications of all the work study techniques, and should either be a practitioner or have attended a good basic course. Books, while helpful in the initial phase of learning,[1] are not a substitute for practice in this field.

In this chapter an attempt is made to take a look at those work study techniques which are most valuable in the areas of handling and layout, and to describe their uses for extracting information.

Work study has two basic and complementary divisions – method study and work measurement. The first of these is used to define the methods by which a process, routine or human activity is carried out, and the second to determine how long that activity requires. Both aspects are essential as we shall see, and the definition of the job method must obviously always precede the measurement of the time required.

Method study can only be carried out from direct observation of the activity being investigated. 'What the soldier said is not evidence',

[1] See R. Curry, *Work Study* (Pitman, 1960) and A. Fields, *Method Study* (Cassell, 1969).

as the legal tag goes, and asking people about an activity is liable to produce as many different answers as persons questioned. The steps of an investigation are:

1. Select the area of the investigation.
2. Record all the available relevant information.
3. Examine this information for validity and purpose.
4. Use the results of this examination to prepare a 'best method'.
5. Develop this method, experimenting where possible to test validity.
6. Install the method in the working situation.
7. Provide means for maintaining the new method.

Work measurement can only be brought into use at step 5 above, and then takes the following pattern:

1. Define the job method activity to be measured.
2. Decide the appropriate means of measurement.
3. Carry out the agreed method of measurement.
4. Establish a standard time for the activity.

So first the method has to be decided, and then a time agreed for its operation. These two aspects are essential for planning and forecasting accurately in terms of persons or equipment required, calculating amounts of material to be moved in unit time, and areas to be occupied.

The various steps of the investigation will be discussed in detail in later chapters, and we shall now look briefly at those method study recording techniques most frequently used in materials handling and layout.

FLOW PROCESS CHARTING

This method of recording is essentially **sequential** in character, and while it can also give limited spatial and relational information, these aspects are secondary to its main purpose, which is to set down on paper the series of related events which make up an activity, so that they can be seen and examined for purpose and validity.

There are five basic symbols, each of which stands for a class of activity:

○ Operation, activity, process.
□ Inspection, examination, check.
⇐ Transportation or movement of any kind.
D Delay which does not further the activity.
▽ Storage, bulk supply, stock.

Using these five symbols, with an appropriate legend alongside, makes it possible to break down any activity into its constituent parts or **elements.**

There are several **types** of flow process chart (FPC) which are used for particular aspects of recording:

Material charts, where the events occurring to a particular material are being followed.
Man charts, where the activities of persons are being examined.
Machine charts, where the sequence of operations of a machine, e.g. a fork-lift truck, are being followed.
Outline charts, using only ○ and □ symbols, often used to give a quick outline of a whole series of processes.

There are internationally agreed conventions for the layout of FPCs, the relationship and numbering of symbols and such matters as repetition of any event, change of state of item charted, etc.

Process charts are normally the first tool to be used in an investigation, to gain knowledge of the process or series of events being studied. Observations are **always** carried out, and supporting questions asked, at the actual point of the activity, and not indirectly by asking intermediaries who claim to have a full knowledge of the situation, but who will always, and often unwittingly, introduce errors and irrelevances.

Process charts, as will be seen, are ideal for getting an overall picture of a series of events or movements, and looking at the relationships of each part to the whole. Some instances of their uses follow:

1. *Processes.* If we are familiar with a process, either a single machine or operator, or even a large group, there is a tendency to think it requires no further consideration, and that there is no need to chart the activities. Nothing could be further from the truth. Actually following a product or component through a process will always reveal some aspect of it previously unknown

to the observer, and it is in these kind of differences from a previously thought-of standard that improvements frequently arise. (For example, at a very simple level, try making a cup of instant coffee, after having first written down what is required, and then charting the actual actions and materials needed.)

2. *Work patterns*. If, using a man-type chart, we record the actions of an individual worker carrying out a known task, we may well find far more 'transports' and 'delays' in his actions than was thought possible. Often these are due to poor handling methods, i.e. poor positional placement of feedstock, etc.
3. *Equipment*. Detailed observation of the actions of a fork-lift truck and driver carrying out a normal activity, e.g. vehicle unloading, will often reveal inconsistencies and lack of a systematic approach to the job.
4. *Material*. Flows of material and products through stores, processes or distribution methods.

Preparation of any form of chart is only a means to an end. One must not fall into the trap of making such a good job of the chart that it becomes an end in itself. All forms of recording are means of obtaining information in readily available and repeatable form, and so long as the chart contains all the information obtained, is clearly and sufficiently well drawn and close enough to the standard conventions to be understood by other people, this is as much as required. It is the use to which the chart is put that makes it valuable, and we shall now look briefly at the way in which this examination should be approached.

There follows a small FPC material (Fig. 2.1) and man type (Fig. 2.2), together with an outline chart (Fig. 2.3), showing the preparation of a cup of instant coffee, and we shall use this example to see how the use of the questioning technique should be applied.

These examples show clearly the differences of approach for the several types of chart: the complexity of the materials chart as compared to the straight-line flow of the man type, or the simplicity of the outline chart. But each of these exposes different aspects of the activity: in the case of the material chart, the large number of different objects or materials which are used to achieve the end-result; in the case of the man chart, the wide range of different activities, particularly the large number of 'transports', and the astonishing total distance covered for so simple a result. But note that although the distances and times have been added to the man chart, it is of little value in recognising the physical layout of the area in which the coffee is being made. So although we have found out quite a lot about the process, we have learnt very little about the existing spatial relationships in the working area.

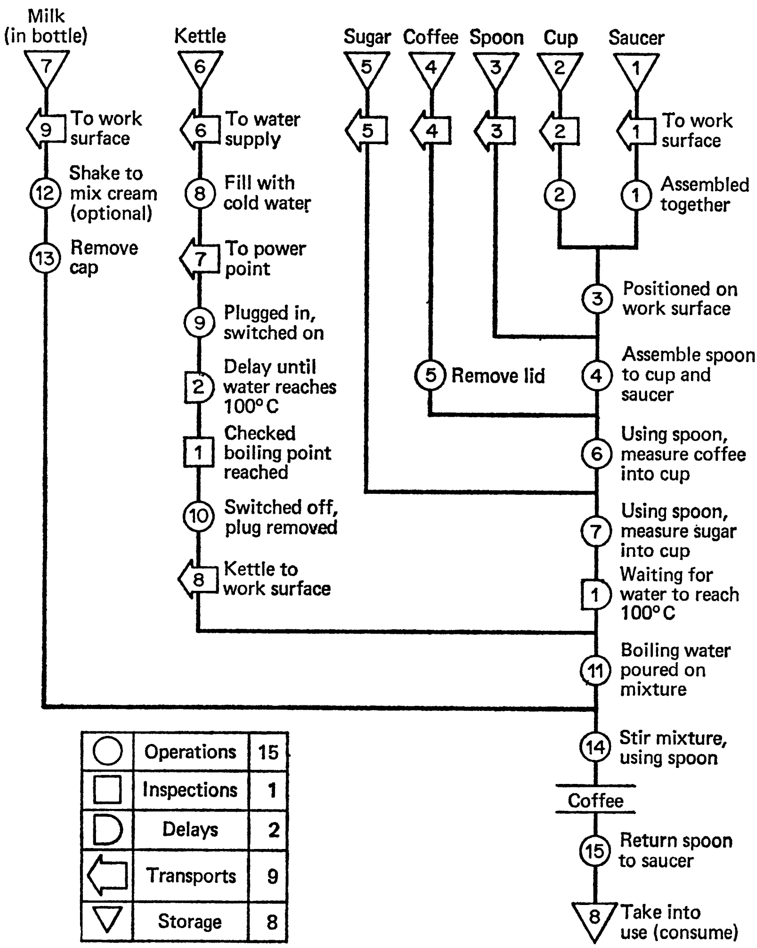


Fig. 2.1. Material-type flow process chart

○	Operations	18
□	Inspections	1
D	Delays	1
⇦	Transports	11
▽	Storage	–

Time (cumulative)	Approx. distance (feet)		
	12	⇦ 1	Walk to kettle at work surface
		○ 1	P/u kettle and remove lid
	6	⇦ 2	Move to tap with kettle
½ min.		○ 2	Fill kettle from cold water tap
	6	⇦ 3	Take kettle to power point
		○ 3	Plug in and switch on
	8	⇦ 4	Walk to crockery store
		○ 4	P/u cup and saucer and assemble together
	8	⇦ 5	Move to work surface
		○ 5	Position cup and saucer on work surface
	4	⇦ 6	Move to cutlery drawer
		○ 6	Select and remove spoon
	4	⇦ 7	Return to work surface
		○ 7	Assemble spoon to cup and saucer
	10	⇦ 8	To food store
		○ 8	Select and p/u instant coffee and sugar containers
	10	⇦ 9	Return to work surface
		○ 9	Position sugar and coffee beside cup, remove coffee jar lid
		○ 10	Using spoon, measure required quantity of coffee and sugar into cup; replace spoon
	5	⇦ 10	Move to refrigerator
		○ 11	Open fridge and remove milk bottle
	5	⇦ 11	Return to work surface
2 mins.		○ 12	Position milk bottle and remove cap
		D 1	Wait for water to reach boiling point
3½ mins.		□ 1	Check water boiling (steam emitted from kettle)
		○ 13	Switch off power supply to kettle and unplug
		○ 14	P/u kettle, pour boiling water on mixture in cup and place kettle aside
		○ 15	P/u spoon and stir mixture, return to saucer
		○ 16	P/u milk bottle and pour required quantity into coffee in cup
		○ 17	P/u spoon and stir till mixed, aside spoon to saucer
4½ mins.		○ 18	Drink coffee
Totals 4½ mins.	78 feet		

Fig. 2.2. Man-type flow process chart

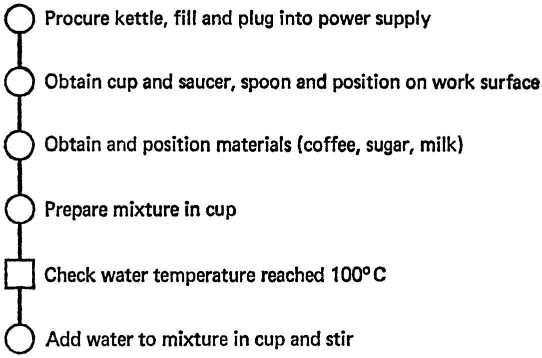


Fig. 2.3. Outline flow process chart

CRITICAL EXAMINATION

Now that we have a record of the existing situation in sufficient detail to be able to understand and communicate all aspects of it to a third party, we must also be able to question the use of the existing method to achieve the required end. We know, for example, that all the activity recorded above did was to provide a warm drink which we call coffee, and that the method used is simply one taken out of a wide variety of possible other methods. The objective is to prepare a cup of coffee, and the limitations are not the method of preparation as such, but the acceptance by the consumer that the result has been **achieved**, and is satisfactory to him or her. This is what is meant by recognition of the **purpose** of any activity: what is being **done** is the method at present in use. So that as long as we can produce a drink which is acceptable to the consumer, the method is open to question. Thus many of the activities in the charts above are quite irrelevant to the **purpose**, although some are necessary to achieve the desired result, which is the production of a drink of coffee. If we start with the premise that we are preparing this drink from a dehydrated powder (and this in its turn could lead to further questions), then to achieve the end-result we must add water of the required temperature, plus other ingredients which make the mixture palatable.

We are now in a position to look at the charts in a much more objective way. Our reasoning has led us to see that the crucial point in the chart is the addition of the heated water to the mixture of ingredients which will produce the desired result: most of the other activities are simply means by which this is accomplished, **in the present situation.** Thus we can postulate that, in order to produce a drink of instant coffee, all that is necessary is to bring the various ingredients together in a suitable container, and add a measured quantity of water at the required temperature. The methods by which this can be achieved are now open to question.

So the first question we must ask in examination of data is 'What is being achieved?' and the second must be 'Is it necessary?', since if no one is going to drink the coffee, we are all wasting our time. If necessity is proved, we can then go on to ask a series of questions which will further expose the workings of the present method. Is the present method the only way in which the result can be achieved? Is it being done at the right point in the sequence of events which are known to us? Where should it be done physically? Is the most suitable person doing it?

We can now see the importance of asking the question 'What is being achieved?' first, followed by 'Is it necessary?' If we accept without question that the purpose is necessary, we are only at liberty to change the method, and we could reach the result of finding a rather better method of doing something which, on further investigation, was found to be unnecessary.

This kind of thinking is the basis of the examination process: a constant probing to establish the necessity, and a consideration of the minimum effort needed to achieve the objective. When it has been established that the item under consideration is necessary to the furtherance of the process, then we are at liberty to design a new method which will achieve the required end at less effort, cost or both. And in considering alternative solutions our main criterion in the commercial world is that of cost. So any solution to the problem which achieves the same result at less cost is worthy of examination; this examination must be no less critical than that which was applied to the original problem.

If we continue to pursue the present example by looking at the man chart, we see that it takes 4·5 minutes and 78 ft of movement to prepare a cup of coffee in the situation studied. If we have to serve 200 people in less than 20 minutes we shall clearly have to look more closely at this method, which may be all right for an individual, but useless for large numbers. Why all that movement, for example? So our first attempt might be to place everything within reach of the operative, which would certainly reduce the effort involved. On the other hand, if it takes the kettle 3·5 minutes to reach the required temperature, the gain will simply be less effort and more waiting for the operator. If this is an activity for which we have to pay wages, then clearly we shall not make any financial savings by simply changing the layout. So perhaps we should consider speeding up the heating process at the same time as changing the layout, in order to **save time** (and thus money) over the whole process.

We have already established that all we have to do is to bring the ingredients together at the same point in place and time, in a suitable container, and add water of the correct temperature. It is not a very big jump from this position to considering whether such a process could be mechanised, since it appears to require little actual skill – and the idea of a coffee dispensing machine is almost upon us. But note: if the activity is occasional – as it would be in the home – the question of investment cost would automatically make us consider whether it was 'worth while' mechanising the process.

So the idea of isolating the activity from its context is not a good one: solutions to problems must be looked at in the light of the circumstances in which the activity is to be carried out, and the final criterion, as ever, is one of cost.

The major difficulty which confronts most people in attempting to use their critical faculties in this way on any situation with which they are familiar is the inhibiting effect of experience, background and education. To try and look at a situation with an unbiased mind and eye is exceedingly difficult. The first reaction of any normal person when any familiar method is questioned is to think – or say – 'But we've always done it like that, what can be wrong with it?', whereas the trained investigator says 'Why **should** it be done like that, and in no other way?' Once the enormous step of questioning the rightness of an existing situation has been taken, the way is cleared for further questioning. But note that, however thorough the questioning or extensive the analysis, all we can expose is the basic requirement; the questioning technique itself will not lead us inevitably to a solution of a problem. For that, the knowledge gained must be combined with the knowledge of the requirement for the future, and to match one with the other demands a kind of 'creative jump'. That all knowledge is gained by pure deduction is a fallacy; at some point in the chain of events what we might in crude terms call an inspired guess takes place, and we are launched on the road to a new solution of the problem. In scientific terms we would call this creative jump the formulation of a hypothesis: it is in testing this hypothesis against the experimental evidence that advances are made in knowledge. And so we see that the industrial investigation is exactly analogous to the scientific, and therefore may fail if insufficient examination in detail of the evidence is made, or inadequate experimentation with new methods.[1]

FLOW AND STRING DIAGRAMS

As we have seen, process charting is sequential in character, and spatial information, though it can be added in terms of distance moved or covered, is not an essential part of the technique. Most problems of layout and handling are particularly concerned with spatial relationships, and their representation in some form of recording is essential.

A **flow diagram** consists of a plan or formalised drawing of the area under consideration, with the patterns of movement or flows depicted as drawn lines. Such a diagram can be used to show the path of materials, persons or equipment through the area concerned, different types of material, etc., being shown either by different colours or different line patterns (i.e. dots, pecked lines, etc.). As a primary investigating tool, to get an overall picture of existing practice, a flow diagram is ideal: often the usually confused paths exposed are sufficient to encourage the co-operation of those working the area. They do not have to be to exact scale, as they are representational rather than accurately descriptive, but they must show the correct relationship of the different points or areas. The drawn lines may incorporate process chart symbols, particularly if such a chart already exists, when the flow diagram can be used in support. Fig. 2.4 shows a flow diagram of the same situation illustrated in the preceding FPCs.

String diagrams are similar to flow diagrams, but the information inserted and required is more definitive. String diagrams are always prepared on an accurate drawing of the area concerned, on a scale which is sufficient to display the total requirement, usually $\frac{1}{4}$ in. or $\frac{1}{8}$ in. to 1 ft (or 5 or 10 mm = 1 m). Thin string or thread is used to depict the path of movement of material, persons or equipment in a similar manner as for a flow diagram. In the case of the string

[1] For further reading on critical examination, particularly the mechanics of the questioning process, see Curry, *Work Study*, chap. 6.

diagram, the **actual** path is plotted on the drawing, using pins as anchors and turn points for the string, and taking care not to show any short-cuts which could not be taken in the real situation. Flow diagrams are usually constructed from the knowledge of material flows; string diagrams are strictly accurate, and the information used to construct them must be collected at source, either as a form of

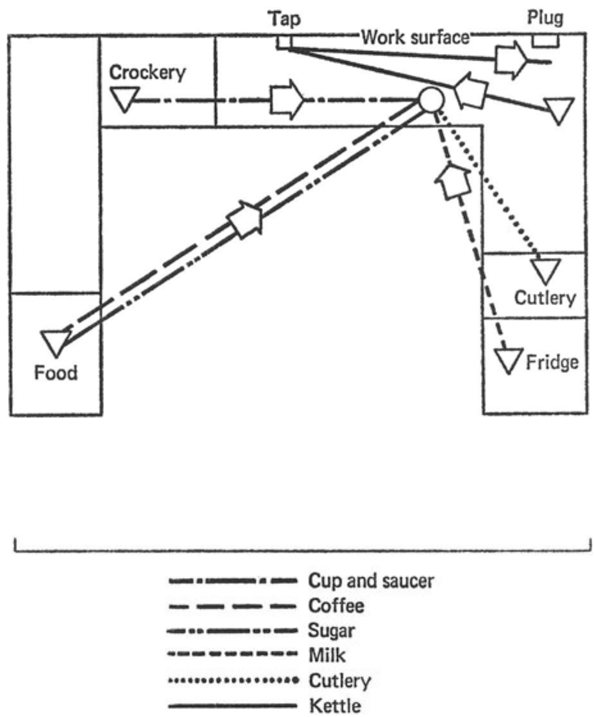


Fig. 2.4. Flow diagram

time recording with description, or as a longhand narrative. The diagram can either represent flows or movements of specific items, or can show total movement over a period of time, by winding additional thread every time a path is taken during the period covered. Thus the result will show not only flows, but frequencies, distances (by measuring the string), volumes moved, or both.

Though sometimes lightly regarded because of its apparent simplicity, a string diagram is an excellent tool for getting to grips with a complex layout. It has the great merit that when the proposed solution is being developed, a similar diagram using the same pattern of movement and frequencies can be constructed, and the original and proposed layouts or methods compared, giving an immediate visual comparison. Different colours of thread are used for different flows, materials or both (see Fig. 2.5).

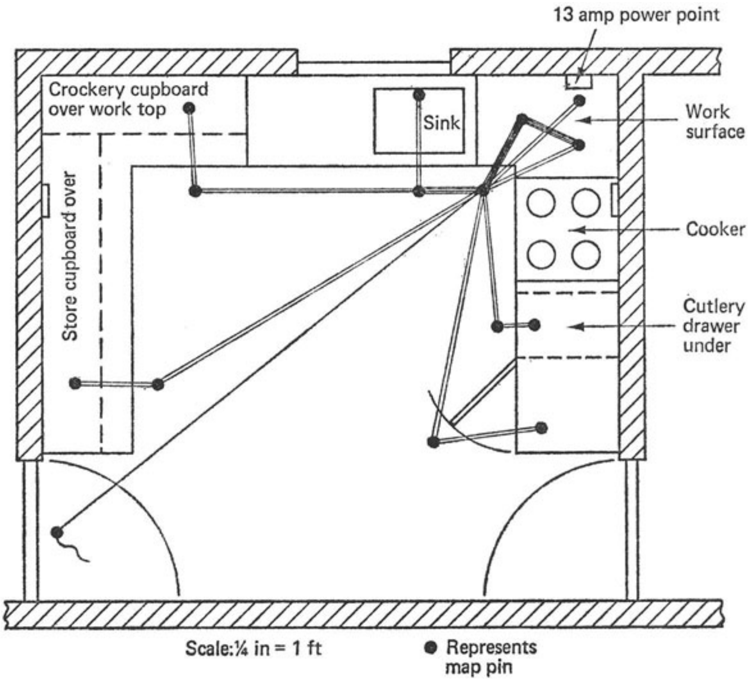


Fig. 2.5. String diagram

The only limitation of both these techniques is the distinguishing of complex patterns involving many flows. In such cases, flow diagrams can be prepared on transparent material and added as overlays to each other, or several string diagrams of the same area showing different functions can be shown adjacent to each other.

PHOTOGRAPHIC TECHNIQUES

Most investigations in the handling and layout field are concerned with matters which are widely spread in both time and area, and many of the work study uses of photography are not applicable. It is not generally realised how valuable an ordinary photograph of a working area can be: not only can it be referred to for direct information, it can serve as a 'before' and 'after' record of the investigation. One particular technique which is of extreme value in some cases is time-lapse photography, sometimes known as memo-motion. This consists of using a cine-camera with an attachment which will operate the single-shot mechanism at fixed intervals, thus taking a shot of the working area and all the activity therein. If the camera is sited to cover, say, the dispatch bay of a warehouse, with a shot every eight seconds, the whole day's work can be recorded on a single reel of film which, projected at either half normal speed to expose the general activity, or studied frame by frame for detail, can save hours of time-wasting human recording (and with complete accuracy as well). 16 mm cameras for this purpose, if not owned by the investigating firm, can readily be hired through most good photographic dealers. It is normally necessary to use 16 mm as very fast film can be readily obtained, thus avoiding the necessity for additional lighting of the subject. Although time-lapse can be used with 8 mm cameras, until recently it has only been possible to purchase relatively slow colour film which is totally unsatisfactory for indoor work without considerable additional lighting.

The amount of time covered by a standard 100-ft roll of 16-mm film can readily be calculated from the knowledge that at 18 frames per second (normal 'silent' film speed), the total filming time available is 4 minutes. A camera set up in this way can be used to cover dispatch or unloading bays, production lines, areas of major activity, marshaling areas and any other situation where a long period of observation is necessary to cover the investigation. Two rules which should never be departed from are: (1) avoid using supplementary lighting, and (2) never use a camera in this way without making quite certain that all the persons who are likely to appear in the record are fully aware of both the method of use and the purpose behind the recording. After a few minutes' consciousness of the fact that there is a camera operating, the work pattern will settle into its normal routine, and a true record of the situation covered will be obtained. Choose a position for the camera where it is out of the way of casual meddlers, and has an unobstructed view of the area covered. And once the reliability of the mechanism has been established, do not keep going back to 'have a look how it's going'. If you feel there might be a doubt about the validity of a particular recording, leave the camera in position for a day or two until everyone has become familiar with it, before taking the shots. And, if possible, show the film when processed to those who were involved; the use of these techniques as 'effects' in television will have made most people familiar with the results of projection at a higher speed.

ACTIVITY SAMPLING

This is a form of recording which can be used in many situations where the object is to analyse the proportions of different kinds of activity, i.e. how much work, handling, walking or waiting occurs in a group of people or machines. It is a statistical sampling technique, which has been developed in such a way that a single person may record the activity patterns of many separate events with a chosen degree of accuracy. The details of the method will be known to all work study practitioners.[1] A detailed description of the method is not given here, as an understanding of the statistical basis of the technique is necessary to achieve confidence in the results.

Activity sampling can be used in similar situations to those described in the use of memo-motion photography above, although the information gained will be limited to the states of activity overall, and no indication as to the positional movement can be shown. Suppose, for example, that a study had been made to determine the amount of fork-truck activity in a given area, the results would appear as follows:

Trucks operating (stacking/unstacking)	11%	(of total time studied)
Trucks operating (moving, loaded)	5%	
Trucks operating (moving, unloaded)	3%	
Trucks waiting (driver aboard)	3%	
Trucks waiting (without driver)	15%	

[1] An excellent description of the technique appears in Fields, *Method Study*, chap. 13.

(If the trucks are not permanently in the area studied, the total percentage will not necessarily add up to 100.)

This is a powerful technique for gaining a rapid overall picture of different kinds of activity in the early stages of an investigation, is relatively cheap to carry out in terms of labour and, provided the right levels of confidence and activity categories are chosen, can give a very clear result.

OTHER METHOD STUDY RECORDING TECHNIQUES

There are many other method study techniques which will find their place in particular areas of an investigation, but those referred to above are most likely to be of use in the handling and layout field. Such tools as multiple activity charting and man–machine charts are only likely to be needed where a teamwork activity is being investigated, particularly one with a repeating work-cycle. This kind of activity is rare in the handling situation, although there may be need in such instances as packing lines or pallet loading. However, this kind of work is usually regarded as being amenable to the ordinary work methods investigation, and would not normally be treated as part of a handling or layout study.

On the overall planning of a major move, the use of critical path and arrow diagrams can be very helpful. By means of these techniques it is possible to plan the correct sequence of events in time and resources which can result in a considerable saving in time and money at the implementation stage.[1]

WORK MEASUREMENT

Once the method of working has been agreed and installed, it is essential that steps be taken to measure the length of time covered by the activity. Without this information, both handling and layout cannot be planned with any degree of certainty. It is necessary to know as exactly as possible how long a particular process takes in time, as well as how big an area it occupies; for on this information depends the planned production quantity per hour or week, as well as the number of personnel required for a given level of output.

[1] See Fields, *Method Study*, chap. 10.

There are three basic approaches to the problem of the measurement of work:

1. Time study, in all its derivatives and developments.
2. Predetermined times, and the various uses and developments from data.
3. Combinations of these two, in the form of standard data, synthetic time standards and related systems.

Time Study

This is the oldest and best known (and frequently most disliked) method, carried out by using a properly trained human observer who records all details of the work being done, and times each part of the operation with the aid of a stop-watch, noting the information on a recording sheet which is later analysed to provide the data for the 'standard time'. Contrary to common belief, a long time is required to train someone to carry out time study, and it is a most exacting task to perform. It is probably the most accurate method of measuring work, since it is always done from life, but can be open to abuse by falsification both on the part of the worker and the study-man. This latter fact is the reason for the technique being brought into disrepute, although the proportion of cases in which abuse occurs is minute in regard to the tremendous amount of time study carried out in industry.

When properly carried out, the study-man first watches the work in progress, and breaks the various actions down into portions which can be recognised as separate activity patterns. These are normally not less than 5 seconds, or longer than 30, and are known as **elements**, although in some non-repetitive work the elemental times may be longer. Each element is then separately timed and a **rating factor** applied which relates to the speed and effort involved in carrying out the task. This enables work being carried out at different speeds to be calculated to a common base known as **standard time**, which is defined in the British Standard 3138 as being 'the time for a qualified worker to carry out a specified job at a defined level of performance'.

There is usually very little difficulty about the use of time study so long as the times produced are used for planning and control. It is when the times are used for the payment of cash incentives based on time study that difficulties arise, since every aspect of the definition given above can be used to question the validity of the time values. Hence the need for completely full and accurate descriptions of the work being studied, and scrupulous care and accuracy being taken to arrive at the time value.

Time study is expensive to carry out since it requires the presence of a full-time observer of high skill over the whole period of the job, and possibly through many repetitions of the job in the interests of accuracy. (The number of observations required can be quite simply calculated from the variability of the job elements, using standard statistical procedures.) It follows, therefore, that it is best employed on repetitive jobs where the data can be used over a long period of time. However, it will still be necessary from time to time to take a lengthy time study to determine a particular activity, especially if the information is required for planning purposes. Examples in the handling and layout field would be for loading and unloading vehicles, stores handling, order-picking, packing and checking, internal to factory production handling, distribution and delivery routeing. Times needed to calculate machinery and personnel required are usually available in most firms from the time study department: if they do not exist, it will be necessary to carry out a programme of work measurement on these also. No control is possible without measurement.

Predetermined Times

These are elemental times which have been accumulated and validated over long periods of time for very small elements of work, and published in the form of tables. Several of these systems were originally installed on a commercial basis, i.e. Methods-Time Measurement (MTM) and Work Factor (WOFAC), under the control of specialised management consultants. MTM has now been established in its own right, having been accepted internationally as a method of measurement for human work. In both these systems the elements are fractions of a second, and detailed build-up of the movement patterns is required to produce work times for particular jobs. Like time study, observer training is long, and the time taken to determine a time is generally of the same order, although since the data are standardised and usually provided in tabular form, a more objective view is taken of the resulting standards by the critics of work measurement.[1]

None of these systems is of much value for other than human work,

[1] For further reading see D. W. Karger and F. H. Baher, *Engineered Work Measurement* (Industrial Press, New York, 1965).

and where machine time or equipment impinges on the situation, time study is needed as well to build up a total value, although attempts have been made in the past to provide a form of predetermined data for fork-lift trucks. Since this latter kind of data must depend on machine capabilities, it rapidly becomes outdated, as equipment is developed in size, and speed of operation.

Combined Systems and Synthetics

These are, as the names imply, methods of producing standard times by making use of both time study and predetermined systems. In doing so, we must look first at the use of synthetic data, which forms a large component of many such systems.

In building up time values by time study, situations frequently arise in which the time for a particular operation appears to vary with one or more parameters of the work. For example, in screwing a nut on to a thread, for a wide variety of sizes, the action of the hand is practically identical, although the size of the thread and its length may cause the run-on time to vary. Similarly, in the sewing trades, the length of a line of stitching (which may be only one 'element' in a particular job) may be found to have a direct relationship with the time taken. A graph prepared from a series of such times can then be used for predictive purposes, without the necessity to re-time the work. Of course, the validity of the curves used must be established before taking this step, but many industrial operations lend themselves to this kind of treatment. Taken together with the times for standard elements such as picking up and putting down, a total time can be synthesised in this way.

An example of the use of this kind of data in handling would be the compilation of times obtained by time study for particular motions of a handling vehicle, i.e. stops, starts, turns, lifts, engages, lowers, etc., and building these into tabular form, with perhaps a graph for time/distance of run. Such data can be invaluable when planning a stores function, or loading stores for production or dispatch. Great care must always be taken against wrongful use, i.e. data gathered for a 2,000 kg FLT will not be applicable to one of 4,000 kg lift.

Summing up, before we can use past knowledge of work for future planning, that knowledge must be in definitive terms both as to method and time required. Failure to comply with this stricture will mean that no reliance can be placed on predictions that the new set-up will be an improvement in terms of production or control on its predecessor, and the only improvement may thus be a marginal one due to better external organisation of the work. The requirement to produce a new layout should always be made the opportunity for looking closely at existing work methods, and the closest possible liaison must be maintained with the work study department to see that this is done.

3 | Visualisation Techniques

As we have seen from the preceding chapter, work study uses a number of techniques which enable us to visualise the existing and projected layouts with regard to flows of material and personnel, but much more than this is needed to gain a meaningful picture of a large layout problem. First, we need to see the present situation in detail, so that we may learn why it is failing to give satisfaction, and what the physical limitations are. Next, we must be able to project forward to a new situation, and see what effect a change in layout will have on the future production demands, and what this means in terms of space and equipment.

Just as in the first appreciation of a military problem, where the opposing commanders attempt to get a photographic reconnaissance of the areas in dispute, so the layout problem commences with the same need – to get an accurate representation of the existing position. Unfortunately, we are unable to call for aerial photographs, and even if we were, the cost of getting them would probably multiply the cost of the investigation, so we must settle for something less. And the least that we can settle for is an accurate drawing of both the existing and proposed production areas, to a scale which will enable us to recognise most of the details we need to know about.

SCALE DRAWINGS

The most important fact to remember about drawings is that they are **never** either accurate or complete. No matter who has produced the drawing of a given building or production area, or for what purpose, there will be errors in it. The first thing we have to do is to establish the magnitude of the errors, and find out how much corrective work will be necessary before we can use the drawings as the basis of an investigation.

Most drawings used in the layout and handling fields are required to a scale of $\frac{1}{4}$ in. = 1 ft. This is a convenient scale for general industrial purposes, and enables on-the-ground accuracies of ± 3 in. to be achieved, which is about the best one can expect, without producing drawings which are unwieldy in size. Alternatively, where the plant itself is on a large scale, and minor inaccuracies can be tolerated, it is possible to go to ⅛ in. = 1 ft. Examples of situations where the latter scale might be used are heavy and immovable plant, such as rolling mills, chemical works and refineries, or very large warehouse projects exceeding, say, 60,000 sq. ft, where it is not required to show individual workplaces or machines smaller than a fork-lift truck. Drawings provided are usually dye-line prints, black or dark purple on white or grey, or they may be tracings of an original, on paper or cloth. It is a good idea to have more than one copy, if possible, so that alterations made, either to the drawing's accuracy, or modifications, can later be transferred to a 'clean' copy. A useful addition at this stage is a sheet of transparent material, printed overall with a grid to the scale being used, i.e. ¼ in. squares. This can be obtained from any good drawing office supplier and overlaid on to the drawing thus saving much time in measuring and calculating areas.

The drawing must now be checked for accuracy against the real situation. First look at the building outline, position of walls, windows, doors, steps, inclines, etc., and take actual measurements in sufficient positions to establish the validity of the drawing. It is astonishing how often a fire-wall or extra door can be found to have appeared without entry on any major drawing. Check that such measurements as the width of door apertures and their height are shown, and that any services in the floor which may have to be left clear (drains, manhole covers, pits) are marked in. It is quite likely that there will be no record on the drawing of major electrical fittings, switchgear or bus-bars, nor other services such as compressed air, steam, etc. If the positions of such items are important to the layout, they must be shown. (The extra cost of laying a three-phase 200 amp main over a distance of 100 ft can be quite alarming, if not allowed for.) Try also to secure a section drawing of the area being investigated, to establish maximum and minimum heights from floor to roof, lighting fittings and any obstructions such as pipe runs or heaters. This is particularly important if the area is going to be used for storage, as items such as these will limit the amount of space which can be utilised. If a section cannot be obtained, mark the low headroom items in on the plan, using dotted lines and titling them, together with the height figure clearly marked. In cases where the existing plant or equipment appears on the drawing given, make additional checks to establish that they still represent the present locations; very often a manager or foreman will have had a piece of plant moved a few feet for a well-established reason, but the major drawing will seldom if ever show the alteration.

Never grudge the time spent checking drawings, and never omit it. The additional expense incurred when the errors are revealed at a late stage and corrections have to be made are out of all proportion to the checking cost.

The next stage is to ensure that the existing situation is clearly shown on the drawing. If machinery, etc., does not appear or is incorrectly shown, it will have to be drawn in. The accuracy must be of a high order; errors of a few inches can sometimes make a difficult situation impossible. Who actually prepares the drawing is a matter for agreement within the organisation, although often the responsibility for plant position details can be established either with work study or the plant or production engineering staff.

Finally, check the corrected drawing against the live situation, and discuss its accuracy and use with the departmental manager or managers concerned, so that they may have confidence in it as a true representation of their departments' physical layout.

Preparation of drawings may be carried out in a variety of ways. In a large firm there are usually draughting staff with responsibilities for plant and building drawings; in a smaller one the investigator may well have to prepare the drawings himself. If draughting staff are used, keep a very close liaison throughout the preparation, to ensure that no deviations from the corrected data occur. If you have to prepare the drawings and have a minimum of draughting skill, remember that accuracy is more important than presentation at this stage. Much time will be saved by the use of proper architects' scales rather than trying to make instant conversions from a rule marked in quarter-inches. If the actual execution of the drawing is felt to be beyond the skill of the investigator, there are many excellent tools which can make the job simpler. One of the best of these is in the form of pre-printed adhesive transparent tapes, which are available in a wide range of designs, from thin lines in several colours, to sections of brickwork, shading, etc. Used on tracing paper or cloth over an outline drawing, a very creditable representation can be built up in this way, with little skill beyond the ability to place the tapes accurately (Fig. 3.1). Another method is to use rub-on transfer (i.e. Letraset) material, which again is produced in a variety of styles and patterns. One advantage of such a built-up drawing is that the whole thing can then be put through a dye-line printer, and copies produced as required.

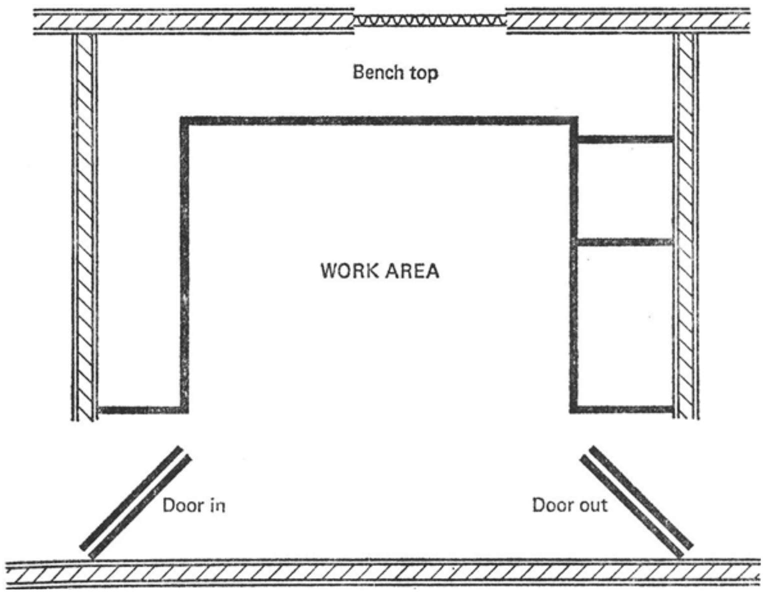


Fig. 3.1. Drawing using tapes and rub-on lettering

PREPARATION OF TEMPLATES

In preparation of a layout, or for experimenting with possible layouts, it is necessary to have some way of representing the items of plant which have to be moved or positioned. This is a field where experimentation is either costly or impossible; you cannot have any trial runs when the cost of movement is £400 plus the loss of five days' production for each machine. We are all familiar with the use of simple templates for experimenting with the position of objects too heavy to move readily: most people have attempted to lay out their kitchen or living room to best advantage in this way. When we apply the same techniques to industrial plant, the need for accuracy both of template and placement becomes paramount.

Never use paper for templates: it curls, is easily damaged and is too light to stay in place experimentally. The first material to consider is light card, about the same thickness as a postcard, and preferably in a range of colours, so that static equipment such as racking or shelving, mobile equipment such as FLTs or tractors, conveyors, etc., and production machinery can be clearly distinguished from each other. The templates must obviously be to the same scale as the drawing, and must be very accurately cut: even the thickness of a pencil line at $\frac{1}{8}$ in. to 1 ft can have a noticeable effect on a layout. Beware of copying machinery from catalogue drawings; often these do not show modifications added to the production machines, or omit the driving motor altogether (since it may not be supplied with the machine). Check measurements may have to be taken of machinery before preparing the templates, particularly if new machinery not shown on the existing drawing is to be introduced. It can be helpful to show on the template the position of any operator, and the connection point for services required. Always use at least two pins or double-sided adhesive tape to secure templates to drawings, or the orientation may go astray. And never leave a layout with templates in position where it can be tampered with: visitors to an office in the absence of the occupant are faced with an almost irresistible urge to modify the layout to their satisfaction. If the investigator later fails to notice this, the consequences can prove expensive, if not disastrous!

The next degree of sophistication to be introduced is to use transparent self-adhesive material as the basis for the templates. This can be obtained both plain and photo-sensitised. The latter will take dye-line prints from a previously prepared tracing, and is a simple way of preparing a large number of similar and accurate templates, which can be stuck in position on either the drawing or a transparent gridded overlay. This method is ideal for the larger layouts which are later to be discussed with production staff: the proposals can be put through the drawing printer and copies handed round. Modifications as a result of such a meeting can then be carried out, and further copies produced, without jeopardising the 'master set'.

Another method of preparing templates for experimental layouts is to use magnetic rubber. This material is used widely for such purposes as refrigerator door seals, and can be obtained in sheets approximately $\frac{1}{16}$ in. thick. To distinguish different categories of equipment, the rubber sheet can be covered with a layer of coloured plastic self-adhesive sheeting used for such purposes as shelf covering, and readily obtainable from most chain stores. This composite material can be cut easily with a sharp knife or a pair of scissors, and will adhere firmly to any ferro-magnetic material. In use, the drawing under discussion is taped to a thin sheet of tinplate or mild steel, and the templates can be applied and moved about as required. This is probably the best and easiest 'working tool' available for layout preparation, but has the disadvantage that copies have to be made by tracing or photography rather than direct printing. Additional uses for this material will be found as experience is gained; the pre-printed adhesive tape referred to above can be applied to the sheet rubber and cut to act as templates for walls and areas; large templates can be made and used for discussion by placing a sheet of steel in place of a blackboard which will have the area under review marked thereon.

None of the methods outlined above for preparing drawings and templates is expensive. This is an important consideration, for no matter how large the reorganisation envisaged, it is extremely difficult in most firms to get authority for expenditure on layout materials at an early stage. The most expensive method is the pre-printed adhesive tape, as it demands an initial outlay for a number of complete rolls of the different tapes required, even if only a few inches are to be used. However, it is a once-for-all cost, as a roll of tape will last for a year or two without deterioration. Rub-off transfer is also fairly expensive for the same reasons, though it is possible to buy this in small quantities. The magnetic rubber method is the cheapest, but involves a certain amount of preparation, and has reproducibility limitations. The most expensive method of all is manual draughting, using skilled labour, since this usually means a complete redraw for every major modification, and should be avoided wherever possible. This latter method can also introduce the greatest number of errors, since the draughtsman is seldom the investigator, and the information has to be passed from person to person.

USE OF MODELS

The use of models at the experimental and development stages of a handling or layout investigation is hardly ever justifiable, either in terms of cost or convenience. All models must of necessity cost more than flat templates, and their use as layout working tools adds very little to the visual appreciation of a situation which is almost always concerned with areas rather than volumes at this stage. There are, of course, exceptions to this generalisation, although they are few and specialised. In the construction of large static plant with highly complex detail, such as refineries or chemical plant, it is often the practice of the architects or engineering consultants to provide a model at the final planning stage. This model is to an exact scale, and is often used on site as a three-dimensional drawing to assist in plant erection. For example, a feature of this kind of construction is that it often contains many thousands of metres of piping of various diameters, borne on steel girder gantries or in channels. Such complexes can only be inadequately shown by drawings, and their overall disposition is difficult to visualise – hence the model. The other situation where a model is often prepared is when a new building is to be provided, particularly one which may have some prestige value as well as practical use. In this case a specialised model-building firm is usually employed under the architect's direction to prepare it, but the scale is generally too small for it to be of any use for detailed layouts.

In the plant layout context the only use of a model is for three-dimensional visualisation. Thus the requirement is not from the planner, and seldom from any of those directly concerned with the implementation of schemes, since most of these people have the ability to read and understand drawings as part of their normal activities. However, there may on occasions be need to make a presentation of layout either to explain the new circumstances to works staff, or for discussion at board level, where models, with their immediate appeal, are likely to make a quicker impact. The necessity must be proved, because even a small model requires a fair amount of time and probably money for proper presentation. The objective must be borne in mind, so that unnecessary time and expense is not incurred if the model is to be used only as a supporting aid for a presentation; more resources can be expended if something more permanent is needed. The following methods are arranged in order of increasing cost.

Wood or Polystyrene Foam

Models made from balsa wood, or cut from polystyrene foam with a hot-wire cutter as used for cutting foam tiles, can be made cheaply and with little effort. Placed on a copy of the drawing, and with plasticheaded map pins stuck in to represent controls, operating positions or supply connections, being about $\frac{3}{4}$ in. to 1 in. high, and showing only the ground plan shape, are usually adequate (Fig. 3.2). If more realism is needed, walls and doors, etc., can be cut from cardboard and taped into position on the drawing.

Obviously, painting and more complex cutting can be indulged in, but this really takes us into the field of the next type.

Wood and Hardboard

Here the plant models are cut from softwood, and perhaps a little more detail shown. They are then mounted on a hardboard or ply base, painted and detailed to represent the building floor. Walls, doors and window apertures can but cut from hardboard, keeping to scale heights, and perhaps using a sheet of perspex to represent the ceiling or next floor.

Models such as this can be used in discussion, and moved and handled without damage. Any semi-skilled man handy with wood-working tools can produce quite a large model of this type in two or three days, at negligible material cost (Fig. 3.3).

Die-cast or Moulded Models

With a basic background constructed as above, it is possible to purchase metal and plastic models of most metal- and wood-working machinery from commercial sources. These are quite detailed, usually ready-painted, and available in $\frac{1}{4}$ in. and $\frac{3}{8}$ in. to 1 ft scales. They are naturally quite expensive, and are unlikely to cost less than £2 per item, and this for quite small models (Fig. 3.4).

Proprietary Model-building Kits

In recent years quite a number of these have come on to the market, and their great appeal is their apparent universality of use. One, similar in design to a child's building set, is composed of discrete blocks in multiples of 5×5 mm, with many special shapes and fitments. Although very attractive, these kits have serious limitations for plant layout planning.

Most of the parts are rectilinear, and it is difficult to make representations of objects or buildings which are not of similar form (Fig. 3.5). Representations of machines, etc., are symbolic rather than realistic, and since the whole plan has to be built up from separate small pieces, it can take much longer to prepare than the wood-and-hardboard home-made types above. Properly prepared, however, in a suitable context, the kits do fulfil a need. They have the additional advantage that once the requirement for the model has ceased to exist, it can be dismantled and the parts used over and over again. There are also special kits for chemical plant, or for demonstrating building techniques, etc.

All these proprietary kits are expensive, and it is often difficult to judge just how much is needed to be bought for a given model.

The golden rule to apply to the use of models is critical examination: 'Do we have to use a model? Is it necessary? Why is it necessary? What alternatives are available or suitable?'

In the case of both drawings and models, as in the preparation of various charting methods, the objective must be accuracy in use, unless presentation is important for a particular purpose. So long as all concerned can understand what is required, and are able to interpret the method used in terms of hardware and production, this is all we require. The more sophisticated a method of presentation, usually the more costly it is, and this is truly a case of 'art for art's sake' being a redundant requirement.

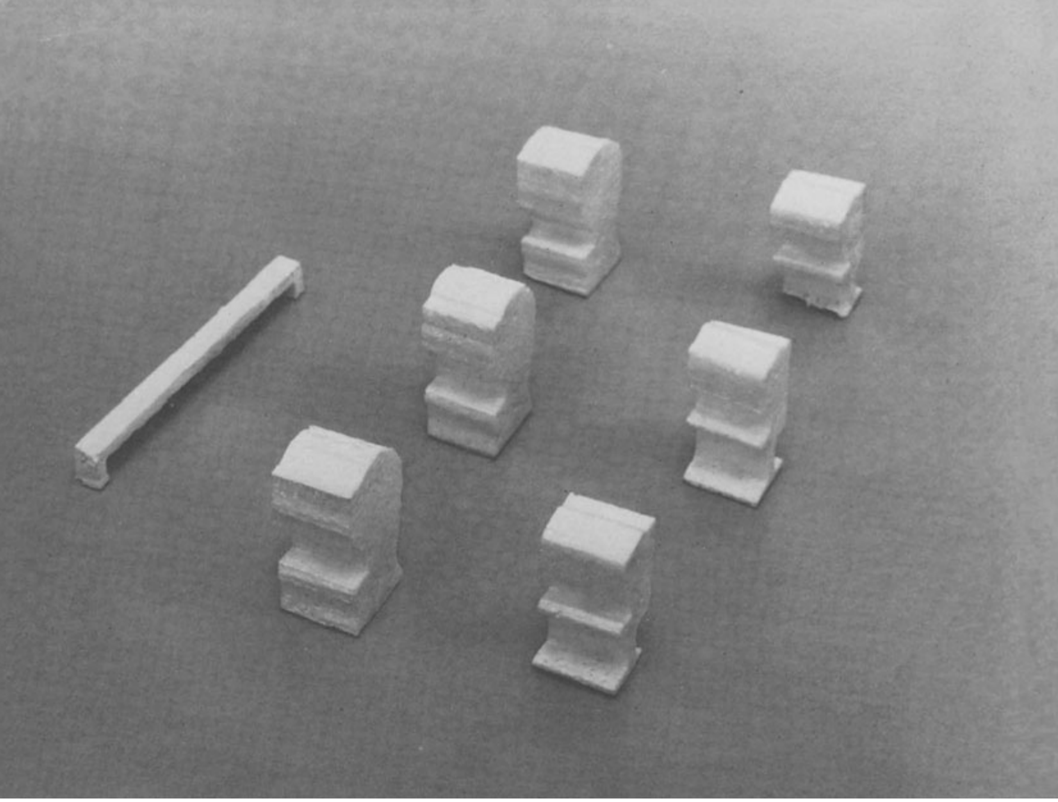
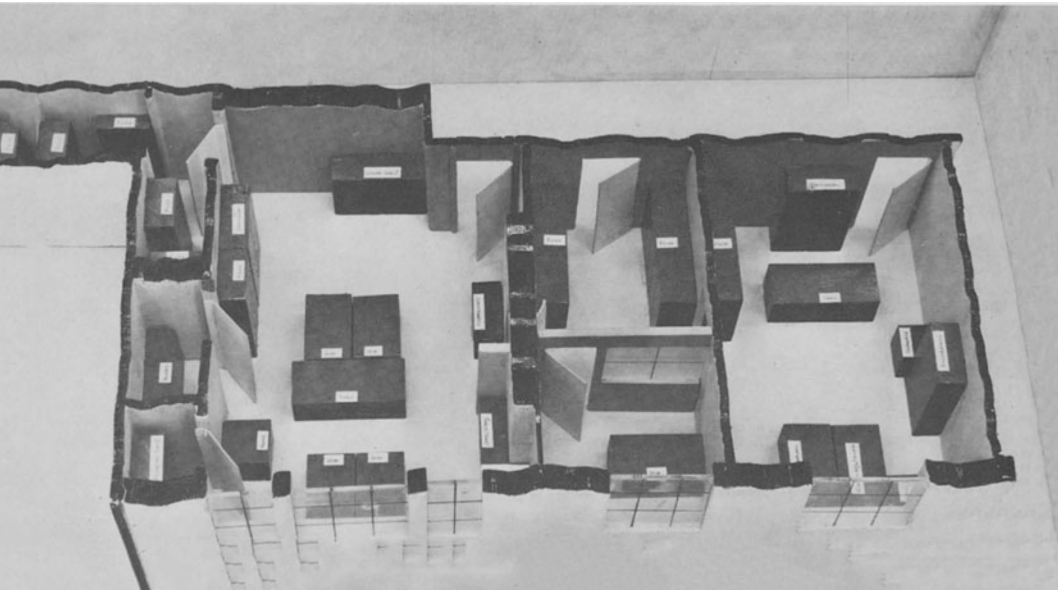


Fig. 3.2 Balsa and foam polystyrene models

Fig. 3.3 Hardboard and wood models



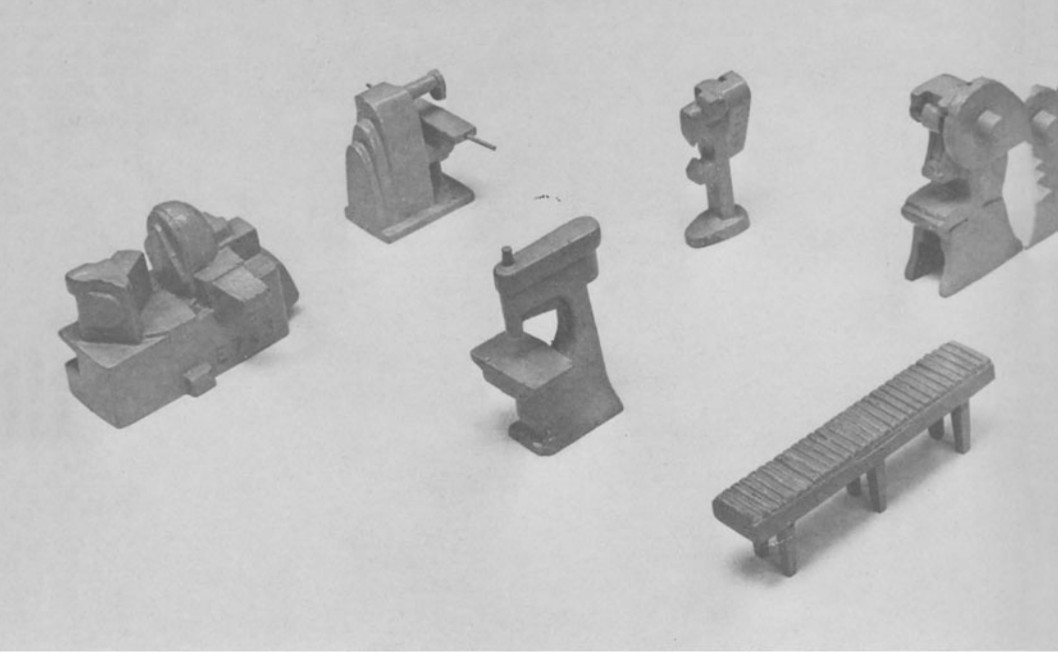
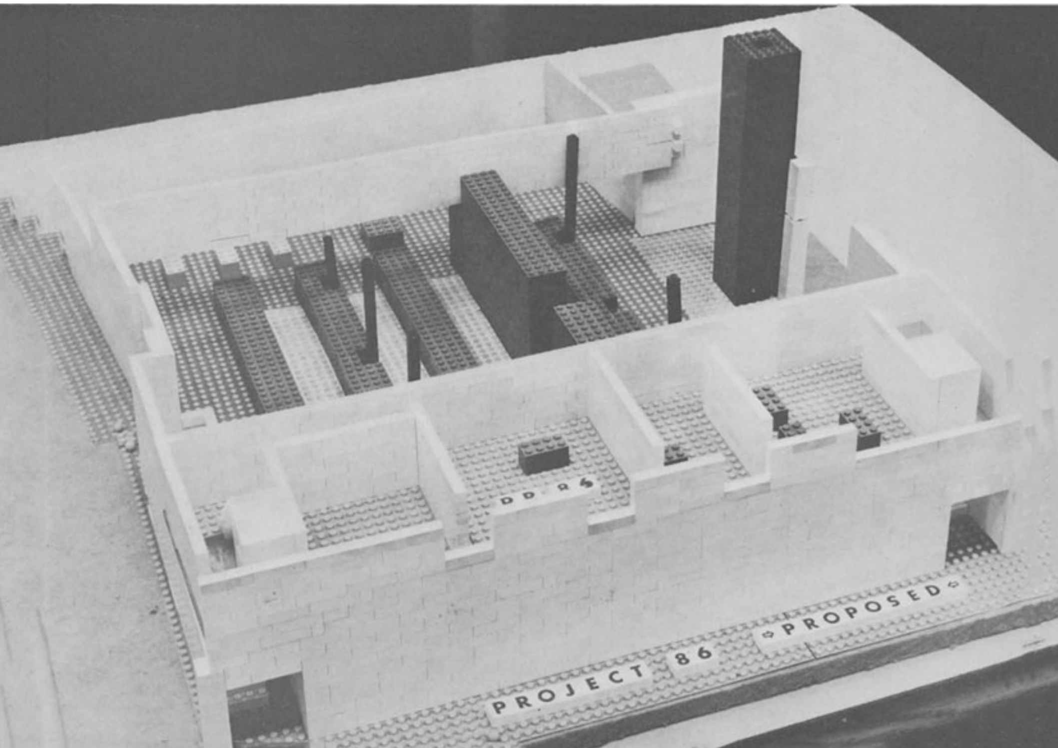


Fig. 3.4 Metal machine models

Fig. 3.5 Proprietary modelling kit model



4 Materials Handling: Analysis of Product

Before we can attempt to decide the method of handling materials and products in a particular case, it is necessary to have a very clear understanding of the manufacturing processes required in that industry, and all the raw materials which are used. It makes no difference whether the investigator is reviewing a production unit or a distribution depot: unless he has a clear understanding of the chain of events that extend from supplier, through his own organisation, through to the customer, he is in no position to make recommendations.

In all commercial enterprises we are purchasing one kind of material, subjecting it to some form of processing and selling it, usually in changed form. In primary manufacturing we may purchase a raw material and sell a sophisticated product; in distribution we may buy in large quantities to sell in smaller ones, but in each and every case the material undergoes a **change in form** as a result. Sometimes these changes may be great, as in the production of tableware from raw clay; in distribution it may be simply a change in pack size. But in every case the material is handled many times between input and output, and our job is to see that this handling is reduced to a minimum. Movement uses energy and costs money; having established that it is necessary to move an item, we must then use the lowest-cost energy to move it. And moving things by human labour incurs the highest cost of all, at least in what we usually describe as 'developed countries'.

THE RAW MATERIALS: GOODS INWARDS

Except for the primary producers, whose raw material consists of ore, sand, clay or similar materials, all industries are purchasers in one way or another of products produced by others. (The supreme example of this is the motor industry: some of the smaller makers could be described as merely assemblers of parts produced elsewhere.)

When goods are ordered from a supplier, very often little attention is given to the form in which the items will be delivered. It is likely that the supplier has a standard pack which he will use, regardless of customer; it is also probable that the buying department of the purchasing firm will have discussed the minimum cost of delivery, without reference to the methods of unloading in use or available on their premises. In other cases particular methods of delivery may have been agreed which were satisfactory, say, five years ago, but now, with changed equipment in the recipient's premises, have become difficult or time-wasting. So the first place to look for economies in handling is the receiving bay. The primary question should be: 'Does this material come to us in the form in which we are best equipped to handle it?' and the next follow-up: 'Are the suppliers aware of our inward handling arrangements, and how far can dispatch from them be made compatible with our receipt?'

Sometimes it is only a question of a phone call: items which are sent loose on a drop-sided lorry could be palletised, with savings in load and unload times. But this must depend on both supplier and customer having compatible handling equipment, i.e. pallets and FLTs, and an agreed method of loading the vehicle. It would be of little advantage, for example, if the supplier loaded a lorry with two-way entry pallets end-on from the rear if the receiving firm either had no loading dock, or were obliged to unload from one side of the vehicle.

As materials travel through a handling chain, they change in form, weight and complexity. A firm manufacturing instruments or alarm clocks may buy raw materials as steel bars or sheets; in the manufacture of plastic articles the raw materials may be powders, liquids or pellets, received in tankers, sacks, drums or boxes. It may be that equipment used for handling in the goods receiving area may not necessarily be the same as, or even compatible with, that used elsewhere. Engineering materials are usually in long lengths (tube, bar, rod), coils (strip) or sheets, and in such quantities that equipment capable of handling tons at a time is required to unload it from the incoming transport and place it in store. The same type of equipment (or it may, in fact, be the same equipment) will be needed to transfer it from store to the first process. But in most cases, after the first process, quite different handling methods can be used. Pursuing our engineering example, once the stock of bars has passed to the cutting-up machine, we have a large quantity of smaller pieces, which may be put in boxes, loaded onto pallets, or even placed on conveyors. So that whilst the ideal in handling is to make all handling compatible with the next process, it is not always possible to use the same type of equipment.

For a given firm a great deal of data is available about the material being received. Quantities, weights, volumes and frequencies of delivery are all known or can be predicted. So, too, is the number of vehicles in a given unit time and the capacity and type of vehicle which can be expected, and the physical circumstances under which they are unloaded: open-air, closed shed, loading dock, level floor. From all this information a picture can be built up of the volumes and tonnages which have to be moved daily, and thus the minimum amount of handling equipment which will be required can be estimated.

IN-PROCESS HANDLING

We have seen above that material to be handled usually changes its form after the first process; it may change many times in the course of manufacture. At each of these changes of form it may be necessary to look at the handling system employed, and decide whether it is compatible with the material. If the handling system is required to be different, it can usually be arranged to change over at one of these 'change of form' points without incurring a double-handling penalty. And it is these form and characteristic changes that we must first look for. Starting from the first process, list the characteristics of the product at each stage of manufacture or movement, in terms of 'handlability', and compare each with the previous and next, to see whether any change in handling is **possible** and if such a change is **necessary**. The aim, as stated before, is to get the largest amount moved at lowest cost.

The most obvious factors controlling handling of any article are those of size, weight and volume, or, if you prefer, the bulk–density ratio. So the dimensions and weights must be known for a given quantity of the product at all the points. In addition we must also list special characteristics at each stage, such as fragility, liability to damage, orientation (it may be necessary to 'nest' the articles, or line them up alongside each other, perhaps because of their shape). Tendencies to roll about, jam together or suffer crushing damage if at the bottom of a heap must all be looked at. It is possible to carry out checks of this sort against a 'check list', but the major difficulty is that either the check list has to be enormous to be comprehensive, or, having filled in all the checks, there may well be something which has been overlooked because it didn't appear on the list.

'Mark-off', where an article picks up marks or paint from another, damage to polished surfaces, and general mechanical damage to finished surfaces is another area for examination. Next look at the **effects** of handling the article in various ways, i.e. shocks due to accidental dropping of a container, etc.; sideways movements on acceleration and deceleration, imposition of weight on the articles when stacked, and the limits, where known. For example, food or other material in cans packed in cartons can be stacked to a considerable height: the can will take the load – **but the carton may not**; corrugated cartons can suffer in these circumstances by collapse of the corrugations in the double-thickness top and bottom. If this happens irregularly, and the stack is not properly bonded together, an accident is inevitable.

Next, look to the quantities which **are to be moved** at each stage of the process or chain of events. Not the quantities which are moved **at the present**, as these may be limited either by the existing methods of handling, or simply because it is a historical method ('It's always been done like that'). It will be necessary to examine the quantities of materials being moved just as closely as the methods for moving them, applying critical examination to the situation, and pursuing the answer as far back into the organisation as necessary. For example, work may move between two processes in quantities which can be carried by a man or woman, although many of these loads per hour may have to be moved to keep the second process fully loaded. On the other hand, the batch sizes may be so small that it has never occurred to anyone to move them in larger quantities. Or again, the production control department has little idea of the weights or volumes required for a period of work, and may be running on an unsuitable 'batch size'. All these aspects will have to be checked and investigated, until we are sure that the quantities which are required to be moved at any one time are those which it is **necessary** to move. The physical size and weight of these quantities will now give us the requirements for moving them, i.e. they can be carried, they will make good pallet loads, or the speed of movement and frequency would be best suited to a conveyor. Note that we are not actually selecting equipment at this stage, but getting to know

how the material can be moved. There may at this stage be a number of alternative means by which this can be done, but the choice of which piece of equipment to be used in a particular situation cannot be made here; other factors besides the material to be moved will bear on this, as will be seen in the following chapter.

The value of the material-type flow process chart will be apparent when making this analysis. If it is followed through logically, and notes made at each stage, on separate sheets from the chart, but with a reference to the symbol numbers under consideration, the picture will be much easier to comprehend. It is not always wise to formalise the method for collecting information, as particular circumstances can vary so widely, but the analysis falls into three sections: the reason for the movement, and the distance involved, with processes either side of the move; the characteristics of the product at that point; and finally, the possible methods of movement. An example of this sort of analysis is given in Fig. 4.1. But beware of producing pre-printed forms with little squares on: they are never big enough, and you will only ever need a few sheets at a time.

Pursue this analysis right through the organisation, from goods arrival to goods departure, if you are doing an overall investigation. If you are only looking at part of the chain, go backwards and forwards far enough to link up with existing methods – you may not be able to make too much variation in these circumstances. Remember, too, that handling doesn't stop at your loading bay; the customer has the same problems. These should be explored and taken into account in the analysis on the delivery stage. It requires a lot of hard work and application to get all this information together, but there seems no other way to get satisfactory results.

CO-OPERATION AND LIAISON

At this point a word of warning is necessary. It will be apparent from the foregoing that a vast amount of information about the product has to be extracted and collated in order to arrive at what one might call the 'handling characteristics' of material passing through the chain of events from delivery to dispatch. While this information is best collected by someone in the investigating department, it is foolish to think that it can be done as a personal activity. It is extremely unlikely, one might almost say impossible, for the investigator to be in full possession of all the facts about the material

Reference: FPC Material Type — Job: Cut-off Steel Bar — Date:

Movement (reason, distance, process)	*Product characteristics* (dimensions, weight, normal move quantity, special attributes of material, etc.)	*Possible movement methods*
Steel bar stock from raw material stores to cut-of m/c. (Cut to 15 cm lengths.) Distance – approx. 30 m. Material normally placed on floor beside operator who feeds into m/c as required.	25 mm of steel bar in 6 m $\mp$10 cm lengths (approx. weight per length, 24 kg). Since 1 length required 8 mins. to cut, at least 1 hr's. work required at workplace = 8 lengths.	1. Manual handling by operator (not more than 2 lengths per move) (present method). 2. Trolley – manually pushed up to 20 lengths per move (but unload time required). 3. FLT or sideloader up to 50 lengths per move. (But provision must now be made to store working stock.) 4. Specially designed mobile rack to hold ½ to 1 day's work load in RMS, push or tow to cut-off m/c. (At least 2 required if delay to be avoided.) 5. O/H crane. But this will mean moving cut-off m/c at least 20 m. (Crane already in use for other purposes.)

Fig. 4.1. Movement analysis sheet

under review, although many people delude themselves that they are so equipped. No matter how familiar you are with a product or its components, there will always be some aspects of it which will be revealed for the first time in the course of an investigation. Therefore, on each occasion when a section of the analysis is compiled, the investigator must not only familiarise himself with the particular situation, but must discuss the product characteristics at each point with the operators, chargehands, foremen and supervisors concerned. For example, a foreman may be well aware that a particular component travels between processes at a given rate, and that the operator always positions the box in a particular place which the foreman has accepted. It may well be that the operator places the box at a particular orientation in order to facilitate loading or unloading parts which have to be grasped at a precise point because of a projection or sharp edge. Of course, such matters should have been dealt with by previous investigations into work methods, but it is foolish to assume that this is so without checking. And to a large extent these details do fall within the orbit of the method study, **until you change the handling method.** This action may mean introducing a different size box, a pallet, or even hanging the item from a conveyor, and the problem of the operator getting control of the object will remain, and must be met by any solution to the handling.

This discussion leads to the question 'Where do I stop?' in dealing with handling problems. The answer to this really depends on the organisation of the investigating department. It would be unwise to start analysing handling methods in an organisation where the jobs themselves have not first undergone some form of methods investigation, and the materials handling investigator must (if he is not the same person) work closely with the work study department, where the latter exists. In the larger organisation, where layout and handling is treated as a specialist activity, albeit usually part of the main management services department, then agreement must be reached as to what activities form part of any investigation. A good rule of thumb is that all handling after delivery of the material to the workplace should be dealt with by work methods or production engineering, and the broader-scale inter-process and inter-department movement left to the specialist. But under no circumstances should either party attempt to define separate areas of activity to the extent that each party might say 'That's not my job . . .'. Just as the investigator must work closely with the production staff if the application is to be a success, he must also have a proper method of liaison with any other investigating department, so that a joint approach can be made to a problem which is exposed by either party. This doctrine of continuous co-operation and consultation cannot be too highly stressed; probably more failures in overall handling systems are due to this cause than to any other. In a known case where a large warehouse handling system had been installed by external consultants working with mechanical handling engineers and equipment manufacturers, very little thought was given to co-operation with those who had to operate the system. As a result, when the system went into operation it was very efficient at moving materials, but left a great deal to be desired with regard to information flow and communications between people. In fact, one large piece of mechanism actively discouraged people from making the necessary decisions, as it appeared, quite falsely as it happened, to be self-controlling. The resulting tangle took internal investigators some eight months to unravel, before the concept could be said to be working satisfactorily. Significantly, when the firm decided to enlarge the warehouse at a later date, no outside consultants were employed, and the expansion was merged into the existing system with no difficulty.

BULK HANDLING

In discussing the analysis of material movement, most of the situations referred to in the foregoing have been assumed to be discrete objects, however widely different in character. These types of material do, of course, make up the great majority of handling investigations in manufacturing and distribution, but most of the analytical methods are equally applicable to the handling of bulk materials. In this context, bulk materials will be taken to mean those which are liquids, powders or granular materials of all kinds, and which are normally transported and delivered in tonnage quantities. The solutions to handling problems in this field are nearly always mechanical, because of the weights and volumes involved, and often because of the material's unpleasant characteristics.

Manufacturing and processing in industries dealing with bulk materials are generally concerned with moving the materials through processes at varying flow rates, and subjecting them to widely differing conditions of heat, agitation, compaction, or mixing with other ingredients to form compounds which may or may not be processed in other forms. Compare, for example, blending cattle foods from various mixtures of grain and seeds, to producing biscuits from flour, sugar, syrups, water, etc.

By the very nature of the processes involved, most of the handling problems fall into the hands of the plant designer, whether he is a chemical or mechanical engineer or a specialist in the field. In such cases the materials handling and layout investigator will either have been involved right from the outset, or will not have appeared until long after plant commissioning, when problems have begun to arise. This book is no place to deal with the design of specialised plant, so we shall confine ourselves to those situations where interfaces between the arrival and departure of materials exist.

When bulk materials are delivered, the vehicle is almost always of a specialised type, whether tipper, tanker or pressurised vessel. Such vehicles have a high investment cost, and therefore their turnround in as short a time as possible is vitally important both to the customer and the supplier. Therefore any handling system designed to cope with delivery of bulk materials must have a capacity in excess of any delivery vehicle, and a buffer storage capacity equal to the stock level necessary to keep production satisfied between deliveries.

In making the analysis of product we must take into account many properties which are unlikely to be found in the discrete object situation.

Particularly important is the end-use of the product being received. Take, for example, common salt. This has a number of forms each of which is compatible with its intended use. Used in food manufacture, it is likely to be vacuum-dried, free-flowing, fine-grain material, largely anhydrous, and one requirement will be to keep it, throughout its handling, free from contamination which might affect its use as a food constituent. The same substance used in animal feedstock might have a slightly lower contamination factor, and be probably in coarse granules. Salt which is intended for use on road surfaces in bad weather will have none of these limitations, and may be dealt with in the same way as sand or other fine-grain materials are handled. But in each case the properties of salt as a material will have to be looked at as part of the handling analysis. It tends to absorb water, and in the dampened form can be highly corrosive to the surface of certain metals, notably steel; so in any situation where it is either mixed with water, or can absorb it, a number of metals are precluded as handling or containing adjuncts.

Thus in the analysis of bulk materials we find that their chemical properties are important in deciding the containers or surfaces on which they are to be moved. The next factor might be the substance's abrasive qualities (contrast silica sand with flour), and this will help to determine the type and quality of any container, whether static, i.e. tank or silo, or dynamic – pumps, piping, valves, etc. Another property might be the material's effect on human life; materials such as chlorine, sulphuric acid or pyridine must be contained entirely within the system, as well as requiring special containers.

So we see that while the characteristics of bulk materials which will have to be looked at are different from those of general manufacturing or distribution, the analysis will still tell us within fairly close limits the kind of equipment we shall need for the material. Additionally we shall find out whether it can be an open or closed system, and whether the material will flow naturally under gravity or is required to be impelled by some fluid, usually air or water. This leads us to yet another factor, that of combustion or explosive qualities. Many substances, some of them quite innocuous in their normal state (flour is a good example), become an explosive mixture when mixed with the optimum quantity of air. Containing systems must therefore either prevent that particular condition from arising, or contain some inert gas which inhibits explosion.

Enough has been said to recognise that the handling of bulk materials is a specialised field, and one which cannot be dealt with adequately in this book. Further reading on bulk handling is given in the Bibliography.

5 | Choice of Materials Handling Equipment

FACTORS BEARING ON CHOICE

When a particular product is being manufactured or processed, certain limits of material and quality are imposed. It is likely that wherever this particular product is being made geographically, at any point in the world, similar conditions of material and quality will prevail. In many cases the machinery of manufacture will be of similar characteristics; indeed, in some industries the machinery of production will be virtually identical, there being perhaps only one or two manufacturers of specific machines on a world scale. All metal-working industries, for example, will be equipped with machine tools having virtually identical functions: lathes, presses, forging machines, grinders, millers, etc. The spread of technology and technical information is so rapid today that innovations can be accepted at a much faster rate than would have been thought possible fifty years ago. It is difficult to imagine a portable radio being constructed anywhere in the world today which did not make use of transistorised circuitry, and the use of new integrated circuit devices is separated by months rather than years even in countries not generally recognised as world producers.

So the material and the process may be looked at as a fairly constant factor in the handling requirements of a given product, but they are only one part of the total handling problem.

As we saw in the preceding chapter, a given material and process may offer a number of different ways of handling the material or product, based on its individual characteristics and the quantities to be moved. The deciding factors as to **which** of these methods will be the most effective lies outside the production process.

Although we have postulated similar production and process methods for a given product, the factor that will be different for every possible case is the **local environment.** Inside the local environment, and indicated by the materials handling requirements, come the many available types of materials handling equipment, together with the knowledge of their various capabilities.

So, summarising, there are three basic factors to be examined in any handling situation:

1. The material, and the processes through which it passes.
2. The local environment.
3. The equipment which is available.

ENVIRONMENTAL FACTORS

We have looked briefly at analysing material flow in a previous chapter; we must now look at the environmental factors, which are so important that we can say with total confidence: 'No handling situation is exactly like any other; each problem must be examined afresh in the light of local circumstances.' Most of the handling failures that are too often recorded in industry arise entirely from failure to comprehend this dictum. Sometimes the differences are marginal, but on most occasions they are so widely disparate as to defy comparison. Evidence of a successful installation is no guarantee that an exactly similar installation will be successful elsewhere. As an example, one large British warehouse handling system was copied almost slavishly from a similar set-up in the U.S.A.; the repercussions of its transplantation have not yet been entirely resolved after ten years of operation. The reason here was that the sales pattern and delivery distances in the U.S.A. are in no way comparable with those existing in Britain. The failure was compounded by the fact that the British operation was at least one order of magnitude larger than its American prototype.

The major environmental factors which bear on handling methods are:

1. Buildings, either existing or proposed.
2. The layout of the production machinery.
3. Safety regulations and fire hazards.
4. Sales and distribution patterns.
5. Production and stock control policies.
6. Labour or union attitudes.
7. Capital cost or financial controls.

Some of these are important enough to merit considerable examination, and (1), (2), (5) and (7) are the subject of separate chapters, so will be only briefly referred to at this point.

Buildings

The buildings in which operations take place are the most important factor after the material itself in determining the appropriate handling system to be adopted. They can range from a modern single-storey building with full services and a monolithic permanent floor, to elderly multi-storey buildings erected in the nineteenth century for a purpose totally different from their present use. And whereas it would be nice to say that all layouts should be designed so that they can then be covered by a purpose-built enclosing shell, we know that in a practical situation this is seldom the case, and most people will have to 'make do' with what exists now for the foreseeable future. It is not necessary to be a civil engineer or an architect to make a satisfactory assessment of a given building, but you must know how to acquire the right information, and to have confidence in it. Most of the matters that affect handling and layout are related to the size and shape of the buildings, the various levels and floors and the relative heights of roofs or clearances. Particularly in the case of buildings used for storage purposes, the scale and capacity of the floors, the height of the roofs and the access areas are most important.

The limitations of the building will often dictate quite clearly the choice of handling system to be employed. For example, let us suppose that in a particular situation, regarded from the standpoint of the material and process, we would find it possible to use either an overhead conveyor or some floor-movement device with wheels. The building in question has a lightweight concrete shell roof which is totally incapable of safely supporting additional imposed loads, and thus we are required to use some form of surface movement. Take next the case of a building which is to be used for storage, and has previously been used for another purpose, resulting in damage to, and irregularities on, the floor. Before small-wheeled vehicles such as pallet trucks or straddle trucks can be used, complete reinstatement of the floor surface may be necessary. In such a case it might be cheaper to consider the use of conveyors over at least part of the area.

Plant Layout

The proper consideration of handling systems is crucial to the satisfactory layout of a production area. The two matters are so closely interrelated that failure to recognise their dependence will prevent a satisfactory solution being achieved.

Some layouts are plant design problems: chemical plant, refineries, rolling mills or steelworks are usually designed 'of a piece'. Any handling devices or systems must be built-in and regarded as part of the design, because after construction there is very little room for manoeuvre. It may cost as much to move piece of plant of this nature 2 ft as to move it 60 ft, and once structures and foundations have been laid, changes are either impossible or prohibitively expensive. In such cases the handling engineer must work closely with the plant designer; each must have a good knowledge of the other's problems, and the total foreseeable requirements for handling.

At the other end of the scale are industries such as the sewing trades, where a workplace consists of an operator and a sewing machine, the latter being readily moved by two men at a few minutes' notice, and plugged into the nearest electrical supply as required.

Most industries fall somewhere between these two extremes, and plant moves are matters of days' rather than hours' work. The position of the pieces of plant, and the amount of material which is required at the various points, will often determine which of several alternative systems can be used.

Safety Regulations and Fire Hazards

Most of the matters which affect safe working in industry are covered by the appropriate section of the Factories Act, the compliance with and enforcement of which is the duty of H.M. Factory Inspectorate. Any person concerned with either handling or layout should make himself conversant with those sections of the Act which his actions are likely to affect. This does not mean that we should all become experts in this field, but that we should have a working knowledge of the Act and its provisions, and know where in it to look for detailed information. A very useful introduction to the Act is published by the Stationery Office (*The Factories Act: A Short Guide*), and there are many 'Safety, Health and Welfare Booklets' obtainable from the same source, which deal with particular subjects and industries. A list of these, together with their prices, can be obtained from any Government Bookshop, direct from HMSO or through booksellers.

Do not expect the Factory Inspectorate to offer advice on matters of safety. Their duty is enforcement of the Act, and they are neither obliged nor required to do more than this. Most Inspectors, however, are reasonable, knowledgeable persons with considerable industrial experience, will often volunteer explanations of difficult areas of the Act, and might in some circumstances be willing to look at projected plans before installation with a view to their compliance with regulations.

The Royal Society for the Prevention of Accidents (RoSPA) has a wide-ranging knowledge of industrial safety problems, and is the proper body to turn to for advice on industrial safety. It has a large staff of Technical Officers, who specialise in particular aspects of industrial safety or in particular industries and who are freely available for consultation. If the problems you face are large-scale or could have long-term implications, a short consultation with the appropriate RoSPA official might not only save time but possibly money as well.

Safety regulations in the U.K. are governed by the Factories Act, and most industrial countries have very similar legislation (some of it, in fact, based on our Act). Despite this, there are differences of emphasis and intention in some cases, so when buying machinery or handling equipment from overseas for use in Britain, a thorough examination of the safety aspects will be necessary to ensure compliance with British regulations. As an example, in some European countries the law is interpreted to mean that so long as the employer has incorporated the necessary safety devices into the equipment, provided the necessary ancillaries, i.e. gloves, goggles, etc., and has instructed his employees in their safe use, the employer is exonerated from blame if a worker injures himself by disregarding the rules. This is not the practice in Britain, and each case has usually to be tested in court before a decision can be given.

In organisations where a full-time qualified Safety Officer is employed, he should always be consulted about any change in handling or layout which may affect safety rules and regulations.

Fire regulations are even more variable. Besides the overall rules of built-in fire protection which are an integral part of current building regulations and therefore applicable nationally, there are many regional regulations and by-laws which may differ widely in their demands. For example, the Greater London Council, because of the density of urban buildings, lays down a particularly stringent set of standards for fire protection of industrial buildings, while a county authority in a rural area might not expect more than the national minimum. The local Chief Fire Officer for the area should always be consulted in the case of new or changed layouts; he is conversant with both national and local regulations, and should be able to interpret them in terms appropriate to any proposals. Such advice also extends to the positioning and upkeep of fire protection devices, emergency exits, fire-break doors and walls, etc.

Never lose sight of the fact that if you have, even unwittingly, contravened some national or local regulation with regard to either fire or safety, your organisation's insurance policy may well be invalidated with disastrous financial results, both to the organisation and yourself!

Sales and Distribution Patterns

Although these factors are seldom considered in the normal course of handling and layout problems, they can have a decisive effect on the proposals. This book is more concerned with the immediate problems relating to industrial handling and layout than with the overall policy of an organisation, but it would be unfair not to say that the overall distribution policy, particularly in the case of an organisation involved in wholesale or retail selling, can have a governing voice in the initial placement of depots and warehouses. The actual geographical placement of such facilities, in relation to the pattern of trade, and the strategic advantages of good communications can narrow down the possible area of usefulness. Such matters as the forecast of future sales, or introduction of new products, must be considered before a new or revised layout relating to such products can be designed.

Even at lower levels of investigation, the methods of handling goods should be related both to the organisation's capabilities as well as to customer requirements, and such matters as collection or delivery on common-user pallets or containers should be explored. The question which must be asked here is: 'Do the items come to us, or are they delivered to the customer, by methods which are the most economical and convenient to all parties?'

Packaging is an area of handling which is often greatly influenced by sales policy. The original purpose of packaging is to protect goods between production and use, but many products today use the packaging as a major sales aid. Difficulties arise when the objectives of the sales department are not clear, such as demanding a three-colour printed carton for canned goods from which the carton is invariably stripped before either display or sale. Cosmetics, on the other hand, are an example of the total sales value of the package, where the contents sometimes seem subsidiary to the container. Try always to obtain maximum protection at minimum cost, and always be prepared to pursue demands for special treatment back to source.

Production and Stock Control Policies

The effect of these factors on equipment choice becomes obvious as soon as we ask the question: 'What quantities of material are required at each production point, and how many minutes', hours' or days' work does this represent?' The quantities required for satisfactory working must be capable of being moved within the production time limits and thus will have a determining effect on the choice of equipment. Similarly in stock control, unless we have a clear picture of the stockholding pattern, and the flow of materials in and out within a period of time, we cannot attempt to design a stores or warehouse, much less provide it with handling equipment. Since this subject will be treated in greater detail in a later chapter, it is sufficient to emphasise at this point that a good working relationship must exist between the individuals charged with layout and handling duties, and the production and stock controllers. The latter must be able to understand the objectives of any new scheme, and to see if any system modifications will be required as a result of the changes in layout or manufacturing process.

Labour or Union Attitudes

It should be hardly necessary today to bring such matters to the attention of members of management as being of particular importance; it is likely, however, that many people may be unaware of the dramatic effects on attitudes that changes in layout and handling can have. A new machine or a new process can often be absorbed by the work-force with little difficulty; changes in layout frequently cause total relocation of people's places of work, sometimes hundreds of metres from their original point, and to different surroundings.

Few people react pleasurably to change, many actively oppose it, and therefore any investigation which may result in such changes must be discussed at all levels before work is commenced. Union representatives or shop stewards should be informed of the aim and objectives of an investigation into handling or layout before the work is set in hand, and kept informed of progress in step with management. The classic case of failure to observe these simple rules is provided by the dock authority who decided unilaterally to introduce fork-lift trucks into dock sheds. As a consequence, all fork-lift trucks were accompanied by a chargehand and eight men (the dispossessed crew) until the work loading was agreed some six months later.

Suffice it to say that labour relations is a difficult plant to rear, and success depends entirely on local climate. In some areas and organisations anything may be possible and agreement reached in hours. In other situations, and particularly in industries or areas with a long history of difficult labour relations, the investigator may find himself with less latitude. As was said earlier about other matters, it depends on where you are geographically located, and success will often depend upon the ability to gain acceptance for new ideas rather than new equipment.

Capital Cost and Financial Controls

Methods of costing, while paying lip-service to a standard system, are widely disparate in detail. Anyone engaged in handling or layout would be well advised to make himself conversant with the costing system in use in his organisation, for without this knowledge he will be helpless. This does not mean that you have to become a qualified chartered or cost accountant, but that you must have a working knowledge of how the costing system works in your own organisation. Costing, like statistics, is as much an art as a science, and a set of figures can be prepared in a number of different ways, any of which can be claimed as valid. Take, for example, the value of 'work-in-progress' (WIP), the reduction of which is a frequent target for investigation. If the accountants wish to show a large amount of funds tied up in stock, then WIP can be valued at material plus added value of processing, so that it ends up at sales value before entering stock. If, however, it is necessary to show a lower figure, it can quite legitimately be shown that WIP has only a material cost until it enters the warehouse. Where the product has a high intrinsic value but the material cost is low, these two assessments can be incredibly different.

So it is necessary to know how the accounting system works **for you**. How long a 'payback' or depreciation period can you expect on capital equipment? Is capital cost more important than labour cost, or vice versa? Is it considered more economical to hire transport, or fork-lift trucks, than to purchase them? The answers to these questions must always be discovered **before** a recommendation is submitted, not afterwards.

EQUIPMENT

Method of Choice

Two overriding factors must first be considered when recommending or purchasing equipment for handling.

The first rule is, wherever possible (and this includes 99 per cent of all possible cases), use standard equipment. By this is meant those items which appear in manufacturers' catalogues as readily available, either as separate items or as built from standard components held in stock by the manufacturer. The range of equipment of all types which is so available is so wide and comprehensive that it should hardly ever be necessary to design or require a 'special'. Specials and prototypes are a constant source of worry. Failures are often more frequent than with proven equipment, and nearly always spare parts and replacement items are a long-delivery prospect. Competition in the materials handling industry is fierce, and there is almost certainly something available that is near enough to your specific requirements to be usable.

The second rule of selection is order from requirement, not from catalogues. There is so much equipment available, and in such a wide variety, that you must start with a fairly narrow specification of the sort of equipment required. Every firm producing materials handling equipment produces technical literature describing it – in the utmost detail. Particularly if you have an engineering background, you can be almost seduced by the sheer volume and quality of the information provided. Weights, heights, lifting capacities, speeds, turning circles, power consumptions, all are given, excellently displayed on high-quality paper, accompanied by graphs, diagrams and illustrations.

If you have carried out your handling analysis correctly, taking into account the environmental factors bearing on the particular situation, you should by this time have been able to define at least the basic type of equipment required, i.e. cranes, conveyors or wheeled vehicles. Further modified by the amounts to be moved in unit time, and the characteristics of the material itself, you are sufficiently well advanced to write a brief technical specification for what you are seeking. Now is the time to consult the buyers' guide for the industry (and there are several of these) to find out who manufactures which kind of equipment. Many manufacturers produce several different categories: a firm manufacturing hoists and cranes may also make conveyors. It is best to approach a manufacturer who specialises in a particular field.

At this point you will find a number of manufacturers who can supply very similar equipment; write to each, requesting technical literature, but **not** a representative. You are now in a position to compare specifications, and you may very well find that there is little to choose, on paper, between comparable equipment. Take up those replies which come closest to your requirements, and ask in your next letter for a **technical** representative to discuss the uses of their equipment in your organisation. This should bring a man who knows what is required. Ask, before you get too involved, whether he has any knowledge of a similar installation or equipment in your area. Most reliable firms will already have this information to hand; in cases where it is not forthcoming, view the equipment with a very critical eye: you may well be the first purchaser. . . . Take the trouble to contact any firm named as an existing user, bearing in mind that they may have a different service or requirement from it than you are anticipating. See or talk to the people actually concerned with the equipment: works managers, foremen, drivers, maintenance engineers. In this way you will get a reasonable assessment of the equipment's uses and capabilities separately from the sales talk.

Service and Reliability

If the piece of equipment which you are ordering is to be an important part of your organisation – a conveyor linking a number of processes, or a fork-lift truck which will load and unload all vehicles – then it must be as reliable as possible. If a failure means your business comes to a halt, it is vitally important that repairs or servicing be as rapid as possible. If you have or expect to buy a large number of the items, and failure of one of them will not totally inconvenience you, than a lower standard of service might be acceptable. Only in these circumstances should you sacrifice price advantage to servicing.

As a general rule, a given piece of equipment **to the same specification** will have a very similar price tag, whoever you buy it from: competition will see to this. Look carefully at any equipment offered below this 'norm': it may be perfectly satisfactory in use, but of overseas origin, and the spares and service aspects need to be closely investigated before purchase.

CHOICE OF POWER UNIT

When purchasing units having their own prime mover (fork-lift trucks, tractors, powered trucks of all kinds, mobile conveying equipment), in addition to a bewildering range of types and makes available, there will in most cases be a choice of power unit. The main breakdown is between electric and internal combustion (IC) engines, the latter being subdivided into petrol, liquefied petroleum gas (LPG) and diesel.

Although equipment manufacturers like to offer a range of power units as alternatives, in practice the choice is nearly always on environment between electric and IC engines. For example, if you are working in the food industry and the vehicles are required for use inside the factory or warehouse, you are obliged to settle for electric on grounds of cleanliness and fume-free operation. If you operate a timber yard and the vehicle is given rough service over a large area, you are almost certainly going to choose an IC-engined type. In between these two extremes there is a wide range of applications where a choice of either could be made, depending on local conditions and requirements. For example, a medium engineering firm with roof heights of the order of 14–18 ft, and having heavy items to move, might be better served by a diesel unit than an electric one, particularly if two-shift working is in operation.

Direct comparisons are difficult, but given free choice it is possible to sum up as follows.

Electric Units

The most important component here is the battery, and it will normally be of such capacity that it will operate the vehicle over a complete eight- or nine-hour shift. For two-shift working a second battery will be required, together with all the necessary facilities for changing them over and charging equipment. Most electric vehicles are fitted with some form of thyristor control, which means that at low speeds of operation, instead of the excess amount of electricity being dissipated as heat in a resistor bank, the supply is pulsed, so at low consumption rates only that amount of electricity needed is withdrawn from the battery. Although extensive claims are made for this method of operation in terms of current saving (and hence battery change), it is only of value if much slow or half-speed movement takes place. Normal running and lifting rates use the full current capacity at all times, whatever type of control is provided.

In the case of counterbalanced-type fork-lift trucks, the enormous weight of the traction battery normally acts as the counterweight, so that with careful design it is possible to make an electric truck slightly smaller than an IC-engined one of similar capacity, but this is usually a marginal advantage.

Some of the areas where the use of electric vehicles is almost certain include food manufacture and processing, pharmaceutical and fine chemicals, cold-store operation, the electronics industry and operation in hazardous atmospheres (i.e. where the vehicle is required to be either 'protected' or 'flameproofed').

IC-engined Vehicles

From the operating point of view, IC engines have several advantages over electric. The power unit is more flexible both in torque and speed, and continuous working can be carried out without loss of power, i.e. on two-shift working the only requirement will be refuelling and change of driver. Size for size, an IC-engined truck is usually faster in operation, although better design in electric vehicles is beginning to overcome this difference.

At least three types of fuel or power unit are available, and most truck manufacturers are able to supply examples of each on demand. All IC engines produce fumes, visible vapour or smoke and some toxic exhaust products, though in a properly adjusted engine of any type there should be no visible exhaust once the engine has attained working speed. There are differences in initial cost and running cost for the three main types, and an attempt is made to describe the characteristics of each below.

Petrol

There is very little incentive in the U.K. to use petrol-engined vehicles in industrial situations. There is no tax concession on petrol, so fuel costs are high. The petrol engine produces the most toxic exhaust of the three types being considered, owing mainly to the low combustion efficiency of spark ignition operation. The petrol engine has a poor power/fuel consumption curve and is therefore rather 'thirsty', particularly at higher speeds such as required for lifting and lowering. As a consequence, petrol engines are rarely used in industrial equipment unless below 500 cc capacity or for intermittent duty. Its main advantage is the relative simplicity of maintenance and adjustment; the lighter weight of a petrol engine in most cases is irrelevant.

LPG (Liquefied Petroleum Gas)

This is becoming a popular method of powering industrial vehicles, but is in danger of being oversold. Its advantages over a well-adjusted diesel engine are few, and it is certainly more costly to operate.

The engine is basically a petrol engine with a modified carburettor–evaporator system. Fuel is carried in detachable cylinders or high-pressure fixed tanks, according to particular needs. If the LPG is purchased in cylinders in small batches, then the fuel cost can be as high as or higher than petrol. If bulk supplies are available a considerable reduction can be expected, but it will still be much more costly than either electricity or diesel fuel to operate. Offered against this is the claim that LPG is a 'clean' fuel, and it is often mistakenly stated to be odourless in operation. Toxic products are lower than in petrol, but certainly not non-existent. Another advantage is that lubricating oil is not contaminated by combustion by-products and the engine may need less maintenance, although this claim is difficult to prove.

If LPG is purchased in bulk, then refuelling presents some problems, both fire and explosion risks having to be catered for. A special refuelling point is required, and regulations on storage and transfer of LPG are stringent.

Since the engines have the same characteristics as petrol engines, fuel consumption increases rapidly with speed of operation.

Diesel

The diesel engine has a good power/fuel consumption curve, and is easily the most economical on fuel of the three types, particularly since up to the time of writing a tax-free concession can be claimed for diesel fuel used by industrial vehicles not subject to the Road Traffic Act. Owing to the high air/fuel ratio, the better combustion produces fewer toxic exhaust products than petrol engines. In certain conditions, particularly at starting from cold, a light smoke is produced, but this should never be in evidence in normal running of a properly adjusted engine. Refuelling is simple and safe. A higher standard of skilled maintenance is required to secure proper adjustment, although the engine itself will need no more (and probably less) maintenance than with petrol.

SUMMARY

In this chapter no attempt is made to describe or illustrate the different types of equipment. One good reason for this is that such information is readily obtainable elsewhere, from catalogues, buyers' guides or illustrated materials handling dictionaries. The second reason is that equipment is changing all the time, new developments are appearing, and to try and keep up with these changes would demand a loose-leaf supplement service.

If the investigator has carried out a proper analysis of the movements and quantities required, the actual selection of equipment is limited both by this analysis and the various environmental factors which impinge on a particular situation. There may well be several possible pieces of equipment which will prove satisfactory in operation. The final arbiter will nearly always be cost: not necessarily capital cost, but the overall cost of satisfying the requirement in the most efficient manner, and this may depend as much on the particular methods of costing employed as the actual equipment.

6 | Buildings and Layout

INTRODUCTION

Next to the product itself, the factor influencing the layout and handling of a production area to the greatest extent is the buildings in which operations are to take place.

The accepted theory of plant layout (if such a tenuous body of information can be called a theory) states that all layouts should be designed to the ideal limits, and that constraints, other than those imposed by the manufacturing processes, should not be admitted at this stage of design. Then a protective shell – the building – should be designed to cover the ideal layout, taking into consideration the total requirements of the situation regarding lighting, heating, services, etc. This, of course, is a counsel of perfection, and like all such statements is very seldom possible in practice. Certainly the layout should be designed to the best limits, but if the building already exists, little can be gained from such an exercise and much time can be wasted. Even in those cases where a new building is called for, the constraints caused by planning authority permission, site availability or development, and frequently a limit on the available funds, impose restrictions which would render the ideal layout untenable. Often buildings which have been purpose-designed have failed to fulfil their promise in operation, almost certainly owing to lack of full liaison between the designers and the operating organisation.

PROVISION OF DESIGN DATA

The purpose of this chapter is not to offer advice on designing industrial buildings; it is simply to suggest to those persons entrusted with a layout design to endeavour to influence the design of any new building as early in the planning phase as possible. It is quite astonishing how far the design and siting of a building can go before the operations which are to be carried out therein are considered in any detail. The writer is aware of two recent cases where either the board or the managing directors of companies commissioned architects to produce notional sketches of new buildings long before the future operating staff were aware of the companies' intention to build, although they certainly knew of the possible site. Once a design has got as far as this, it becomes difficult to make useful suggestions as ideas are already beginning to harden. So the first rule must be: 'In the case of any new building, the operating and layout personnel must be consulted as early in the design phase as possible.'

Many civil engineering firms and some architects involved in the design and construction of industrial buildings have already realised that the successful use of the building is more important than its appearance, and such firms are now realising the benefits of their foresight. Where a contract is placed with such a firm, they require the client to provide them with comprehensive details about the work and processes to be carried out in the buildings, before the design team sets to work. Often this involves the client having to look much more closely at his terms of reference, and nothing but good can come from this. Some of the points that need to be looked at in this way are given below, but this is just a selection and by no means comprehensive:

Process of Manufacture

Types of machinery. Weights and securing requirements.

Materials, volumes and weights being used and their possible effects per unit time on the environment, i.e. fumes, smoke, dust, odours, toxic chemicals, liquids or gases.

Handling system likely to be used, with its effects on roofs, floors, door apertures, etc.

Processes which cannot satisfactorily be placed adjacent to each other, i.e. punch presses and surface grinding machines.

Storage Areas

Weight and volumes of items to be stored, average stock levels expected.

Frequency of turnover of stocks, whether seasonal effects.

Type of handling system to be used, and whether similar or compatible with that in manufacturing areas.

Receipt and Dispatch

Types and numbers of vehicles delivering or being dispatched in given unit time.

Requirements for marshalling areas adjacent to loading bays.

Equipment for handling loads on and off vehicles.

Personnel and General

Numbers of persons to be employed in different areas.

Lighting levels required in each area.

Special conditions, i.e. 'clean rooms', heated or cooled areas.

Catering facilities required.

Fire and Safety Provisions

Details of how the particular industry is treated with regard to factory safety.

Any particular fire hazards or requirements connected with the activities to be carried out in the buildings.

Storage of flammable or toxic liquids and gases.

Interaction between Buildings, Handling and Layout

This subject is best dealt with under separate aspects of the buildings, since the effects are similar whether the buildings are new, old or simply projected.

FLOORS

Although a good floor is the starting-point for any industrial building, it is surprising both how little attention is normally paid to it, and how little is known about it by the occupiers.

The different kinds of use it will receive have a direct bearing on the strength and quality of a floor. For example, floors used for storage must be capable of withstanding both point and area loadings, and these often to a high level of weight. The surface must be of a good standard, since many handling vehicles (pallet trucks, straddle trucks) have small-diameter wheels or rollers which must be allowed to turn freely. Joints, if acceptable, must be as inconspicuous as possible, and the surface should be free from sharp inclines, ramps or declivities. Such requirements may demand resurfacing if an old floor is to be used for modern storage methods, and the cost of this can be high.

In production areas, in addition to most of the above requirements, the floor must be able to withstand without degradation the traffic imposed by the production pattern. There may be special requirements for surface finish brought about by the material used or handled (oils, chemicals, food processing). Special attachment points may have to be provided for machinery, or facilities for drainage. It is not good practice to provide services (i.e. water, electricity, compressed air) from below floor level in general industry, and only drains or similar channels should interrupt the surface. Services are never exactly where they are needed if floor access points are provided, and have a very limiting effect upon layout. Damage can also occur, and repairs are difficult and costly to effect. These comments do not apply to fixed-position layout, such as chemical or heavy processing plant, where services are normally 'built in' as construction proceeds.

As a general rule, it is unwise to pay much attention to figures quoted as floor loadings, particularly in multi-storey buildings, unless full-scale load tests have been properly carried out. Such figures are often a matter of opinion rather than fact, and if a layout is to be permanent, then accurate information is needed. Tests should be carried out under the direction of a qualified civil engineer.

WALLS

Modern industrial buildings are usually constructed with some kind of prefabricated curtain walling to facilitate rapid construction, satisfactory insulation and protection from the weather, and to allow for future expansion. Older buildings will have less sophisticated systems, and brick or breeze-block walls. It is usually only necessary for the layout planner to know what purpose the wall serves, if this is not obvious. Walls, other than those forming the exterior protection, are erected for various reasons, such as division of an area, fire-breaks, protection of personnel, etc. In an old building the original reasons have often been forgotten. Sometimes the requirement is to remove a wall, or make an aperture in it for access or traffic, and the effect of this on the wall structure and purpose must be known beforehand. Advice may be necessary if the aperture is of some size, both for reasons of construction and possible contravention of the Factories Act or fire regulations.

ROOFS

So far as handling and layout is concerned, the roof structure of a building is second only in importance to the floor. Frequently the whole of the layout and handling methods may depend upon the design and load-carrying capacity of the roofing members. In the older type of building the roof covering is usually supported by pitched trusses, either equilaterally pitched or northlight glazed (see Figs. 6.1 and 6.2). Such roofs are usually supported longitudinally

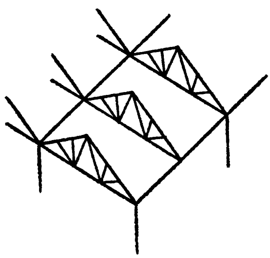


Fig. 6.1

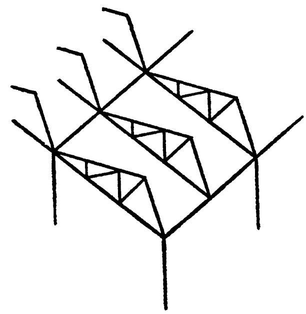


Fig. 6.2

on heavy steel joints, forming a structure of great strength and often having ample safety factors, which enable gantry cranes and overhead lifting gear to be supported without additional steelwork. Thus the provision of an overhead conveyor, for example, presents few problems.

More modern buildings, however, tend to make use of recent design methods, and are provided with roofs which although fully adequate for the purpose of providing cover and lighting, do not often allow heavy equipment to be suspended therefrom without endangering the safety of the structure. Such buildings may employ prefabricated 'system' components, or may be cast *in situ* as a lightweight concrete shell. In these cases the provision of any overhead lifting or moving equipment has to be accompanied by the erection of suitable supports or framing, the vertical members of which may well invalidate the objective of keeping the floor clear of obstructions. So a lightweight roof may rule out the use of a medium- or heavy-duty overhead conveyor, thus dictating the handling methods on the floor below (see Figs. 6.3, 6.4 and 6.5).

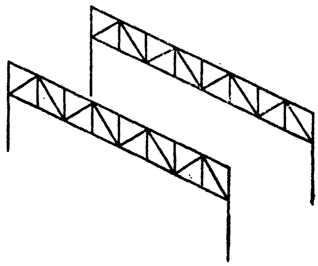


Fig. 6.3

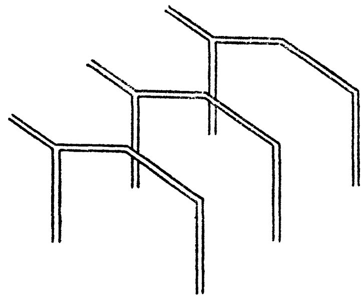


Fig. 6.4

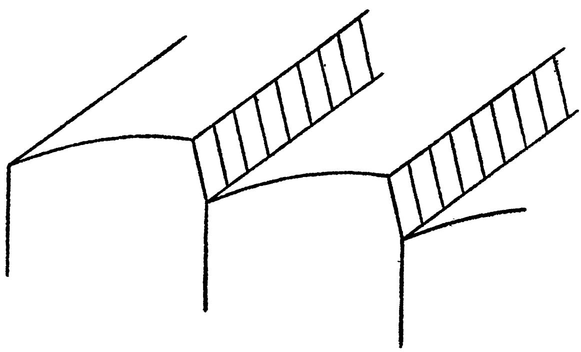


Fig. 6.5

The matter of internal roof height is one which has received very little attention. In the past it was usually thought that roof height was dependent on use, to the extent that a building used for storage purposes normally had a higher roof than in manufacturing areas. This concept is difficult to justify today, since flexibility in use is usually regarded as more important. The cost of increasing the height of walls to enclose a given volume is only about 15 per cent of the cost of lateral extension (if site cost is ignored), and with present-day standards of insulation and air movement the heat losses through the roof with increased height can be disregarded.

The optimum height of roofs for industrial buildings has long been a subject of controversy, but seems to be settling out in current practice somewhere between 6 and 8 metres (18–26 ft). The main factor influencing this seems to be the convenient stacking height of a normal fork-lift truck using palletised loads 1 to 1½ metres (3–4½ ft) in height. Stacking above this height usually calls for more specialised lifting vehicles and possibly greater driver skill. There is also a time element involved, since stacking speed is much lower than horizontal movement (see Appendix). If warehousing and storage is the major activity in a building, then greater heights and increasing sophistication of lifting machines are likely, but for manufacturing and general-purpose buildings the heights quoted above are likely to be regarded as the norm for a long time to come. This chapter makes no attempt to discuss buildings designed specifically for storage, or automatic warehouse equipment, which is a rather specialised development and unlikely to affect general manufacturing in the foreseeable future.

LIGHTING

In many older buildings extensive areas of glazing are provided for in the roof, and possibly in walls as well. When the majority of lighting in a factory was provided for by natural daylight, this was an obvious and reasonable solution. However, it had its disadvantages: in summer these large areas of glass often admitted not only light but heat and glare from sunlight, and a familiar accompaniment to this class of building was the requirement to obscure some of the glazing, usually with whitewash, during high summer. With the levels of lighting in use today, natural daylight can only make a useful contribution over a very small proportion of the year, and the tendency has been to reduce roof glazing and to increase the light levels by installing better lighting fitments. The abolition of roof glazing is usually accompanied by a higher thermal insulation value for the roof, so that heating costs are reduced rather than increased. At high levels of lighting, heat from light fittings can be utilised to provide space heating, thus cutting costs still further. If the psychological effects of external glazing are important, then windows can be inserted below roof level into curtain walling at relatively low cost.

Never try to economise on lighting levels. The amount of electricity consumed by modern discharge lamps and fittings is two to three times less than filament lighting of the same level, although installation cost may be higher. The average light level in British industry has more than doubled in recent years and is likely to continue rising, particularly in those industries which do not yet provide an adequate level. (Heavy engineering firms are often slow to provide high overall levels of lighting, relying mainly on point sources on individual workplaces.) Although the Factories Act is not very specific about lighting levels, there is an HMSO 'Health and Safety at Work' booklet, No. 39, *Lighting in Offices, Shops and Railways Premises*, which gives some guidance.

SUMMARY

The layout planner must have a working knowledge of the various aspects of the buildings in which he is required to operate. This does not mean that he has to be either a civil engineer or an architect, but he must know how to obtain advice on specific points, probably by asking specialist advice. At the same time he must know sufficient about the reputations of his advisers to be certain that the advice given can be accepted at its face value and, if necessary, acted upon. Plant layout has a definite finality about the installation phase, and any action which may lead to doubtful operation or even failure is likely to rebound on the planning engineer!

APPENDIX 1

HIGH-LEVEL STACKING BY COUNTERBALANCE-TYPE FORK-LIFT TRUCKS

There is a growing trend towards making greater use of height when stacking palletised goods, both under cover and outside. Stacking heights of 24 ft are now quite common, and there exist many installations where, by the use of pallet racking, greater heights than this are in daily use.

The implications of this are widespread, starting with building construction, through stock policy and finally to FLT operation and design. If we confine comments to the latter, we see that high-level stacking introduces a number of problems which are either non-existent or of little consequence in stacking to 'conventional' heights, i.e. 10–14 ft. These will be considered under their different headings.

The standard load will be postulated as a 4 ft cube with a nominal weight of 2,000 lb. Stack height will be regarded as multiples of 4 ft, the difference due to pallet apertures being disregarded.

Driver Skill and Lighting

Operation at increased height brings an additional factor into placement of loads. At normal height, the base of the top pallet is only a few feet at most above the driver's line of vision, and there is little difficulty in actual placement of the load by drivers of average skill. However, at heights exceeding 15 ft it becomes increasingly difficult for some drivers to effect accurate stacking. This point is even more important in high stacks, since correct distribution of the total weight over the bottom pallet is important to both static loading and stability.

In this connection, the importance of good lighting, either natural or artificial, must be considered: the higher the stack and the nearer the roof the stacks are placed, the more difficult this will be to achieve. It may be that some additional sensing device will be needed to ensure accurate positioning of the forks at heights. Several devices are already on the market which enable the driver to elevate the forks to a predetermined level, or levels, leaving only the final placement to be effected under manual control. Use of such equipment means that great care must be taken to ensure that all racking is erected to a level of accuracy consistent with the limits obtainable by the machine, and the additional cost involved should be taken into consideration when recommending such equipment. It is certain that where drivers have to operate at these greater heights, both a longer training time and a greater degree of skill will be required, and much more emphasis placed on safe working rules.

Safe Working

The first requirement for safe working at high levels is a satisfactory floor. Where a building has been specifically constructed for high-level storage, it is almost certain this will have been laid down. In older buildings or conversions, attention must first be given to the condition of the floors. Poor joints in concrete flooring can create hazards, and depending on the type of truck and wheel, any unevenness in the surface can be a source of danger.

Most FLTs are provided with overhead guards for drivers, but it must be made an unconditional requirement for any truck which will operate above 10 ft stacking height.

Similarly, back guards behind the forks should be fitted as standard. These not only reduce the risk of accidents, but help to keep the load consolidated if it consists of separate items.

Loads must be prepared with greater care than for lower heights, and in the case of cased or cartoned goods either an efficient bonding pattern, or some means of preventing slippage between items, or both, must be applied.

Limits must be placed on certain motions when the load is elevated, to prevent instability developing. This would be better done by automatic or physical restriction than relying on the driver to apply the rules. Angle of mast (forward tilt), sideshift, and derating of load at height are all-important at high levels, and can have vital effects on vehicle stability. Most makes of FLT can today be supplied with modifications incorporated when required for high-level stacking, and it is well worth the slight extra cost involved.

The most important single factor in fork-truck operation at extended heights is the derating of the nominal capacity for increasing height. This is one of the penalties which has to be paid for increased stacking height, and one of the economic factors to be considered before making the decision to go ahead. This derating, which usually takes into account the effect of the motions referred to above, can be as much as 50 per cent at 24 ft. Thus a truck with a nominal capacity of 6,000 lb. might only be capable of lifting 3,000 lb. to maximum height, and this would have to be allowed for when purchasing. Although this may involve an increased capital outlay for a larger vehicle than would be required at lower stacking heights, the running costs are very little higher, and often the increased reliability gained by operating a higher-capacity truck at the lower levels may offset this. Some decrease in space available for stacking may also result from the increase in aisle width required by the larger vehicle, and this is another cost factor requiring evaluation.

Increasing Time of Access with Height

The additional access time required by high stacking is not a factor that has been given much attention up to the present, but it has a very great bearing on the speed of operation of a store if a proportion of the material has to be placed at high levels. This might be the case, for instance, where order-picking takes place from the lowest two pallets in a stack or rack of six or more, with bulk stock kept vertically above working stock.

Most existing FLTs' forks have a fixed rate of vertical travel, which is governed by hydraulic pump capacity rather than engine or motor speed. This pump capacity has, of course, to be related to maximum load and power consumption. This leads to the situation where empty forks can be elevated only slightly faster than loaded ones. Lowering empty forks takes longer than loaded ones, as the lowering speed is also partly a function of the weight being handled. A good average rate of elevation for a modern FLT is approximately 45 ft per minute with lowering rates of 50 ft per minute for a 6,000 lb. capacity truck, although several models can exceed this by something like 25 per cent.

To summarise, if the forks are being elevated vertically, they travel 10–25 per cent faster **empty** than when loaded. If the forks are being lowered, the rate of travel is 20–50 per cent faster when **loaded**. Thus it is always quicker to unstack than to stack, although there may be additional fork location time before picking up the load at extreme heights.

Although some of this 'dead time' could be incorporated while moving into position, it would be unwise to allow much of this kind of movement to take place with loaded forks, both for safety and stability reasons. This period, during which the truck is stationary while the load, forks or both move up and down, is time lost to the operation of the store. That this may affect the rapid movement of goods is clear from Figs. A.1, A.2 and A.3, and the relevant Notes which show the required access time for the removal of successive pallets and different vertical travel speeds in stacks from two to six high. This, of course, is only of importance where rapid movement of stock occurs and space is not at a premium.

One of the requirements for FLTs engaged in stacking up to 24 ft or more will be increased speed of movement for empty forks, particularly when being lowered. This vital matter must be discussed with the truck suppliers, some of whom have not yet grasped the importance of the problem.

Summary

Before making plans to stack goods at more than the height reached by standard FLTs, i.e. 10–12 ft, it is necessary to consider the additional cost of so doing.

This cost is in two forms:

1. Modifications to the truck and its mode of operation to render it suitable and safe for high-level working.
2. Consideration of the actual methods and stock patterns to be used so that all unnecessary vertical movement is kept to a minimum, thus reducing delays in access time.

It is recommended that where high-level stacking is envisaged, all relevant details of operation and requirements be discussed with the FLT manufacturers before orders are placed, particular emphasis being placed on the points raised in these comments.

APPENDIX 2

COMPARISON OF THE EFFECT OF VARYING VERTICAL TRAVEL RATES

The graphs in Figs. A.1, A.2 and A.3 compare FLTs of similar type and capacity, but having different vertical travel rates (see Notes for details of conditions of operation).

The implications of this are obvious: the slower the FLT vertical travel rates, the less economic in terms of time (and therefore handling cost) becomes the high-level stack. What was not obvious at first was the relationship between vertical and horizontal travel speeds in determining economic stacking heights.

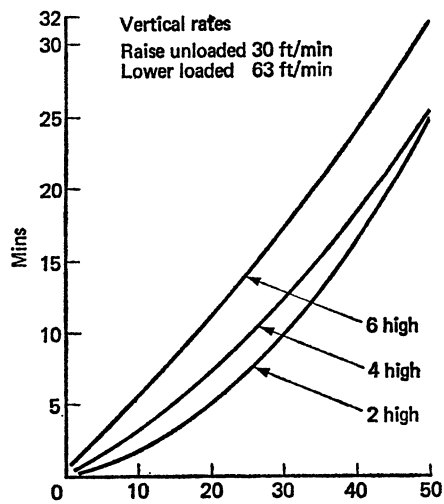


Fig. A.1. Cumulative access time

It will be seen from Fig. A.1, where the relationship between vertical and horizontal speeds is of the order 5:1, that the cost of stacking 6 high is more than double the cost of stacking 2 high up to about 25 pallets, while the cost of stacking 4 high is intermediate, as might be expected. However, although the crossover point between 2 high and 4 high occurs at approximately 50 pallets, the crossover between 2 high and 6 high does not occur until approximately 200 pallets have been moved.

With a decrease in the vertical/horizontal ratio to 3·5:1 (Fig. A.2),

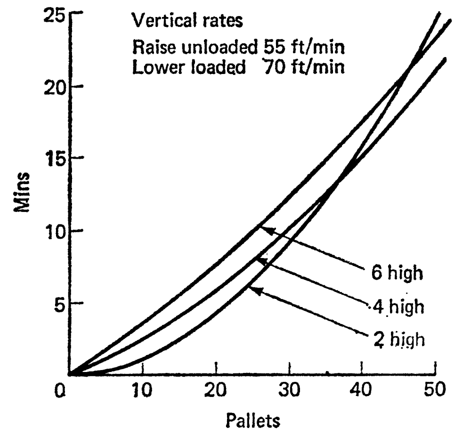


Fig. A.2. Cumulative access time

the cost crossover points occur at much lower numbers of pallets and the cost differential between the different heights is also much reduced, even for the lower number of pallets.

At the final speeds shown (Fig. A.3), the vertical/horizontal ratio

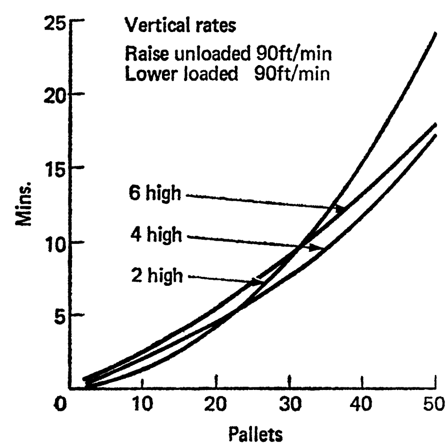


Fig. A.3. Cumulative access time

is down to approximately 2·5:1 and here it can be seen that there is very little difference between the cost of stacking height up to about 40 pallets; beyond this, however, the increased cost of stacking 2 high begins to rise steeply.

Notes to Figs. A.1, A.2 and A.3

In the graphs shown, certain conditions of operation have been postulated in order to give a uniform pattern of handling. These are as follows:

1. A uniform speed of horizontal travel of 220 ft per minute (2·5 m.p.h.) has been taken as the basis of calculation. This figure is one which is frequently taken as representative for short to medium runs in confined areas such as gangways, and allows time for occasional turns and manoeuvres, other than those involved in stacking and unstacking.
2. When stacking or unstacking palleted loads, a FLT performs elements of work as follows:
   (*a*) Turn left or right to face stacking face.
   (*b*) Halt, and position forks for entry into load by raising or lowering.
   (*c*) Run in and position forks in load.
   (*d*) Take load on forks and lift from stack.
   (*e*) Reverse out of stack.
   (*f*) Lower forks to travel position.
   (*g*) Turn into gangway.

   Elements (*a*), (*c*), (*d*), (*e*) and (*g*) are constant or nearly so for any stacking operation, and have therefore been disregarded. This does not affect the relationship between vertical and horizontal travel shown by the graphs. There is some evidence that at higher levels element (*c*) may take longer than at ground level, but no data on this are available.
3. The loads have been taken as 4 ft cubes measured from the fork entry position, with a nominal weight of 1 ton. Stacks are regarded as being adjacent, although in practice a small gap would be left between them.
4. Throughout, one pallet is handled per move, and this is always removed in direct succession, commencing with the top pallet of stack No. 1.
5. In order to reach successive stacks of pallets, a horizontal distance of 4 ft has been allowed for each additional stack,

although in a realistic stacking pattern this might be either more or less.

6. The type of FLT considered is the electric, battery-operated counterbalance type of approximately 6,000 lb. capacity.
7. The rates of vertical movement have been arrived at as follows:
   Fig. A.1. Raise unloaded 30 ft/min. Lower loaded 63 ft/min. These are averages of FLTs in current use, but up to five years old, obtained both from measured time and manufacturers' data sheets.
   Fig. A.2. Raise unloaded 55 ft/min, lower loaded 70 ft/min. Average of a number of current models, taken from manufacturers' data sheets.
   Fig. A.3. Raise 90 ft/min, lower 90 ft/min. This is a rate which could be achieved under present-day conditions, if the necessary equipment was provided by the vehicle manufacturer. (In practice the full movement rate might be even faster, with a slower speed which comes into operation on the last few inches of movement.)

7 | Production and Stock Control

This chapter is not intended as a dissertation on the techniques of production or stock control, but simply to indicate to the man involved in problems of materials handling that many of these, particularly those concerned with production processes, have their roots in one or both of these fields.

Let us take, for example, the physically obvious problem of excessive amounts of material or work lying around the production areas. 'Excess work-in-progress' is the usual term for this, and in many cases it is regarded as within the province of the materials handling function to provide both the answer and the tools to deal with it.

Of course, it is always possible to provide more storage equipment, possibly in the form of racking, or maybe a progress store, and so conceal the excess material, but this is not a solution. Solutions to work-in-progress problems must be firmly based on economics, not on equipment purchase. So if there is a lot of work-in-progress, our first step in the investigation must be a visit to the production control department.

The objectives of production control are often stated as being 'to ensure that the maximum productive capacity of the manufacturing unit is being utilised'. (In plain English, that every machine and worker has enough work to keep them busy over the working period.) This can only be achieved if the productive capacity of both men and machines has been accurately measured and all the possible jobs to be supplied to those men and machines have also been allocated a value in terms of time. Thus production control is fitting a jigsaw pattern of times into a framework of capacity, preferably with no missing pieces. Since the capacity is usually a fixed quantity (which can be disturbed by such items as machine breakdown or absence of workers) and the requirements are often variable, to ensure a good 'fit' requires both accurate measurement and a flexible method of work allocation.

Although we tend to take work measurement for granted, this is often an unwarrantably optimistic view. Many firms are unable to achieve efficient control of production simply because the time values applied to the work are either inaccurate or outdated by machinery or method changes. So the first requirement of any investigation sparked off by excess work-in-progress is a critical look at the time values which production control are using, their accuracy and relevance to present methods. The writer has first-hand knowledge of an instance where a firm faced an enormous volume of work-in-progress as a materials handling problem. Quite early investigation showed that not only was the work measurement inaccurate, but local supervision, works management and finally production control itself had added successive increments to the already inflated time value, until it reached **three times** the actual production time for the operation, while the time for the second operation, which took twice as long, was for some reason regarded as sacrosanct. The resulting build-up of part-finished work between the two processes had reached a volume of some 120 cubic metres before action was taken.

So before checking production procedures, start with a check on the operation times. Do they exist at all? By what means were they obtained? Are they accurate? What limitations must be placed on their use, if any? Only when the answers to these questions can be regarded as satisfactory should we proceed. And if production time values do not exist, they will have to be obtained, for without these crucial data we can neither plan nor forecast.

USE OF PRODUCTION CONTROL INFORMATION

If the production control department is functioning satisfactorily, it should have a record of how much work-in-progress exists throughout the manufacturing departments, and should be able to lay down what quantities there should be in each department. These data, together with the sizes, weights and volumes of the items concerned, are indispensable to the design of layouts, and probably handling systems as well. If there is a wide disparity between the amount of work that production control considers adequate and the actual materials on the factory floor, then an overhaul of central procedures is indicated. If, on the other hand, these amounts agree reasonably well, and, despite this, movement of material presents problems, then both the layout and the handling may be suspect. This latter situation is one that often arises as a result of a steady increase in production without a revision of the layout, which may be well overdue. Another aspect of the interaction between material flow and production control procedures is often shown up in progress stores. These are usually inter-process sub-stores where materials are collected for subsequent use or assembly. For example, a particular product may have a main body or frame and subsequently have fitted to it several sub-assemblies which are made elsewhere in the factory. Stocks of these sub-assemblies or components have to be manufactured often in parallel with the main body, and to ensure that they arrive at the right place and time is one of the major problems of production control departments. So production of sub-assemblies is usually programmed ahead, and the finished items are placed in a progress store until required. Alternatively there may be a progress store simply to collect work-in-progress between two departments with unbalanced capacities.

Subsequent layout and handling changes with improvement in work flow may reduce the necessity for such stores; since they usually form an essential link in production control, any such changes must be fully discussed before implementation. A similar effect can arise from improving the accuracy of measured work times. If production control has not enough accurate information to plan work loads, a progress store is sometimes provided as a buffer between departments.

Always keep a good liaison with production control: their objectives are synonymous with yours – to keep a steady flow of work running. Since their function is largely administrative, while handling and layout are essentially operational, the two sections are complementary and can be of mutual help.

STOCK CONTROL

The stock control function is often thought of as associated with buying rather than production, but its policies and its success or failure in operation can have a direct effect on production. A proper interaction of stock and production control can ensure that the supply of all productive materials and supplies runs smoothly.

As an example, failure of communication between these two functions brought about an almost catastrophic situation in a light engineering firm. Production control would issue stock release orders to stores for items to be used in manufacture. Since manufacture was in batches, these items would be taken out of stock and placed ready for movement into production, anything up to a week before manufacture commenced. At this stage the stores would notify production control that perhaps one item out of a variety of, say, twenty was not in stock; stock control would then reply that it should be, because it was past the agreed delivery date. In the end, the entire batch of materials would be set aside, and another with fully available components substituted. Soon the stores claimed they had a materials handling problem: they couldn't move because of the waiting piles of work and an investigation was started. But worse was to come: since the items withdrawn from stores were **in production** on paper, the computer-controlled stock control system promptly 'filled up' the lowered stocks and soon the accountants were complaining of over-investment in raw materials to the tune of 180 per cent, while customers were complaining of overdue orders. The whole situation arose because stock levels, incredibly, were based on the assumption that agreed regular deliveries would always be made by a given date. In the event of failure to deliver, there was no formal mechanism by which the stock control could notify production control, so the internal demands were issued to stores, which only then disclosed the deficiency.

If handling and layout are in any way concerned with stores or warehousing, and particularly if the investigation could lead to re-design or layout of a storage area, then liaison must be made with stock control before planning starts. A change of stock control policy could make an enormous difference to the area and volume required for a store, so that if such a change were implemented after a store layout was agreed, it could be found to be widely out on capacity. The reason for this is not far to seek. To take a straightforward example, we shall assume that the stock level and replenishment level of a particular item has been agreed, and that in graphical form the pattern of stockholding can be represented as in Fig. 7.1. (Orders are placed earlier than necessary, say one week too early, and the actual stock never gets down to zero, the average stock being greater – in this case 350.)

Ideally we wish to control stock as in Fig. 7.2, placing orders at the latest possible time to be able to supply continuously, because this gives the minimum average stock for the chosen order quantity. In fact it would be unwise to pursue this policy to the extreme, for in many cases it would be impossible to guarantee delivery by an exact date (the problem exposed by the example quoted) and a stock-out would result. So the usual solution is to maintain a 'target stock level' with a constant replenishment cycle, and a minimum buffer stock below which the level will fall in only emergency, e.g. as shown in Fig. 7.3.

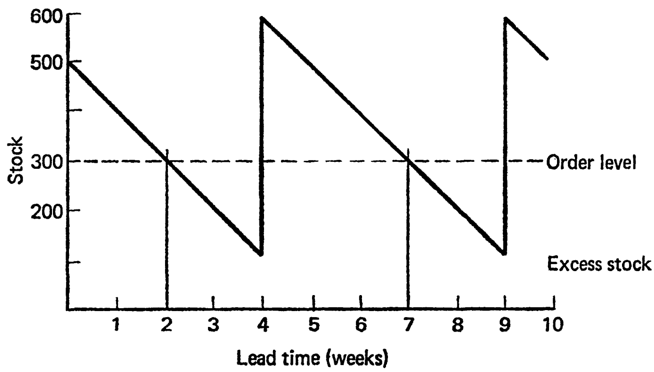


Fig. 7.1

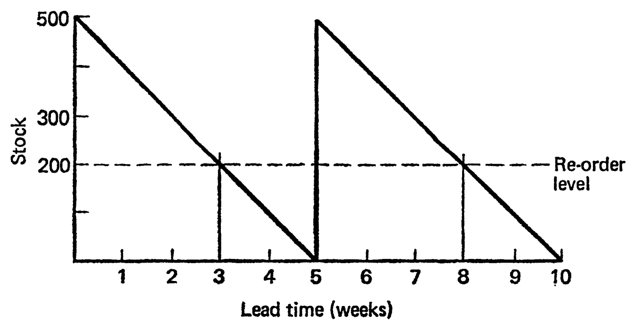


Fig. 7.2

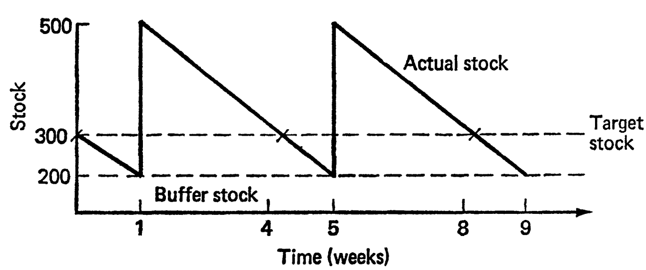


Fig. 7.3. Constant cycle system

Each of these concepts will produce a different level of actual stockholding, which is what determines the space to be allowed for stores; if this is spread back over the total stockholding, there will be an enormous difference between the amounts of space required. So not only must the stock policy be understood by the person who is laying out the stores, but the effect of any changes must also be allowed for.

STOCK LOCATION AND WITHDRAWAL

Additionally, the method of placing items into stock and their subsequent location and withdrawal can have a decisive effect on space requirements. There are two basic methods, fixed position and random location.

In fixed position storage, a particular item is always stored in a given location. This means that at any time there must be sufficient space to accommodate the maximum holding of that item, although for most of the time it will be well below that level.

Random location implies that as a space becomes vacant in store, through usage of an item, that space is allocated to the next batch of incoming goods requiring a similar volume. In this way, as racks or bins become empty, they are constantly being refilled by other, and possibly very different, items.

The second method can save anything from 15 to 30 per cent of the total space required for a given number of items stored in fixed position, but calls for a much closer control of the stores location system. While fixed position methods can be operated largely by the staff memorising locations, correct sequential usage of items under random storage requires a reliable notification and indexing system.

The choice obviously depends on the size and complexity of the business carried out in the store and often on the space available. The decision will be closely tied up with the methods used in the stock control department, and thus the intention to change from one method to the other must be known well in advance by the layout planner.

The design and layout of stores and warehouses is a rather specialised function, and since this book is concerned more closely with production and manufacture rather than with distribution, it will not be dealt with in detail.

Production and stock control are closely related functions, and communications between both of them and the production departments must be of a very high order. Failures in either area can lead to unbalanced working in the production system, and in many cases this may give the appearance of a materials handling problem.

8 | Starting the Investigation

Previous chapters have shown something of the techniques and tools to be used in layout and handling problems; the next few chapters are intended to be guides to their application in practice.

We are going to make the assumption that the investigator is working within his own organisation, of which he has a fair knowledge, and that he is conversant with the product and the processes involved in its manufacture.

Most layout problems are brought about by one or more of the causes of change referred to in the introduction to this book, namely:

1. New factory.
2. Manufacture of new products.
3. Expansion of existing business.
4. Adjustments of production within existing plant.
5. Technical progress.

At the first hint of any of these, the department responsible for layout and handling should try to ensure full briefing as early as possible. This applies particularly to new buildings, as has been suggested in Chapter 6.

The brief for the requirement may range from the deceptively casual 'I wonder if you would have a look at X department; they seem to be getting a bit tight for space' to the mandatory: 'It is necessary to review the layout for Y department, consequent upon increased sales of our product. Please submit your proposals for a revised production unit capable of a minimum increased output of 50 per cent, together with sketches (to scale) of the area required, by two weeks from next Monday.' Despite the apparent differences of approach, the second request is always preferable to the first: at least the objectives have been clarified.

In most organisations the responsibility for layout design will be clearly defined, and the persons concerned will be called in to discuss the course of action. Whether or not there is a formal mechanism for doing so, a small working group should be got together right at the beginning of the investigation, both to provide good communication of information and to get the full co-operation of all interested parties. This group should consist of the following categories of people:

- Works management (includes intermediate supervision).
- Production management.
- Production and stock control (where these are not covered by production management).
- Works engineers and Safety Officer (where the post exists).
- Union or other workers' representatives, personnel department or both.

This group should not be regarded as a committee, and not all members may meet at every meeting, but matters agreed at any formal meeting must be made known to all members, if not all were present.

After the initial brief has been given, it should be discussed at a first meeting, and the objectives of the investigation made clear, in particular those matters which are the direct concern of the participants. Thus the works management might say that they want certain requirements to be built into the new set-up, which do not exist at present, without affecting the output. The Safety Officer may ask for special attention to be paid to some aspect of the production which in his view contains a high accident risk, and so on.

At this point, allocation of responsibility for the project must be determined. Whether this be vested in the works manager, the production engineer or the investigator himself should be clearly defined, and a written notification of the decision given to all concerned. Although the process of laying out plant is a corporate effort, the responsibility for the layout must be vested in one person or function. If this is not done, it leaves the door open for others to introduce changes, and direct information, so that the overall plan can be distorted out of recognition and control of the project will be lost. The channelling of all information through one person or function not only makes for easier working, it means that everyone concerned must work together. Always remember that major layouts are expensive to carry out and their effects are far-reaching. There is also no chance of 'second thoughts' once the equipment has been put in place, so that we must try to be 'right first time'. Split responsibilities render this ideal even more difficult to achieve than it usually appears.

If the layout is a considerable one calling for the co-ordination of a large number of people and services, the use of network analysis should be considered and a critical path network prepared. The critical path network should be maintained in parallel with any changes called for in layout, and in this way the effect of such changes in total project time or resource allocation can be readily monitored.[1]

THE FIRST LOOK

The first step in the examination of the problem is a good look at the existing situation, if there is one. Issue the necessary demands to secure copies of all relevant drawings you will need, i.e. plans, sections, scales required, with a brief note requesting the provider to give the exact date that the drawing represents, and whether or not a revision is under way or expected. While these are being prepared or obtained, go to the area or department involved and, after having contacted the supervisor, ask him to show you round. He will or should know of the impending change; if not he must now be told. This initial survey will probably bring to light many of the existing shortcomings, which will nearly always be highlighted by the supervisor. Explain your position and responsibilities regarding the project and make it clear to the supervisor that you will be leaning heavily on his knowledge and help. (If you get this wrong at the beginning, you may never regain confidence.)

At this first survey you may from experience be able to establish that the existing layout or pattern will be of no help in designing the new one. **But do not make this decision lightly.** You may miss some important fact which may not be exposed until much later in the investigation. So keep an open mind, and discuss the existing layout, picking up any faults or advantages it may have. To familiarise yourself with the process, it is reasonable at this stage to make a detailed process chart of the main product flow. This in turn may lead you to look more closely at some processes than at others as possible areas of improvement.

If the product flow is complex, flow and string diagrams may be necessary to depict it and the drawings will now have to be taken into use. This is the point at which drawings will need to be checked against the existing building features and layout (see Chapter 3). Never omit this step.

[1] For further reading on networks see A. Battersby, *Network Analysis* (Macmillan, 1967).

There should be method sheets for all work in the area under study, together with all the necessary time values. Check not only that these exist, but also their accuracy and up-to-dateness. You may well find that a comparison between the method sheets and the job, as it now is, will show many differences. If this is so, the reasons for this must be established, so that only the correct method is prepared for in the new layout. A change in layout is a good opportunity to examine working methods in a department, since changes may radically affect the new layout. This is the point at which to examine the product variety and flow to establish whether a change in concept might produce major benefits, e.g. from batch to line production, or from line to a cellular system.

Never accept a method or situation without question or supporting evidence. That vast reservoir of inertia, 'We've always done it like this', should be tapped to improve the flow of ideas. It may even be necessary to call for a full method study investigation before commencing to plan changes. If this proves to be the case, have no hesitation in setting it up. Any delay caused to the new layout will be quickly repaid from improvements, and the delay can always be substantiated by the findings of the inquiry. Once you have prepared a new layout the methods can be frozen in, like a fly in plastic, for years. And if the methods then turn out to be unsatisfactory. . . .

Do not accept that product features, which could radically affect layout if examined in depth, cannot be changed. Pursue any possible advantageous design changes as far back as you can, even to the customer if necessary. Often details that cause hold-ups have been designed in by junior draughtsmen and, with persistence and some tact, can be designed out again. Never give up trying in this area until you get mandatory instructions from the recognised authority to do so; the gains are always greater than the rebuffs.

Possibly the method study aspect referred to above may be the responsibility of a separate department from the investigator. If this is the case, make a written request for investigation, state your reasons, and say clearly why you wish to delay layout planning until further investigation. If this is then refused, it is at least clear where responsibility for methods improvement lies.

MACHINERY AND EQUIPMENT

Next, take a look, with the supervisor and works or maintenance engineer on hand, at the production equipment. Is it good enough to be used again in the new layout? How many machines are worn out and require replacement, and will this be possible? Are additional machines required? Will they be the same or similar to those existing? Has the process undergone some technical change which will call for different equipment in future? How far ahead in time are such changes? Have present-day and replacement machines different performances, shapes, sizes, etc.? What are the problems of maintenance and do these (e.g. access to rear, inspection covers, power unit changes) affect the layout? Look at the equipment provided for moving work between machines and processes. How did it come to be used? How much labour does it need? Was its purchase a function of the requirement, or the space available, or the amount of money which could be spared at the time of acquisition? Is it indeed the **right** equipment for its present purpose?

Next, having first checked its accuracy, go over the existing layout plan with the supervisor and engineer. Take notes of any difficulties in manning, installation or power supplies which have arisen. Try to get estimates of the time required for actual dismantling and re-assembly of equipment where this arises. Check for ventilation or similar health and safety hazards.

COSTS

Have the cost figures brought out for the department under investigation. Where possible, ask for these to be broken down into material, labour, capital and running costs (i.e. power, lights, other services). From these, an assessment of present costs can be made, and compared with the future projection for the new layout (see also Chapter 13). Check the charges apportioned or levied in terms of area, so that a comparison can be made later of productive capacity between old and new areas.

BUILDINGS

Look at the physical accommodation in the existing layout. Is it satisfactory? What changes, if any, will be required when considering the new set-up?

Look at floors, roofs (considering the support any of the latter may give to lifting and handling equipment). Look at lighting levels, and try to determine whether these are part of a proper design, or have been added piecemeal to the existing layout. What is demanded by the standard of work or accuracy being achieved? How many of the circumstances of the present layout are affected by the existing building? How should any new layout take account of these matters?

PERSONNEL

Discuss the existing staff with the supervisor. Are these the same people who will be working in the new layout? Is the supervisor himself going to be in charge of the changed situation? What are the requirements in terms of toilets, rest rooms, etc., and how are these catered for at present? Look at the individual workplaces with regard to jobs done: Do people have to stand or could they be seated? If the latter, what effect might this have on the layout? Does the existing layout have an inhibiting effect on communication between individuals, or between operatives and supervision?

The more information which can be acquired from an existing set-up, the better you are equipped to decide what shall be done in the future. But mere observation is insufficient; what is required is an understanding of how the present layout came to its current state and why this is now considered unsatisfactory.

The latter part of this chapter has been written in what might be described as the active interrogative because this is what the investigator should be doing: asking questions, looking at existing situations and methods and finding out why they came to be as they are. Only a full understanding of these matters will enable him to see more clearly the failures and inadequacies of the existing layout and to plan with confidence for the future.

9 | Examining the Data

Many books concerned with investigational method, i.e work study and method study, are content with treating this subject as a questioning technique in much the same way as the various charting techniques are described. There is a particular method by which the subject can be approached, and certain conventions to be followed. Once these criteria have been satisfied, the results of the examination are presumed to be self-evident. Nothing in fact could be further from the truth.

The critical examination of working methods calls for as much pursuit of details as is required by scientific investigation; only the final aim is different.

All investigations commence with the hypothesis that some improvement is possible, or that a solution can be found. It is totally untrue to say that at the commencement of an investigation no one involved has any idea of the probable outcome. If this were so, it would not be possible to plan an investigation, and no conclusions could be drawn from any possible results. The target is always clearly in mind, whether as improved efficiency, increased output or a direct reduction of cost. Critical examination is not simply a technique to be practised, but an introduction to a method of analytical thought. Its great power lies in the fact that very seldom do any commercial or industrial investigations receive such intensive questioning, most people being reasonably content with what often turns out to be a quite superficial level of inquiry.

BIAS IN OBSERVATION

Before we can train ourselves to look as objectively as possible at a situation, we must recognise that pure objectivity can in practice seldom be obtained. All our previous experience tends to force us into making subjective judgements of events: we consciously or otherwise recollect from our memories information of many different kinds relating to the subject under examination. The greater has been our experience in a particular field, the less likely we are to hold an objective view – we 'know all about it'. The idea that the situation may have different features from similar ones recalled in memory is seldom admitted; the circumstances have arisen before, and have been dealt with – the present subject is simply another example.

Not only experience, but education and training will affect the thinking brought to bear on a problem. Mechanical engineers will tend to see solutions to certain problems in terms of machinery, while a degree in social studies might persuade the bearer that the problem is in personnel. It may well lie in neither field, and only a clear objective view will expose the real issues. For this reason alone, it is a good plan to have people from different disciplines working on an investigation. It is seldom possible to eliminate biased thinking, but much can be done to reduce it. The very fact that the investigator is aware of possible bias tends to make him more objective in his approach.

So far we have been looking only at the observer as a source of bias; the observed situation can contribute its share as well. The mere fact of an observer being present can cause change to take place. The extreme example, of course, is the visiting senior officer to a Services unit: any resemblance between the normal routine and that which exists during such a visit is purely coincidental! Royal visits to an organisation have much the same effect. At a more lowly level, the daily visits of a works manager around the factory departments can cause some quite surprising changes of work pattern. A visiting observer seldom sees a situation as it normally exists, so the ideal method is to disturb as little as possible, and get people accustomed to seeing the investigator about. Usually, after a few days, the new presence is accepted, and observation can then start in earnest.

When questioning people, try to avoid asking 'why' as a direct question. The aggressive 'why' always brings up the defensive 'because', and the investigator may find himself receiving information which is either being put forward as some kind of justification, or else being offered something which the person answering the question feels that the questioner would like to hear! Either way, the answers are likely to be far from objective.

QUESTIONING THE EVIDENCE

There have been many attempts to formalise critical questioning, but since the method of use is more a matter of an attitude of mind rather than a specific technique, not many have stood the test of time. In any case, such formalisation is only necessary while we become accustomed to directing our critical faculties towards a specific objective. Perhaps the most useful method so far has been the use of a 'Critical Examination Sheet' which has appeared in various forms, and has been attributed to many authors. An example of this, shown in Fig. 9.1, is a slight variant on one designed some years ago at Imperial Chemical Industries. The slavish filling-in of such sheets is to be deprecated, but at an early stage of learning to think objectively it can be a very useful aid.

THE PRESENT FACTS

The Critical Examination Sheet is divided horizontally into purpose, method, time, position and labour, and vertically into present situation, alternatives available and recommendations.

The examination usually commences with a close look at information collected by one of the charting methods, more frequently a flow process chart. The sequence of events is studied to discover what items are **essential** to the process under review and which are ancillary to these. For example, in the chart shown in Chapter 2 (repeated on page 106 as Fig. 9.2) in order to prepare a cup of instant coffee, only operations 10, 14, 15 and 16, and perhaps 17, are really **essential** to achieve the objective, i.e. a prepared drink. Of these, 14 is the crucial one, and should be examined first. (It is a good plan to shade in or colour these symbols which are going to be submitted to more rigorous examination.) The rest of the chart shows the ancillary actions required **by the present method** to arrive at this point. Many of these depend on the physical layout, some upon the method used, and all will have to be examined to see why they occur and in the sequence they appear.

Although we look at each item individually in this way, we must never lose sight of the fact that the essential elements are all parts of a connected whole, and changes in any aspect of one may affect others to a greater or lesser degree. Now we are ready to start, and the first question (Fig. 9.1) is designed to expose the **purpose** of the activity. Note that it reads 'What is achieved?', NOT 'What is being done?'; the latter phrase implies the use of a particular **method**, while we are interested in the **purpose.** If we can establish this, the next question is 'Why?', and if this can be reasonably answered, the follow-up question becomes 'Is it necessary to do this?' followed by a second 'Why?' If genuinely satisfactory answers can be given to all these,

DESCRIPTION OF ELEMENT ____________________

Reference ____________________

Page ____________________

Date ____________________

The Present Facts		Alternatives	Selection for Development
WHAT is achieved?	WHY?	What ELSE could be achieved?	What SHOULD be achieved?
HOW is it achieved?	WHY THAT WAY?	How ELSE could it be achieved?	How SHOULD it be achieved?
WHEN is it achieved?	WHY THEN?	When ELSE could it be achieved?	When SHOULD it be achieved?
WHERE is it achieved?	WHY THERE?	Where ELSE could it be achieved?	Where SHOULD it be achieved?
WHO achieves it?	WHY THAT PERSON?	Who ELSE could achieve it?	Who SHOULD achieve it?

Fig. 9.1 Method study: Critical Examination Sheet (reproduced by kind permission of I.C.I. Ltd.)

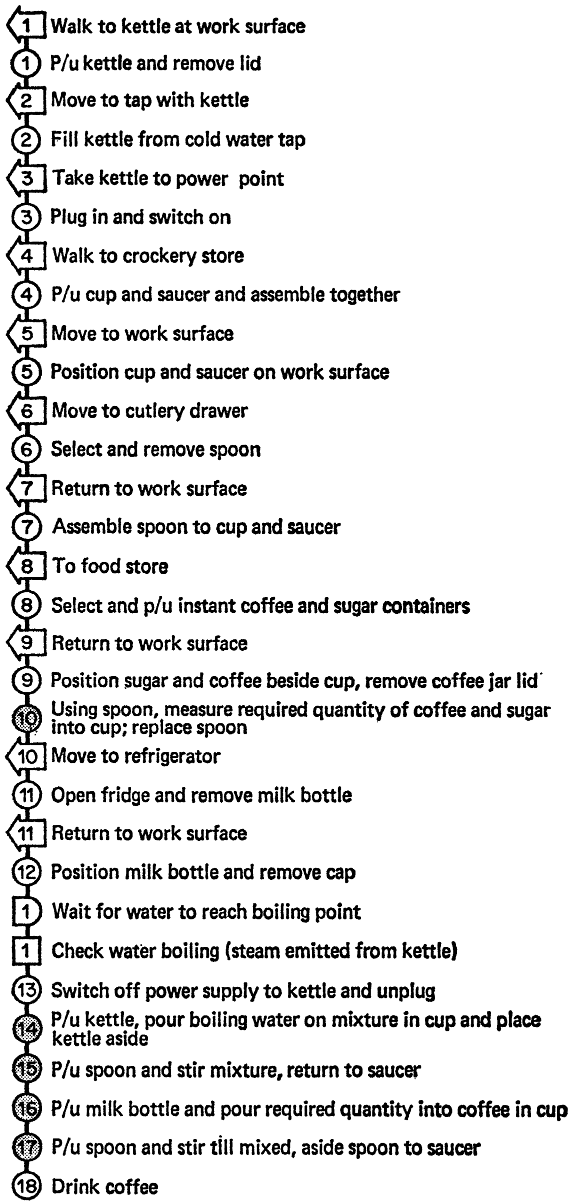


Fig. 9.2. Flow process chart

we write down the information, and pass on to 'How is it being achieved?' The answer here is usually a description of the present method. 'Why that way?' may provoke a wide range of answers, each of which must be tested for validity. (The commonest reply to this particular question is 'We've always done it like that'.) Expansion of questions here may expose training problems, machinery dispositions, etc.

The same procedure is then followed through the other horizontal sections. Questioning must be thorough and exhaustive; real, acceptable answers must be obtained and recorded before passing on to the next item or element. Securing the answers may seldom be possible by consulting second-hand sources; asking a manager will never expose what actually happens at a workplace, so many visits to different parts of the organisation will be necessary before we can be certain that we have definitive information. Failure to be exhaustive will result in an unsatisfactory solution, as the real reason will almost certainly come to light later – and it may be too late. When a situation or process has been examined in this depth, the investigator may well find that he knows more about that area than any other person in the organisation (including the supervisor). Beware of flaunting this knowledge!

So far we have been looking only at the present situation; now we must see what alternatives are open with a view to change.

THE CONSIDERATION OF ALTERNATIVES

If we have truly examined the purpose, and have found that we have inescapably to carry out the action, we must apply a further test. Is it possible to combine this operation with some other or, failing that, to simplify it in some way? So the alternatives, if we cannot write 'Eliminate – unnecessary', may be a change in sequence of events, only carry out some part of it, or combine it with other operations.

Now we see why the purpose must be verified before alternative methods are examined. If we start by looking for a new way of doing a job, we may well come up with a brilliant new method, only to discover later that there was no need to do the job at all in the first place. Additionally, the adoption of a 'bright idea' at this stage of the inquiry should be firmly resisted: problems have a knack of bending to fit solutions, and the brilliant idea sometimes diverts attention from the true objective. So certainly note it down or write it up, but do not attempt to apply it until the rest of the examination has been carried out. Do not be inhibited in the choice of alternative suggestions. Again at this point, bias in the investigation may override consideration of an idea or a suggestion; at this stage it is often a good idea to get as much help as you can. Do not ever say 'We couldn't do that', however outrageous the method may appear to your specialist-trained mind. It just **might** work given the right development.

Sometimes, as a result of this process, the list of alternatives becomes very large. Some of these will, of course, be readily eliminated upon closer examination, but there will still remain a number of possibilities which ought to be considered. Often the choice of alternatives may have to be narrowed down by specialist opinion; the investigator himself may not be sufficiently qualified to differentiate in a highly technical matter. The expert advice should be limited to feasibility and practicality; the final choice may rest as much on available resources as upon economics.

SELECTION OF ALTERNATIVES

The actual choice of one alternative method or aspect of a method against others must usually be made on the basis of economic cost. Note that lowest cost does not necessarily mean the cheapest **method,** but must take account of the resources available. For example, let us suppose that a solution depended finally on the ability to weld two pieces of metal together; the welding method considered the most economical in the circumstances might be using oxy-gas techniques with electric arc welding as the next in line. In the case under review, if the company already holds an electric welding set, but has no facilities for making gas welds, the overall choice will be electric welding, which will not demand additional expenditure and will utilise existing equipment.

There may be occasions where economic cost is not the primary factor in alternative choice, but these are likely to be few. For example, the choice of a method may hinge on the inherent safety of the process, and in such a case the danger to operatives has to be the main consideration, with cost running some way behind.

After a few weeks of using the Critical Examination Sheet, the investigator will find that the habit of questioning purpose and method is becoming more and more a part of routine thinking.

When this stage is reached, the use of the sheet can be discontinued, although an occasional glance through the different aspects of examination may be of considerable help.

DEPTH OF QUESTIONING

The most important aspect of the critical examination procedure is the need to pursue the question of purpose for any activity back to the ultimate cause. Many activities are accepted as a matter of course or simply habit. The investigator will frequently discover that the real reason for carrying out some activity may have ceased to be valid some years ago, but the activity continues unchecked. Finally, it becomes hallowed by 'custom and practice' and the idea of eliminating it just never occurs to any of the participants. (Possibly by this time it has provided jobs for a number of people, all of whom now have a vested interest in keeping the activity alive.) The writer has personal proof of routines initiated for a particular purpose, continuing year after year without check, simply because no one asked 'What is being achieved?' and 'Is it necessary?'

Do not accept reasons given unless they are supported by evidence, and try to pursue the reasons back to first causes. For example, you may be told that the sales department have asked for a particular part, process or item to be continued. Subsequent investigation may show that the customer may be either unaware or uninterested in the particular item, but the sales department may never have checked back to see what the real effects of change or withdrawal might be. Critical examination, properly carried out, is probably the most powerful tool in the hands of the industrial investigator. Like all powerful tools, its use and working must be thoroughly understood by the user, and it must be applied at exactly the right place to be most effective.

10 | Preparing the New Layout

Now that the investigation is well under way, we should be in possession of a large amount of information about the processes we are being called upon to lay out, and the area in which this is to be done. The principal items of information and their relationship in the build-up of the project should now be as under:

1. *Scale Plans, Drawings and Templates*

Depending on whether the existing set-up will have any value or influence on the proposals, a detailed drawing of the present situation, showing plant positions, major work flows, etc.

A completely checked-through outline drawing of the proposed area of operations, with as much detailed information included as is required to fulfil the brief (i.e. if such an item as the positioning of bus-bars is crucial to plant placement, then this must be included; if not, it may safely be left to the works engineers or contractors). (See also under 'Scale Drawings' in Chapter 3.) This plan should have been prepared by one of the methods described in Chapter 3, and be capable of being readily reproduced. If the time between the planning stage and implementation is extended, a further check should be made between the drawing and the area, as changes do take place, often without notification.

A copy of this drawing should also be prepared and made available for use as a discussion tool, using one of the more flexible methods of illustrating plant positions, for example magnetic templates. Small sections of the area which may require greater detailing, and therefore prepared to a larger scale, may also be required.

Templates should have been prepared from existing equipment where this is to be reused, or from manufacturers' drawings and data in the case of new equipment. Sufficient sets of these templates should be prepared to allow the total requirements to be depicted, and every effort must be made to ensure their accuracy. On this may depend the success of the layout.

Remember that not only templates of machinery are required: pallets, handling machinery, stores racking and equipment, stacks of raw material and work-in-progress will have to be represented, and for those jobs which require an area in addition to the equipment (e.g. for material or movement of personnel) a similar template should be provided. Using different colours for the different types of template, and providing a colour key, is one way of distinguishing items. As an additional aid, it is also advisable to write or print on the template what it actually represents, together with the overall dimensions. (This can prevent scaling errors creeping in.) Do not forget scale representations of the personnel required, showing, where relevant, their areas of reach or movement.

2. *Flow Process Charts*

Two flow process charts, material type, should be available at this time: the original, prepared from the existing method already in use in the present situation, and the proposed version, showing the methods to be used in the new layout. (In the case of a new product design, of course, there will be only the proposed method.) The proposed chart will have been agreed by those members of management responsible for production as being a realistic, feasible and agreed method to be adopted. Sufficient copies of this chart should be prepared to allow all members of the working group to examine it.

3. *Work Measurement Data*

Time values for all the jobs to be carried out in the new layout must be available. In the case of new products these may be reliable estimates rather than actual timings, but the use of such techniques as predetermined motion-time systems and analytical estimating should do much to reduce the area of uncertainty. Method changes can similarly be predicted from existing data, with or without the use of synthetics, etc. It is useless to attempt a layout without information of this kind; it is not possible to make the most essential calculations without it.

The number of articles required to be produced multiplied by the time values for the various jobs will give us the number of personnel required, the number of machines required for specific operations or both. In addition to this it will also show us how much work-in-progress we shall need, to keep all these persons and machines in operation. This in turn will give an indication to the preceding and following departments of the increased load they may expect as a result of the new layout.

If no satisfactory work measurement data exist at the time the layout design is required, it will have to be obtained, even if this means the delay of the project. **No satisfactory forward planning is possible without this information.**

4. *Product Information*
Total information about the product must be available, in terms of quantities required, dimensions, shapes and volumes of all components or assemblies forming part of the product. This is necessary in order to calculate the amount of storage or 'feed space' required for a given production level, and its siting in relation to the processes using them. In the case of chemical or coating processes, for example, the correct type of coating or plating must be specified, together with the thickness of paint coating or plating to be applied. All this information has then to be correlated to the type of plant capable of producing the effect required. Other data will be required in particular cases; for example, certain items may not have to be stacked upon each other, or have a high possibility of damage if handled carelessly. All these matters will affect both the handling of the product and its manufacture.

5. *Handling Characteristics*
The material movement analysis sheets described in Chapter 4 should also be available. These will tell us suitable methods by which the material **could** be moved, which will in turn have to be modified by the exact circumstances we are now faced with. These latter will have been considered when we looked critically at the proposed method (see Chapters 5 and 9).

6. *Flow and String Diagrams*
Flow and string diagrams will almost certainly have been prepared for the existing layout, both to highlight its inadequacy and to point the way to future changes. They may have been prepared against individual products or, in the case of larger organisations, in product groups. They will be of value in deciding whether a change of emphasis might be beneficial in certain products or groups; a common series of processes might indicate the possibilities of manufacturing some items on a line or mass production basis, while retaining the flexibility of batch production for the remainder.

7. Safety, Fire and Factories Act Provisions

Copies of the relevant safety regulations relating both to the industry and to the geographical location of the situation under study must be available. Such matters as the minimum space and volume allowable for a given number of persons to work in a particular area, their access to toilets, rest rooms and first-aid points must be known. Copies of any relevant booklets in the Department of Employment series 'Health and Safety at Work', obtainable from any Government Bookshop, should be on hand, together with any relevant British Standard specifications relating to layout and safety. (A list of such publications will be found in the Bibliography.)

A copy of the Factories Act and, where applicable, the Shops, Offices and Railway Premises Act should also be available for reference. A few minutes' examination of controversial points against the context of the Act may well save days of delay in implementation.

Make copious notes of any fire hazards which may be likely to appear, so that these may be discussed at a later date with the local chief fire officer, whose duty this is. The kind of item which may subsequently develop into a fire hazard is difficult to define, but close attention should be paid to any item which involves the use of flammable liquids, either as solvents, adhesives or paint coating components. Large quantities of flammable materials, i.e. wood wool, polystyrene or polyurethane foams, formed lightweight plastic articles, wooden articles, furniture, certain types of fabric, suspended dusts of many kinds, wood, coal, cotton, etc., can all present fire risks in certain circumstances.

Use of particular types of materials handling equipment can sometimes introduce unforeseen safety or fire hazards into a situation: the installation of a floor-mounted conveyor running down the centre of a shop or department can effectively bisect it into two separate areas, thus demanding that each side of the equipment may have to be treated as a separate area for fire precaution purposes. Obstructions against existing fire-fighting equipment may demand their resiting. If this is not all examined and agreed at the time of installation, your organisation may find itself in a situation where the insurers refuse cover in the event of an incident occurring or, worse still, may refuse to pay against a claim on the grounds that they had not been notified of the changed circumstances!

FIRST ATTEMPTS AT LAYOUT DESIGN

As someone who has spent a fair amount of time devising and advising upon industrial layouts, the writer would have extreme pleasure in being able to impart a foolproof method of doing this, preferably backed by a suitable packaged computer programme. Although a great deal of the arithmetical calculations involved in layout can be performed by machines, and in certain ideal circumstances it would undoubtedly be possible to programme a machine to produce an optimum layout, in practice the number of constraints that will appear in a particular real situation makes this approach of academic interest only. There is no doubt that it can be done, but the time spent on preparing the programme and running it a sufficient number of times to cover all the constraints would often take longer than the time allowed for completion of the project.

The first calculations must obviously be the production job time values multiplied by the total product requirement. In this context it is wise to look at the target requirements asked for over the forward period of time in which the new layout will operate. Some 'insurance' is usually necessary, particularly if the forecast of future requirements is made against a rising market. Even if the output figure has been the subject of total agreement between production and sales (a most unlikely contingency), it is reasonable to build into the new layout sufficient flexibility that the agreed total output can be exceeded by 10–15 per cent in emergency.

These basic calculations will show us how many machines of each type are needed, and the number of persons required for a given level of production. Knowing the total throughput required in unit time (hour, day, week), we can now calculate from the figures provided by (4) above the area and volume required for a given amount of material and product, and what this will demand in terms of movement equipment (i.e. so many cubic metres, weighing so many kilograms) and what space this material will occupy on the ground. From the latter figures the templates referred to in the last paragraph of (1) above will be prepared.

Next, a look at the original layout string and flow diagrams, plus a knowledge of the quantities which are expected from the new layout, will bring up the decision whether to change the basic methods of production from, say, batch to line, or even vice versa, for the various product groups. Before making decisions in this area, however, the future labour situation must be carefully considered. Line production usually means specialisation on a particular task, with the corollary that the absence of a worker can seriously hamper production, a situation which is less likely to arise in batch production. Alternatively, should one take advantage of the present-day approaches to labour flexibility, and plan for a 'job enlargement' method, whereby small groups of people are trained to carry out a range of tasks which are then shared equitably between the members? Overall decisions of this kind may well represent an overlap between layout planning and management policy, and may be influenced as much by political considerations as by production requirements.

The first attempts can now be made to position the various types of template (men, machines, material, etc.) on the drawing of the proposed area or building. The planner is guided in this task by an overall recognition of the factors referred to above, and the limitations imposed by the physical constraints of the building or area. (The idea that one carries out this step on a clean sheet of paper to arrive at an ideal layout is subsequently to be covered by a building dies hard, but is totally unrealistic in 99 out of 100 cases.) In doing so, consideration must be given to access to working areas, sufficient gangway or aisle space being provided to permit of personnel, equipment and material movement, and the avoidance of those limitations of the building which may subsequently prove hazards (i.e. drains, roof supports, minimum heights, etc.).

The planner will at this time be in possession of a wide range of information, most of which he will draw upon to make this initial placement. Nevertheless, this is a first attempt in a process which might fairly be described as one of optimisation, and it is highly unlikely that this first layout will prove ideal or be totally acceptable. It must now be tested by being submitted to the working group referred to in Chapter 8.

OPTIMISING THE PLAN

After an introduction by the layout planner of his attempt, accompanied by a full statement of his reasoning and the supporting evidence which he has used, the meeting should be asked to consider the layout carefully and comment upon it. Any such comment should be supported by either evidence or knowledge of its validity, and frivolous or uninformed remarks must be deprecated. Considerable time should be allowed for this discussion, each member of the group being provided with his own copy of the layout proposals. This should present no difficulty if one of the methods referred to in Chapter 2 has been adopted. One reasonable idea is to have the meeting in the afternoon, and recommence it the following morning, so that the members may have an opportunity to consider the layout in detail.

All suggested modifications and comments should be recorded, together with the name of the speaker or proposer, so that subsequent recriminations cannot take place. All such suggestions should be considered by the group, taking into account the effect such changes may have on their particular interests. Minutes should also be kept of this meeting, and the decisions at least circulated. Subsequent to this meeting, the planner may have to reconsider the proposed layout, taking into consideration the points raised; some modification of the first attempt is almost always necessary.

The revised layout is again copied and circulated, and may be the subject of a second meeting, at which the planner will detail his reason for the adoption or otherwise of the suggested changes. This process may have to be repeated yet again in difficult cases, although most layouts can usually be agreed at the second or, at the worst, the third reissue.

FINAL STAGES OF PLANNING

Depending on the allocation of responsibilities on the planner and his team, as referred to in Chapter 8, the agreed layout may now go forward for implementation, or, in the case of a major plan, may have to be submitted to board level for final approval. In either case a full report will now have to be written up, giving details of the reasoning which led up to the proposed layout, and giving details – and credits – for suggested modifications. This report will have in support all those items listed as (1) to (7) above as appendices to the report, together with copies of the existing and finally agreed proposed layout drawings.

If possible, and in many cases this may be a mandatory requirement, the report should be accompanied by an estimate of the cost of carrying out the changes, the analysis being broken down under the headings of machinery, structural alterations, movement costs, etc. This statement will have to be prepared in conjunction with the organisation's accountants, and will entail close liaison with departments such as the works engineers, whose time and labour will be involved. Be careful to state that the figures given are estimates based on the latest available information, and ensure that the date is inserted; costs have a habit of escalating rapidly in a short period of time.

Last, but far from least, when the new layout has been agreed, but before implementation, make sure that all shop-floor personnel are made fully aware of what is happening. This may mean calling all the persons affected by the changes together at a special meeting in works time, and an undertaking to answer all queries about the effect of the changes as far as these can be foreseen. A simplified version of the layout plan could be posted on the works notice board, and a time and date given for anyone who wishes to ask for detailed information from either the personnel department, the union representatives, or both.

11 | Installation of the Plan

We now come to the most testing part of the layout planner's job: the transfer from paper to hardware, and the translation of methods and ideas into a working situation. We must be sure of our responsibilities and authority before we enter this phase; much has already been said about this aspect of the job, but it must be clearly known at this point 'who does what'. Once a piece of equipment is concreted to the floor, or an overhead conveyor is secured to the roof structure, changes become very difficult, if not impossible. Very close liaison must therefore exist between planning, line management and works engineer at every stage of the installation, and constant reference made to the agreed implementation plan. At the same time a degree of flexibility must exist, so that if an unexpected difficulty arises, minor changes can be accepted and agreed. No one can foresee everything!

One of the major difficulties about layout planning which makes it different from most other production-oriented activities is that it is seldom possible to experiment. The proposed layout can be assessed only in relation to the existing situation (if indeed there is one), and until all the machinery, equipment and personnel have been deployed there is no real way of testing the projected plan. (This is not strictly true, of course, because it is possible to produce a good mathematical model of a layout, and programme a simulation on a computer. However, the difficulties of doing this, and the cost, are sufficient to deter most people from attempting it, except for an extremely large or critical project, where it is essential. The technique would not normally be considered for the small-to-medium changes mainly discussed in this book.) Like quality control, layout planning must aim at being 'right first time', and the more research and effort spent in the planning stages, the fewer difficulties there are likely to be on implementation.

PLANNING AIDS: USE OF CRITICAL PATH ANALYSIS

While for a simple layout programme some form of bar chart, which plots activities against time, can be used, the additional advantages of network analysis previously referred to can be clearly shown.

At the commencement of a layout there are many variables which, as the project progresses, become more and more predictable, and these will have interacting effects upon others, either holding up the work as a whole, or accelerating it. The recognition of this kind of pattern, and the way in which these kinds of variables can be shown to have a particular effect, is what makes the critical path analysis (CPA) methods such a valuable tool.

For example, buildings seldom conform to forecasts in construction time. The sequence of events in building is fairly rigid, i.e. foundations, floors, walls, roof, and these are to a large extent interdependent. Failure of a contractor to secure sufficient structural steel to complete a particular building could delay installation of equipment, and the interaction and ramifications of such a sequence would have far-reaching effects. Using CPA, a good estimate can be made of just what will be affected, by how much, and what action can be taken either to compensate or to switch resources to another point. In the early stages of planning the move or layout an arrow diagram or logic structure is prepared. Since very little is known about each step at first, only fairly vague estimates for the time required to carry out each step are possible.

The management usually has some idea of a time-scale that is desirable, for many reasons, e.g.:

1. A major sub-contract for heavy machinery with a long lead time may have to be placed, or has been accepted.
2. Management meetings are infrequent, and a particular meeting is assigned as the most likely one to be able to give financial approval.
3. A forecast date has been notionally fixed, perhaps by the chairman or board.
4. Start dates of buildings may be controlled by planning permission being obtained, or contractors being available.

As an example of (2), a large organisation planning a multi-million-pound project had a management committee which met at thirteen-week intervals (i.e. quarterly). At one meeting they were asked to approve a large contract running to many thousand pounds, which they duly did. However, the estimate included a ninety-day cost-escalation clause, which meant that by the time the approval had been transmitted the estimate had been revised, requiring approval of an additional sum. Owing to the rigid management structure there was no mechanism for calling an additional management meeting, and the approval for the increase was sought at the next quarterly meeting. By this time the ninety-day clause had again taken effect. . . . Unbelievably, this train of events occurred twice in succession before any emergency action was taken to accept the next estimate.

The rather vague estimates of planning event times referred to earlier can be used to give a clear indication of the possibility of success or failure to the management time-scale. It is here that the major advantages of the critical path method can be brought to bear. Before failure to reach a given deadline takes place, various contingency plans, or even a major replanning to give realistic programme dates, can be done – without the emotional panic of possible failure in the air. Clearing problems **before they take place** – perhaps finding a solution – is a more appropriate way of stating the end-product of network analysis at this stage.

The next phase is to refine the estimates. (As time goes by, more details become known and some of the vague areas of the plan become more distinct.) It can be said that a network plan proper is now available: the information displayed is not absolute by any means, but it is complete in so far as is possible. All parties concerned in the layout or move can now be better informed of the requirements of their departments. Engaging labour, moving equipment and individuals – the timing can now be seen on the network. When time-scales alter, owing perhaps to some unforeseen difficulty, the effects on other parts of the plan can be shown immediately.

A network of this kind can also be used to time-scale all other subsidiary activities, although care must be taken to avoid the possibility of clouding the main features by a mass of detail.

Perhaps the major advantage of network analysis in plant layout is that it tends to take the uncertainty of the finish date out of the crisis category and restore it to the context of the predictable. This is a tremendous step forward in layout planning, as there are usually more than enough technical problems to worry about!

EQUIPMENT SUPPLY

One of the most important factors which may disturb the installation phase is that of equipment delivery dates. As referred to above, one of the advantages of using network analysis is that adjustments for such failings can be made; but it is far better to be aware that this is likely to be a problem than to be preparing means to deal with it. Most firms supplying materials handling equipment, for example, have forward orders and are subject to strong competition. There is therefore a tendency to optimism on delivery dates which may well be unfounded. On laying out plant or designing a new department or factory, probably the most critical factor is the date and time when the actual move or layout **can** be carried out. If this is a large project, affecting many machines and people, it will usually be planned to take place during a period of closure, such as annual holidays, or at a time known to be a minimum work-load period. Thus we reduce the latitude of adjustment, and a changeover planned for a particular time **must take place as planned** or we pay a penalty in production, labour cost or both.

Delivery dates are therefore critical, and are one of the key points to be watched in any forward planning. It is not sufficient simply to accept a delivery promise given, say, ten to twenty weeks before the implementation date. Buying and ordering staff must be instructed to keep a constant check on supplies of machinery and equipment, with strict instructions to notify the planning team of any possible deviation from promises. Even if no pressure can be brought to bear upon the suppliers, knowledge of possible failure to meet deliveries will at least be built into the network or other plan. It is courting disaster not to keep a constant check on equipment supplies, whether production machinery or handling equipment.

STOCKBUILDING FOR CHANGEOVER

A new layout or factory move is always undertaken in a mood of optimism. That is to say that most of the production and line management are always hopeful that a planned production level in a new set-up will be achieved within a short time of implementation. Experience shows, however, that this is far from true. For the purpose of this illustration, let us postulate that a new layout has been prepared which is expected to produce at least 50 per cent and possibly

70 per cent in excess of the existing. A date of start-up or changeover has been agreed, and all the problems associated with delays have been accounted for. On implementation, the new department fails to reach even the previous output within the first week, although by the end of the second week the figures are more promising. This result is quite normal and should surprise no one. For the first few days personnel and machinery are in a 'shakedown' period, where capabilities and capacities are being assessed and tested, and it would be totally unrealistic to expect normal output. By the end of the first week of operation the new layout will have been accepted, and over the next few weeks both work-force and supervision will gradually be able to exploit its potentialities. Unfortunately, in many cases, the production of parts or products may have been geared to the forecast, and failure to meet demands will result in a fall-off of production.

If the line management can be made aware that this situation will develop, plans can be made to build up stocks of parts or product to tide over this initial start-up period. Although this is nominally the responsibility of line management, owing to the 'optimism effect' referred to above, the stock build-up may be underestimated. The cost of this pre-move stock build-up may be quite high. If the present layout is working to capacity, it is almost certain that in order to achieve an adequate supply of parts or material, overtime working may be necessary, and the cost of this will have to be taken into account when estimating the cost of changeover.

PHYSICAL IMPLEMENTATION

After the discussions which have taken place with the planning working group (see previous chapter), the team of people concerned with the actual layout of equipment will have been allocated and have accepted their responsibilities. Postulating that all the movement and layout can be carried out by internal engineering staff and labour, it will probably devolve on the works engineering department to make the actual arrangements for the move, with the planning team in close attendance. The works management may at this stage be holding a watching brief, but ready to comment and assist in any case of difficulty relating to production.

Many firms carrying out internal layout changes are inclined to use shop-floor labour on moves, paying them overtime for work over a weekend or shut-down period. Although this may be administratively convenient, it is not always an economic solution. A man may be a skilled operator and conscientious worker, but his capabilities as a machine-mover may be totally inadequate. It might be much more profitable to have a complex move carried out by an outside contractor who specialises in this type of work, and who can be held responsible for any consequential damage. The writer has vivid memories of a large machine tool being handled by two production fork-lift truck drivers during a factory move. The cost of damage occasioned by the almost inevitable mishandling would have paid for a whole team of expert movers, without the subsequent delay in production due to machinery repairs.

If the planner has been vested with the responsibility for layout implementation, it is essential that he should be present and available during the whole of the move. The drawing to which the layout is being prepared should be always to hand, and any last-minute modifications found necessary must be immediately incorporated. If a crisis arises, then an emergency meeting of the working group can be called, and the matter settled as soon as possible. Never ignore a suggested change in the hope that 'it will go away': it won't, and it may bounce back later as a major problem.

THE PERSONNEL ASPECT

As suggested in the previous chapter, all shop-floor personnel likely to be affected by the new layout should have been informed of the objectives of the layout, and what this would mean to them in terms of workplaces and operation. This must be done at two levels: shop-floor supervision and work-force.

Supervision

The implementation of a new layout imposes immense strain upon shop-floor supervision (chargehands, foremen, supervisors). Quite apart from their having to cope with a totally new environment (in the case of a new building or factory move), they will certainly have to accept new or different production methods and the introduction of new or modified machinery, and their work-force may have been either increased or decreased, according to the degree of mechanisation achieved. All these matters will occur simultaneously from the moment of start-up in the new location. Not many people realise what a difficult position the shop-floor supervision is in at any time; management responsibilities, and perhaps split loyalties between workers and the management, impose stress which makes the job of first-line supervision extremely hard. The line management should be consulted first, to gain their opinion on how a particular supervisor will be affected by any changes, and their advice sought about help and support for him during the first week or two. Not only will he have his usual job of attending to the needs of production, which will be particularly onerous during the changeover, but he may have numerous personnel problems brought to him by the work-force. Remember the old adage: 'An ounce of help is worth a ton of sympathy.'

Work-force

There is a tendency on the part of management to underplay the effect of layout changes on the work-force. This is not only unfair, it is downright foolish. A man or woman who may have spent a good proportion of his or her working life in a particular environment may suddenly find themselves uprooted and moved to a new location, with only a minimum of explanation. Of course, if it is a total factory move, to a location many miles distant, then almost certainly steps will have been taken to make the circumstances known. People may have been invited to move with the firm, and assistance, housing or both may be offered as an inducement. But these are exceptions rather than the rule. Only too often, second- or third-hand information filters through that changes are imminent, almost certainly accompanied by the often unfounded fear that some people are to lose their jobs as a consequence. Hence the need for accurate advance information as mentioned in the previous chapter.

It should be clear to the planner that not only is it necessary to ensure that the plant and machinery is correctly placed, but that the amenities and requirements of the work-force are provided for. The Factories Act covers such matters as toilets, washrooms, drying rooms for wet clothing, etc., but the personal comfort and well-being of the work-force requires more than the Act can cover. Women workers have handbags and frequently a second pair of shoes. Men may have lunch boxes and personal gear also. When workplaces have been established in an area for some time, they become as familiar to the occupiers as their own home: indeed, most of us spend more time at our workplace than we do in our own sittingroom. If the management moves offices, we expect our personal filing and our books at least to accompany us. So arrangements must be made for these minor comforts: the women found a place for their bags and so on. Unless there is some good reason, let people take their pin-ups or whatever they regard as personal to their new place of work, or give a good truthful explanation why they should not do so. This is really the job of shop-floor supervision, of course, but they may well be too busy or preoccupied to attend to it. It may seem trivial in print, but it is very important to the persons concerned, and could well make the difference between a ready acceptance of the change and a grudging acknowledgement. Make sure that tea-breaks are laid on from the first day, or vending machines positioned before the department is open for work. Ensure that either notices are placed or everyone is told where the various amenities and services are to be found – clock cards, toilets, cloakroom, vending machines, etc. – before they enter the new area.

START-UP

If the planner's responsibilities require him to stay with the project during the start-up period of the new layout, he may well find himself acting as supervisor's assistant during the initial day or so, and this is no bad thing, provided he is personally acceptable and on good terms with the supervision. There is much at this stage which he knows and the supervision does not: the exact relationship of each piece of plant and machinery, and the **reason** why it has been positioned there and nowhere else. If the layout is successful, the intention of it will soon become apparent, but it may not be immediately obvious. So no one should be at all surprised at the apparent chaos which will reign on day 1 of a department or factory move. For the first hour at least the work-force will be familiarising themselves with the area, their personal work station, examining any new equipment and greeting friends, etc. No attempt should be made to put a brake on these activities beyond the normal ones of safety and good housekeeping. Slowly, almost experimentally, the department will come to life, work will start to move, and by the end of the day people will be settling down. Day 2 will get off to a better start, and there may be signs that the tempo of work is creeping back to normal.

Usually, by the end of the first week, output per head should be reaching at least the level of the old location or set-up, and should then steadily climb. Probably by the third week the benefits of the new layout will begin to show in the shape of increasing output.

This pattern is one of the reasons for the stockbuilding described earlier, and stock levels should be designed to take this slow build-up into account. It is often difficult to get line management to accept that this pattern will occur, especially if they have had little experience of moves or re-layouts up to now, and this is one of the reasons why the supervisor needs all the support and help he can be given during the start-up period.

In most cases the responsibility of the project leader will end at this point, although there are further duties which may be asked of him and which are referred to in the next chapter. But the traumatic point is now over; if the new area comes to be regarded as a success, there is an immense personal satisfaction to be gained from the knowledge of a job accomplished.

12 | Keeping it Going

How far the project leader or planner needs to go along this road depends entirely on the development of responsibility which was advocated in Chapter 8. If the course of preparing the plan and getting agreement of all parties has been taken, and at this point the actual implementation has been passed over to either line management or works engineer or both, then the planner has no further responsibilities and the information in the rest of this chapter is redundant.

On the other hand, if the planner and his team have been vested with the responsibility for seeing not only that the agreed plan has to be adopted, but that they should ensure that the recommendations are carried through, then much more is required.

MAINTAINING THE PLAN

'Plans are not self-achieving.' Whoever said this must have had some considerable experience of factory layout, for in no other field is the truth of this phrase brought home so rapidly! The fact that a large amount of plant and machinery has been laid out to an agreed plan is no guarantee that it will automatically produce the required results.

At the time of the original definition of responsibilities it will, or should, have been clearly laid down at what point in the progression of the layout responsibility for the continuing function of the new set-up passes from the planners to the users. Thus after the full implementation and start-up, the planning function may be reduced to a watching brief to ensure that the methods agreed are being maintained. This calls for a high degree of tact and diplomacy, since the production and output will now be in the hands of line management who will view with suspicion any 'interference' with their function.

Points to watch are the correct function and operation of machinery and equipment, which have been incorporated in the new layout and which were not in the original system. Unfamiliarity with controls, unwillingness fully to utilise unknown capacities or lack of recognition by the supervision or operatives of the production potentialities of a new design can be due to lack of knowledge, insufficient instructions or lack of confidence in the equipment. If this situation is observed, it will require careful and tactful handling. Consult first with the supervisors, making sure that they personally have been fully briefed. Any failings here will have to be tackled first, with the direct intervention of line management as the communication channel.

Provision of printed instruction sheets, handbooks or a short talk by the installation engineers or manufacturers may be necessary. It is often taken for granted by the engineering staff that a particular piece of machinery has a function which is immediately obvious, and therefore no detailed instructions have been given or prepared. If such equipment exists and no specific instructions have been passed down, this is the kind of problem which the layout planner should be concerned with. Make sure that the supervisors understand the function of any such equipment and have adequate information on it so that they are in a position to pass this on to the work-force.

As an example of this kind of problem, a firm producing fractional horsepower motors changed from boring out sleeve bearings on a simple machine to a proprietary boring machine with a high rate of production. The tolerances of the work produced on this machine were much closer than the previous machine, and to some extent were ambient-temperature related. A change of 5–10° in ambient temperature could affect the tolerances sufficiently to put them outside acceptable limits. The supervision spent much time trying to make compensating adjustments for this, without being aware of the basic cause. When the production engineering department was approached, the matter was quickly put right, but their first comment was that they thought 'everybody knew' that the new type of machine was critically affected by temperature changes.

Perhaps no one is in a better position to look at the overall changes than the person or team who has prepared the plan. Despite constant liaison, and even if total co-operation has been given throughout the installation and start-up phase, supervision is often unsure of the capabilities and indeed the viability of the new layout. It is the job of the layout planner, if vested with responsibility to this final stage, to act as helper and adviser to the supervision, until at least the planned output has been achieved. This may mean a constant attention to the details of the new layout: to see that the machinery and equipment provided is running and operated in the way it was designed; to see that procedures for control and documentation which have previously been agreed are being carried out. At the same time as this overall watchfulness is being shown, an eye must be kept on the actual procedures to see that they do in fact fully represent the original plan. Minor modifications to both plant and procedure may still be necessary at this stage, and the planner should be sufficiently flexible in his approach to accept this.

As the new line, department or layout begins to conform to the forecast, and the output reaches the first design level, the project leader and the planning department should begin to disengage themselves from the day-to-day running. Their responsibilities may be coming to an end, but their willingness to co-operate and discuss problems which may arise with the production team must continue. The continuance of amicable relations between the planners and production after the introduction of large-scale changes is one of the surest signs of a successful installation. Never lose sight of the fact that the final result can only be as good as the layout plan **plus** the efforts of production workers and supervision combined. You can have the best theoretical layout in the world, but if the forecast work flow is not forthcoming, it is a failure.

CLEARING UP

Preparing a new production layout is a very satisfying job, but what of the previous or still extant production area? Obviously, what happens here will depend on the kind of layout which has been replaced:

1. Totally outmoded set-up, from which no equipment is required for the new plan.
2. Partial utilisation of either area or equipment from previous situation.
3. Rearrangement of existing plant within present location, with perhaps a number of new items.

Under (1) fall those situations where a totally new factory or layout is provided, and the equipment or machinery from the original set-up is of little value, either from age or as the result of technological change, or where a building such as a stores or warehouse is being given up which includes built-in fitments which it would be useless to remove.

In the first case arrangements may have to be made to dispose of machinery and equipment either to specialist firms, public auctions or for scrap, depending upon the assessment of their usefulness. If the building is to be either reused or disposed of, this action must be set in hand at the same time as the start-up of the new layout. Often no authority is sought for disposal of such items until long afterwards, and by this time some of the items may have deteriorated so far as to be valueless. This is not to say that these matters **should** be the responsibility of the layout planner, but they may become so, often by default. In any event, instructions will have to be given for a general clear-up after removal, whether the building or area evacuated is to be reused or not. Rubbish and old fitments, often of wood, can soon become a fire risk.

In situations (2) and (3) above, most of the decisions about reuse of plant and equipment should have been made under the examination of resources discussed in Chapter 8, although any surplus equipment will not be available until after the move takes place. This should give plenty of time for arrangements to be made about future use of surplus or outdated equipment. A list of the equipment which will be made redundant by the new layout should be prepared, giving all the details of type of machinery, output capacity, etc., and circulated to those departments who might find it useful either as additions or replacement to their existing equipment. Needless to say, such a circulation list must be prepared in conjunction with the works or production engineering function, so that a fair estimate can be given of the usefulness of the machinery or equipment. In large organisations such a list may bear a nominal 'purchase' figure which will be charged against the budget of the 'purchasing' department, the 'credit' so obtained being used to offset the cost of the new layout.

At this time any fixed-path handling equipment which is no longer required in the vacated area should be dismantled and removed. There is always a tendency to leave all conveyor track and similar equipment in position unless its removal is vital. At a later date it will be much more difficult to remove, and the job will certainly be more expensive if it has to be done later at short notice. Another aspect of re-layout which should be watched is the removal or re-routeing of service pipes or ducts, i.e. water, steam, compressed air, etc. As an example, in a plant using a large amount of process steam, a building approximately 20 m by 10 m was cleared of equipment consequent upon a re-layout. The various service pipes were plugged off after removal of equipment, as the area could not be isolated from the main steam supply. A check on subsequent unaccounted-for steam losses revealed that leaks and 'dead' lengths of pipe were causing a fairly high level of power wastage, and an investigation was carried out. Owing to many rearrangements and changes in the department over the years, the service piping had become a tangled mass. An isolating valve was fitted, and over 150 m of 37 5 mm and 25 mm steam piping were removed from the area, in addition to many metres of similar and larger sizes of water piping.

It may be thought that details such as the above are entirely the province of service departments or works engineering, and this may well be so in the larger organisation. But certainly in the smaller firm the pressure on limited resources is so great that jobs of this character may have to be allocated to an outside contractor; the layout planner may well have the responsibility not only for preparing the new set-up but for clearing up as well.

13 | Does it Pay?

This final chapter is an attempt to bring together those financial aspects of layout which may be called into question after the move has taken place. Very seldom (except in regard to building erection costs) is a financial limit placed on the estimated cost of a move or layout: the event **must** take place in the interests of production or continuing business, and the matter of counting the cost will come later.

No attempt will be made here to go into accounting methods or detailed costing systems. There are many excellent books available on this subject, and a companion book in this series by C. Aydon, *Financial Control in Manufacturing*, will enable the inexperienced to get a grasp of the essentials.

Costs are always rising, and with regard to any building which has been erected for new layout it is safe to say that it will always cost more than the original estimate. The same is likely to apply to any machinery purchased, particularly if the delivery period is extended. Many estimates and draft contracts have a ninety-day review period, after which time any changes have to be notified and renegotiated. This is vitally important in relation to machinery and handling equipment, where forward delivery dates of sixteen to twenty weeks are not uncommon. These rising costs must be allowed for, first at the estimating phase and again at the final cost summary.

So we have two points in a project where cost projection will be required: the first immediately prior to approval, as mentioned in Chapter 10, and the second as a summary of costs where the estimates can be compared with reality at the successful conclusion of the work.

In materials handling and plant layout it is very seldom that recoverable returns in the form of cost 'savings' can be clearly defined. In many cases of 'increased productivity' claims it is possible to calculate savings in respect of increased output or, alternatively, reduced labour costs. In the case of changes in layout or handling there may well be vast increases in output, but not directly attributable to a single cause, e.g. 'labour savings'. It is more likely that as a result of the reorganisation there is less physical movement of materials or work, that a reduction of the amount of work-in-progress will have taken place, and that output will have increased as a result of improved layout or equipment. But accountancy systems are generally rather inflexible and, as stated earlier, many of these items will be difficult to separate out.

It is therefore essential that the planner should have a good understanding of the methods of cost and financial accountancy as used in his particular organisation. A close liaison with the accountants will not only make his own work easier, but will ensure that any figures he produces will be acceptable to the accounting function. Find out where the cost centres are located in relation to production and handling and try to ensure that savings in any of these fields can be related to those centres.

Some of the more important aspects of accounting in relation to purchase of plant or installation of handling equipment are referred to below, but the list is by no means comprehensive. Many of the accountancy methods of 'recovering' cost against expenditure are related to the 'write down' period given for the depreciation of items of capital expenditure, and these must be fully understood and agreed.

BUILDINGS

It is seldom that the 'write-off period' for a new building is less than twenty-five years, and it may be as high as fifty. However, certain classes of specialised building may well have a shorter 'life' than this. Capital costs of buildings are seldom placed against the cost of a change in layout, although from an accountancy point of view this may well be important. Make sure that there will be no misunderstanding here.

PRODUCTION MACHINERY

There will be varying write-down periods for different classes of machinery, dependent upon their use and characteristics. Some machinery can almost be classed as 'expendable', but others may have a 'life' of ten to twenty years. It is important to know what this life is, and how it will affect production costing.

HANDLING EQUIPMENT (MOBILE)

This category refers to wheeled internal transport vehicles, covering fork-lift trucks, tractors, hand and powered pallet trucks and similar equipment. Some firms regard this equipment in the same category as external transport vehicles and estimate a 'life' of three to five years. Others take the view that as such vehicles are not subject to the same stresses and handling as road vehicles the working life may be as much as ten years, although in most cases this would be well beyond normal expectations and usage.

HANDLING EQUIPMENT (FIXED)

This covers such items as conveyors, cranes, racking and possibly box or cage pallets.

This class of equipment often proves difficult to allocate in accounting items. Fixed-path equipment such as conveyors or overhead cranes tends to be regarded more as capital items than as 'expendables', and working lives of ten, fifteen or even twenty years are not unusual. Racking and box or cage pallets are less rigidly regarded, but may well have write-off periods extending up to ten years.

So far we have only been considering the payback or depreciation method of allocating cost against time. This is certainly the commonest in British industry, because the taxation system accepts the principle of a 'life' of cost against time, but it is by no means the only method. Many firms, particularly those influenced by American accounting methods, use discounted cash flow where the earnings rate of a project is spread over its useful life, allowing for the effect of the timing of cash flows. The earnings rate is then that rate at which the net present value of the project is zero. Using this method, it is simple to justify the introduction of new equipment, if the latter can be shown to have a higher earning rate than its predecessor.

WORK-IN-PROGRESS

The amount of work-in-progress can have a powerful effect on the costs of operation. Work-in-progress can be counted as a financial asset in the company's accounts, and therefore a significant reduction in holdings can be shown to be highly profitable. Handling and layout investigations often lead to this desirable result, but when it comes to showing a saving in cash terms this frequently proves more difficult. One of the principal reasons for this lies once again in the accounting methods used. By placing minimum value on work-in-progress, i.e. regarding it as little more than raw material until it reaches the final production stages, a quite low figure can be shown for total holdings. On the other hand, if value is added to the raw material in terms of labour and production cost at each stage of manufacture, a totally different set of figures will emerge. In the first case, reduction of the amount of work-in-progress will have a negligible effect; in the second case, quite valuable savings could accrue. So it is essential to know the way in which work-in-progress is evaluated in a particular situation, and only a good knowledge of the local accounting methods will expose this.

COST ESTIMATES

Returning now to the estimate of cost usually required before planning approval of any changes can be given, we can see more clearly what is involved and the sort of information which we shall have to provide. The report should show what the expected costs of the installation are likely to be, together with the cost of any equipment required. Where possible, this should be related to the projected production expected from the new set-up, and a comparison drawn with the existing position. It may be that at this stage of the plan two or more possible methods of working have emerged. Where this is so, a direct cost comparison should be made, and a reference to the report indicating why one method should be chosen rather than another.

The estimate should be broken down under different headings designed to fit in with the local accounting system, e.g.:

Investment Costs

Invoice price of new equipment.

Installation charges (internal or contractor).

Facilities required, e.g. charging bay, fuel stores, pumps (where these are not already provided for other reasons).

Modification to existing equipment.

Structural or other alterations to permit full use.
Spares holdings required.
Estimate of any design work required before installation.

Fixed Charges
Depreciation (showing proposed period).
Interest on investment (depending on accounting system).
Insurance costs (where directly attributable to the changed situation).
Personnel required over and above existing labour for maintenance or supervision.

Variable Charges
Operating personnel (directly related to new equipment).
Cost of operation (fuel, power supplies, lubricants, etc.).
Estimate of additional labour charges.

These cost estimates must be agreed with the accounts department at the time of submission, so that when comparison is made between estimate and subsequent actual charges there will be a basis for agreement. This step should never be omitted, for once the cost figures in a report depart from the actualities of the accounting system, they will be regarded with suspicion, whether this is justified or not!

Costs of layouts must be related to a reasonable period of operation: most production changes and innovations are expected to 'pay off' in a relatively short time, i.e. six months or a year. A new layout should not be made subject to this sort of assessment, since in most cases many of the investment and fixed charges relate to items which would not normally be charged against production costs, i.e. capital cost of buildings and heavy machinery. Again, the reason for the changes may be political or geographical, perhaps due to failure to obtain planning permission for an existing site, or the desirability of opening up in a development area with its grant-aided advantages. All these matters must be taken into consideration when calculating the final cost of any changeover. The running costs must be calculated only from the same factors as were used in the original situation if a true comparison of the improvement is to be made, and to do this requires a full understanding of the production costing system. This will then leave the investment and fixed costs to be apportioned in the financial accounts in accordance with normal practice, and this would not usually fall within the province of the project leader.

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