3 Technology: A Social Product

One of the most immediately obvious signs of variety between organisations is their production of a wide range of different artefacts, extending to all forms of manufactured finished goods, components, refined natural products, communication hardware and software, management consultancy and medical, welfare, educational, leisure and other services. Yet this variety can be interpreted in terms of a common model which focuses not on the products but on their production. All organisations have a core, illustrated in Table 3.1, which comprises the acquisition of inputs of natural, human, financial and fabricated resources and their transformation through a variety of ways

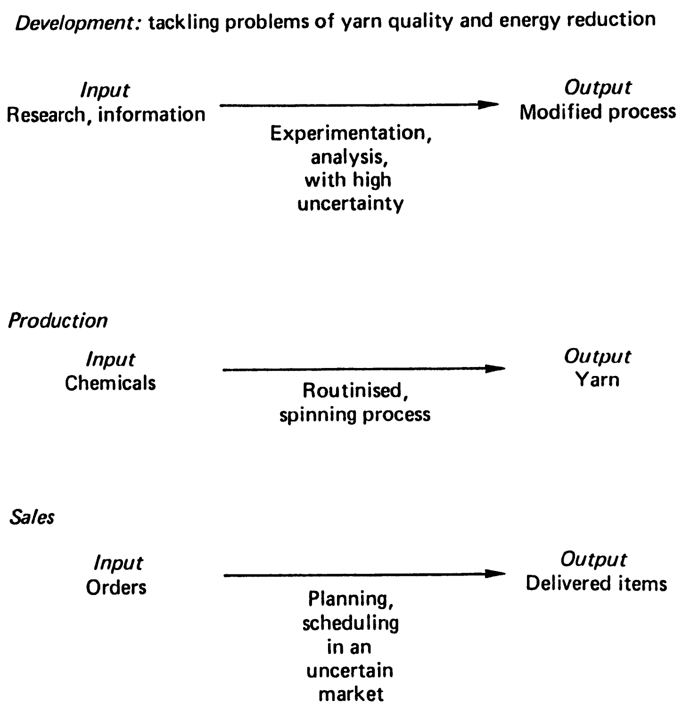
Table 3.1
Organisations as Arenas for the Transformation of Inputs into Outputs

Inputs into products and processes	*Transformation processes*	*Outputs of goods and services*
Raw materials	Labour	Finished products
Energy		
Manufactured components		Components
Data/information	Skills	Information
Cash	Data	Services
Services	Plant	Skills
Skills	Energy	Knowledge
Knowledge	Machinery	Experience

into the production and distribution of outputs of goods and services. For example, people in an electronics factory use mechanical and computer-controlled equipment, skills, labour and knowledge to transform raw materials, energy and components into finished consumer products. Doctors in a hospital admit patients and try to transform them through medication, surgery and advice into healthier people. A construction company assembles supplies and skilled people on a new site and they use tools, plant and energy, labour and skill to transform the derelict land into a new office building.

The overall 'transformation process' in any organisation involves a variety of integrated smaller workflow sequences which cover the identification and acquisition of appropriate raw materials through to the distribution of the outputs. Figure 3.1 takes the example of a man-made-fibre plant and illustrates three very different transformation processes which characterise the development, production and sales functions. This variety means that technology, as Mohr (1971) describes it, is essentially a multidimensional concept. For example, British Rail has an apparently fairly homogeneous

FIGURE 3.1
Functional Workflows in a Man-made Fibre Plant



product range, yet displays great variety in the technologies it employs. There is unit production for the overhaul of preserved steam locomotives, small batch production for prototype power cars being built for a new type of train, and large batch production for the construction of mainline coaches, not to mention the variety of technologies used in maintenance and development.

3.1 Technology: The Concept

The term technology is used in this book to encompass the materials and processes used in transforming inputs into outputs, as well as the skills, knowledge and labour that are part of their present operations and which enabled the technologies to be developed in the first place. Technology thus has both hardware (materials and operations) and human (knowledge) components. It is the product of human endeavour, and its operation is dependent on a degree of human co-operation and involvement. This definition emphasises that technology cannot be seen as either a 'neutral' or a single 'given' force in organisations (see, e.g., Dennis, Gillespie and Mornsey, 1978). For a start it appears to affect some people adversely in the sense of giving them boring, repetitive jobs, or grimy, greasy working conditions, or carcinogenic materials with which to work, while bestowing on others beneficial effects in the form of interesting, exciting work, a clean environment, good share dividends and a flexible working day. But more fundamental than the manifest inequalities of its effects, and indeed underlying these inequalities, is the fact that technology is created by and used by people who, as we have seen in previous chapters, have particular interests which they are pursuing through their association with organisations.

In the preface to his book, *America by Design*, which traces the history of engineering in the interrelated contexts of academia and industry, David Noble eloquently summarises this definition of technology:

> Although it may aptly be described as a composite of the accumulated scientific knowledge, technical skills, implements, logical habits and material products of people, technology is always more than this, more than information, logic, things. It is people themselves, undertaking their various activities in particular social and historical contexts, with particular interests and aims. (Noble, 1977, p. xxii)

Noble documents how engineers designed the technical systems which formed the basis of manufacturing industry in the nineteenth and twentieth centuries and how as managers, educators and social reformers they also designed the work organisation and, in a sense, a whole new social order.

The production processes used depend on the outcome of debates about what is available in terms of knowledge, expertise, ability to pay, materials and energy, and what is seen to be desirable, appropriate and advantageous.

For example, imagine a situation in which process and product innovations are being considered. R & D has a vested interest in pushing for technical sophistication; production an interest in a system which facilitates easy retooling; sales an interest in producing a high-quality, up-market product; and the operators' trade union an interest in preserving jobs and securing the extensive retraining of people who are redundant. Decisions about the purchase of new hardware, changes in the way work is done and relationships structured, as well as the practical implementation of such decisions, must be understood in the organisational context that has been described in the previous chapters. Just as structure is a tool for the achievement of interests, so too is technology. But a problem arises, both for practitioners and analysts of organisations, because many participants do not share this view. This is particularly the case for many people who have had a fairly narrow education in science and engineering and who feel that scientific values and discoveries and their application merely reflect the inexorable and somehow neutral or independent march of progress. Engineers may consider that they merely advise on what is technically the best within the financial limits prescribed. Financial advisers may say they are merely ensuring that costs are kept within budget. In this way each group may say that the selection, creation and operation of technology results from 'rational' judgement which is somehow universally the 'best' in the circumstances. For such an analysis to be valid, organisations would need to be unitary, consensual systems with fairly comprehensive knowledge about alternative, as well as the chosen, technologies. Furthermore, simple linear relationships between a few variables would be the predominant type of interaction between parts of the organisation.

A contrary view is presented in this book. Organisations are shown as encompassing several different interest groups and being characterised by many variables which are linked in an interactive and uncertain way (see Introduction).

In an effort to defuse the myth of technology as neutral and to summarise some of the important findings of the many studies of technology in organisations, the remainder of this chapter will deal with the relationship of technology to developments in work organisation and management structure. This involves an examination of the work of those who have tended to see technology as 'given' or 'neutral', requiring human adjustments to its demand. The limitations of this form of analysis will be discussed with the object of generating a more realistic picture of the opportunities and constraints that are created (by people) when decisions about technology are made and implemented.

3.2 Technology and Work Organisation

The concept of technical controls on job requirements and job performance was introduced in Chapter 1, when it was shown how the design and operation of technical hardware affected levels of discretion, type of supervision, and degree and type of specialisation. For example, on a mechanical assembly line, job-holders undertake repetitive activities in a carefully controlled and monitored working environment in which there is a great deal of task fragmentation. An extreme statement of the meaning of this type of technology for operators is given in Beynon's *Working for Ford* (1974). In contrast, a technician in a biochemistry development laboratory may have a great deal of discretion, be subject only to loose supervision, and be responsible for carrying out a whole range of tasks which she considers necessary for the accomplishment of overall work objectives. The three elements of discretion, supervision and division of labour are often collectively referred to as 'work organisation', and this is the general term that will be used here. A selection of classic but now somewhat outdated studies will be discussed as a prelude to considering contemporary approaches which, among other things, focus on developments in new microelectronic technology.

The Tavistock Institute and socio-technical systems

A group of researchers working at the Tavistock Institute of Human Relations pioneered modern studies of the implications of technology for work organisations (see Trist, 1981, for a summary). Taking the analogy of biological organisms, they developed the concept of organisations as socio-technical systems in which inputs and outputs to and from the environment were exchanged. Rice (1963) argued that any enterprise has a multiplicity of tasks which are performed simultaneously, but one of these is *primary* in that its primary task is generating sufficient money to stay in existence. The more precisely the primary tasks are defined, the greater the constraints on task performance. In achieving the primary task, organisations utilise both a technical system and a social system, each of which sets requirements for the other. The extent to which the requirements are met to the mutual satisfaction of both systems was reflected, the Tavistock researchers argued, in production effectiveness.

Some of the most important Tavistock work was conducted in the Durham coal mines and weaving sheds in India, where managers were advised that they could and should choose a form of social structure that was appropriate to the technical system. Furthermore, when technical changes were being made, the designers of technical systems should pay attention to their social implications. Readers should see Trist *et al.* (1963) for a full description of the work undertaken in the Durham coalfields. Table 3.2 provides a brief account of the changes made in the technology and the social system, and shows that an incompatible mixture of technology II and social system II was associated with a loss of productivity and poor morale. When the social system was changed to one which was more compatible with technology II, the coal mines were more successful in terms of indices of both production and morale. Thus

Table 3.2
Summary of the Research and Consultancy Programme Undertaken by Members of the Tavistock Institute in the Durham Coal Mines

Phase 1: Traditional system
Technology I: traditional handgetting of coal
Social System I:

- work groups of six assigned to particular locations, with two members of the group attached to each of three shifts;
- work group shared an equal payment bonus
- self-regulating and largely self-selected, cohesive work groups
- 'deputy' (supervisor) acted more as a provider of services to the group than as a direct controller

Phase 2: Technical change was introduced
Technology II: mechanical conveyor belt introduced so that coal face worked as a long wall. This change created, by default, a 'new' Social System II:

- established social system destroyed
- tasks divided up between workers
- great problems of supervision and control
- deputy 'forced' to take much more control of the workforce which was resisted

Results of interaction between Technology II and Social System II: loss of productivity; poor morale (which incidentally was exacerbated by the poor economic conditions of 1930s).

Phase 3: Development of Social System III: composite method (as a result of Tavistock consultancy). In place of formal division of labour, a team of forty miners was established with greater 'structured interdependence' between the sub-groups. Workers carried on with the next sequence of work when their own was completed. Development of common pay not based on fixed rate and production bonus. Greater self-regulation in working group; management no longer had to provide all control and co-ordination.

Steady state: Interaction of Technology II and Social System III: more successful in terms of production output, costs, absenteeism, flexibility in division of labour and generation of mutually supportive, semi-autonomous work groups which Tavistock championed here and elsewhere.

the Tavistock analysis showed that both the technical and the social system of an organisation can be seen as the subject of choice, and that decisions made in one area should be compatible with those made in the other. They felt that, unlike mechanical systems, socio-technical systems could achieve a steady state from differing initial conditions and in different ways. No longer, they argued, could it be the technologist's job simply to design the technical system, the personnel department's job simply to organise it, and the finance department's job simply to identify the financial constraints and opportunities. The technical system comprising the equipment and production layout, the work organisation comprising the structure of relationships between people, and the economic organisation comprising the financial constraints and opportunities were, the Tavistock group argued, all interdependent – and subject to choice.

The social implications of different production systems: Blauner, Goldthorpe, Gallie

In spite of the work at the Tavistock Institute, which appeared to throw a large question mark over the idea that technology as such could have universal deterministic effects on work organisation, findings from several significant studies nonetheless suggested strong links between technology, work organisation and workers' attitudes.

Blauner (1964) concluded from a study of four USA enterprises using craft technology (print), machine-minding technology (textile mill), assembly lines (car plant), and continuous process technologies (chemical) that the type of technology had a profound effect on work organisation and workers' attitudes. He found that discretion and satisfaction were higher in enterprises employing unit or process as opposed to large batch or mass production systems. Conversely he found that management control and worker alienation (which he defined in terms of feelings of meaninglessness, powerlessness, self-estrangement and isolation) were higher in mass production. Blauner did note, however, that the effects of strong local communities could counterbalance the negative effects of machine-minding to some extent and could lead to higher than expected levels of satisfaction if workers belonged to strong social groupings which transcended the boundaries of the firm. In short, he felt that the development of continuous process technology, particularly in contrast to mass production systems, would increase workers' control over their work, reduce structural divisions between workers and management, decrease the likelihood of a minute specialisation of tasks, and increase the likelihood of team work. Labour would become a fixed rather than a variable input, and since, he argued, managers would want to keep their experienced workforce, they would be generous in their terms and conditions of employment. In this way Blauner argued that many of the sources of resentment and alienation felt by workers would be removed.

Accordingly, workers would become more committed to their employing organisation, less interested in militant trade unionism, and more compliant towards management.

Woodward (1965) also found in her study of 100 enterprises in Southern England that process technology appeared to be associated with higher levels of social integration. With developments in technical control systems, she argued that the need for close supervision was eliminated and therefore better relations were facilitated.

Goldthorpe *et al.* (1968) were critical of conclusions which drew a direct causal connection about the relation between technology and workers' attitudes. In Chapter 1 their concept of 'prior orientations to work' was discussed, and it is this which they regarded as the crucial link between technology and attitudes. Their studies of workers in a car plant, ball-bearing factory and chemicals plant did not lead them to dispute that technology was a major factor in affecting the level of intrinsic satisfaction derived from jobs, the facility to form cohesive work groups and different forms of supervision. What Goldthorpe *et al.* did dispute, however, was that one could immediately draw conclusions from these relationships about individual employees' attitudes and values. This relationship, they argued, depended much more on the workers' 'prior orientations' to work and thus their present expectations:

> For instance, technological constraints on collaboration in work tasks or on work group formation generally will be far less likely to lead to frustration and pervasive discontent among workers for whom work is an essentially instrumental activity than among men who are in fact seeking for 'social' satisfactions in their employment in addition to economic returns. And, similarly, technologically necessitated methods of control of a bureaucratic and impersonal kind will tend to have far more disturbing and dysfunctional consequences for the latter type of worker than they will for the former. (Goldthorpe *et al.*, 1968, p. 183)

Wedderburn and Crompton (1972) took a somewhat middle view in this debate. In a single case study of Seagrass chemical works they concluded that production tasks and the control systems associated with them did create situations where the actual experience of work and supervisory relationships differed markedly, but that the importance attached to these different experiences did bear a relationship to the workers' expectations and prior orientations.

In contrast to Blauner and Woodward, Gallie (1978) tells us that Mallet (1969) developed a thesis that new forms of process production and the use of electronic control systems, far from easing relations between workers and managers, would stimulate workers to see the indispensability of their skills to management and to recognise that the controls upon them were less irrevocably tied to features of the production technology. Thus Mallet argued that technological development, far from leading to more harmonious industrial relations, would prompt a resurgence of working-class solidarity, class conflict and struggles for control within the enterprise.

The empirical evidence to support these divergent views was thin, and consideration of this issue led Gallie to conduct a study of two similar pairs of BP oil refineries, one pair in France and the other in England. Within each country one refinery was relatively backward and the other relatively advanced in terms of technology. His main concern was to explore whether technological developments had major and direct implications for managerial control and industrial relations in the plant, or whether wider social, cultural, institutional and historical patterns were equally or more important in effecting these things. Gallie's study showed that modern process technologies were not devoid of sources of grievance, although these were focused less on boring, repetitive work, and more on the structures of shift work and manning levels. In general he concluded that:

> the nature of the technology *per se* has, at most, very little importance for these specific areas of enquiry. Advanced automation proved perfectly compatible with radically dissimilar levels of social integration and fundamentally different institutions of power and patterns of trade unionism. Instead our evidence indicates the critical importance of the wider cultural and social structural patterns of specific societies for determining the nature of social interaction within the advanced sector. (Gallie, 1978, p. 295)

The implications of the microelectronics revolution for work organisation

Just as developments in process technology in the 1950s and 1960s stimulated interest in the implications of technological change for work organisation, so more recent developments in what is generally called 'new technology' have sparked renewed interest in this subject. The generic term of 'new technology' is used to describe processes which depend on miniaturised electronic circuitry to process information. It is found in commercial organisations such as banks and building societies, where it can have a large impact on counter service, credit control and investment policy; in retail enterprises, where it facilitates the integration of cash desk data and stock controls; and in manufacturing industry, where its ultimate manifestation is in the development of flexible manufacturing systems in which activities of design, tooling, assembly, sales and quality control can all be streamlined into one system.

Microelectronic technology can process information in systems which handle an immense amount of data speedily and produce analyses which derive from considering far more variables simultaneously than any other system ever invented. The advantages of the new technology in all sectors are said to be its cheapness, its reliability, its compactness, its speed of operation, its accuracy and its low energy consumption. For example, it can facilitate faster and more precise knowledge of operating conditions and results (e.g. in an oil refinery or a nuclear power plant, where a single screen can show all relevant information and facilitate easy forecasting of production data on the basis of altering any number of variables). Similarly in retail, EPOS (electronic point-of-sale) systems facilitate presentation and analysis of disparate sets of data on price, sale rate, stock levels, and so on. In this way the new technology unifies previously segmented control systems and provides the opportunity for a more comprehensive assessment of present and forecast performance. But offsetting these advantages which largely accrue, at least initially, to management, there are many who would argue that the new technology will also herald increasing unemployment, increasing degradation and deskilliing of work for many of the workers who can find employment, and an ever tightening grip of a small, select group of managers and specialists on other employees. Is this a reasonable, if depressing, scenario for the future?

In answering such a pessimistic question one must reiterate that we are not considering some immanent law of technological determinism. Technology is not an independent force, but one which can be differently developed and utilised according to the objectives and beliefs of those in positions of power. In this analysis it therefore seems appropriate to start with the objectives of managers in so far as they can be determined, before looking at the evidence on the effects of the policies and practices they have adopted in relation to new technology.

Why new technology is introduced

In a summary on 'New Technology and Developments in Management Organization', Child (1984b) identifies four management objectives which available evidence from case studies and surveys suggest are prominent in decisions to introduce new technology. The first two of these objectives are reducing operating costs and increasing efficiency. Reductions in the size of the workforce, relocating and retraining employees, and a growth in sub-contracting work to 'home workers' are all ways in which the new technology facilitates these two objectives. Sub-contracting arrangements with workers sitting at home with their own microcomputer or terminal, connected into the enterprise by electronic processes, not only ensures that the 'outworkers' bear their own overheads for space, furniture and facilities, but it can facilitate easy and quick performance monitoring and possibly a payment system which relates only to the actual hours worked as identified by the information system. Increasing efficiency can also come through improved technical services, such as stock-keeping or production scheduling, and from self-diagnostic systems which provide an early identification of process problems in need of maintenance before a breakdown occurs. Easier and earlier fault diagnosis can be complemented by the use of modular components which are easily replaced, often by the operator who looks after the machines. In this way excessive dependence on maintenance personnel is avoided. In manufacturing there is also the possibility of improved flexibility, so that a variety of products can be produced from the same computer-controlled facility with a minimum of cost and delay at change-over times.

The third objective is to secure improvements in quality. The checks and measurements previously undertaken by people can now often be built into the production facility. Finally, the fourth managerial objective often cited as important in decisions to introduce new technology is that it will facilitate improvements in managerial control. This arises from the improved processes for generating and transmitting performance information and the increasing opportunities for decreasing the amount of skill in jobs and the indispensability of workers. This is the area in which there has probably been most debate about the relationship between new technology and work organisation.

The effect on skills and control

Braverman (1974), somewhat echoing Mallet's earlier analysis, was particularly important in the 1970s and 1980s in prompting a resurgence of interest in a Marxist analysis of the labour process. A general theme of his work is that automated production systems are inextricably linked with deskilling, increasing technical and administrative control over the deskilled labour force, and an increasing polarisation of social divisions under 'monopoly capital'. This is a theme largely shared by Noble (1984) in his historical account of the US machine tool industry. He argues that rather than developing numerically controlled machines, engineers could just as easily, and with equal technical flexibility, have developed a 'record/play back' (R/P) technique which would have depended not on specialist computer programmers as CNC (computer numerically controlled) systems largely do, but on skilled machinists 'teaching' new jobs to the machines. He argues that the choice of CNC over R/P was not based on 'technical efficiency' but on increasing managerial control and deskilling.

Littler and Salaman (1982), although generally supportive of Braverman's part in a revival of interest in labour process analysis, point out that there is no single or simple means of controlling labour: technological control is important, but so too is bureaucratic or administrative control, together with other aspects of the employment relationship which ensure compliance. Furthermore, for senior managers of some multinational companies, issues of control of the production process become less important if they have the option of geographical relocation of plant and equipment to areas where the workforce will conform to 'indigenous modes of regulation and motivation'. Littler and Salaman comment: 'The first priority of capitalism is accumulation, not control. Control only becomes a concern when profitability is threatened' (p. 265). This echoes to some extent Marglin's (1974) analysis, that senior managers and entrepreneurs are interested both in productivity (to make money) and control (to keep the money they made).

The available evidence suggests considerable variation in relations between the introduction of new technology and the way control is exercised, the degree of discretion afforded workers, the basis and extent of the division of labour, and the type of supervision. The variations reflect in part management's view, but they also reflect the processes of local negotiations which often result in considerable modification of the views originally held by management (e.g. Wilkinson, 1983; Rose and Jones, 1984). Moreover, the requirements for flexibility and frequent job changes often mean that, in the case of CNC machines, for example, the operators are given considerable discretion (Sorge *et al.*, 1983). In an international context, data from 1340 organisations in twelve countries with over 8000 respondents found that advanced technologies were not necessarily associated with an increase in the proportion of lower skilled jobs in enterprises (IDE, 1981). This IDE project also gave more support to Gallie's view that culture or country is often more important than sector or technology in influencing the attitudes and behaviour of workers.

Much of the new technology itself can be used either to facilitate or curtail discretion and skill among workers. For example, Wilkinson (1983) shows that there is a choice with CNC machines about whether shop-floor workers or specialist programmers do overriding editing or programme development. He found that although generally specialists were employed to undertake more skilled work, in a few cases management had deliberately instructed its operatives in the skills. Even where workers were formally denied access to the skills of machine programming, Wilkinson found that they often attempted to develop the skills by studying programming in their 'spare time' and making keys so that they could get access to the control boxes and so practise their skills.

Similar variation is reported by Child (1984a) from contemporary studies on the role of supervisors in the new technology. He identified three distinct roles: (a) they may become glorified 'provisioners', merely ensuring that the necessary equipment is available; (b) they may develop programming ability; (c) they may develop strong interests in the technical performance of the equipment and thus play an active part in operating the new technology. The supervisor's job in relation to stock control, progress-chasing and crisis management may also change if improved information systems lead to a more streamlined stocking system and self-diagnostic features of new equipment lead to fewer emergency breakdowns.

There is evidence that some managers will use new technology as an opportunity to enhance the skills of their workforce: to develop, for example, a workforce of 'allrounders', capable of operating, programming and routinely maintaining the new equipment. In response to these developments, particularly in times of high unemploymeent, the managerial hope is not only for an efficient workforce, but for one which responds to greater security and job interest with increasing commitment to the enterprise. In this way new technology is being used to augment, rather than replace or degrade, human skills. The success of such a strategy will, of course, be dependent in part on the expectations and orientations of the workforce.

At the other extreme, some managers are involved in using the new technology specifically to degrade skills and to reduce workforces. This might happen, for example, after the introduction of flexible manufacturing systems in which the production, transport, quality control and packaging of goods can all be performed routinely by programmed machines. Similarly, banks may largely use the new technology to handle all routine matters while retaining a group of specialists to handle special tasks. It is suggested that where work can be standardised and handled routinely without detriment to the finished product or service, then managers are inclined to follow a 'replacing people' rather than an 'augmenting people' long-term strategy. If, on the other hand, the work is unpredictable and dependent on personal service or poses considerable risks (of danger to life, theft, or some other disaster) if the electronic system were to break down, then an 'augmenting' strategy is more likely (Child, 1984a, p. 251).

3.3 Technology, Organisation and Management Structure

The arguments and theories relating technology to the shape of the organisation structure and role of management show a similar progression to those concerning the relationship between technology and work organisation. Captivated by the discovery that one could talk in terms of an appropriate fit between technology and organisation structure and that not all organisation structures were equally appropriate to all technologies, some commentators developed fairly mechanistic and deterministic theories about the place of technology in explanations of organisation structure. But these were then overtaken by a fuller appreciation of the role of choice, both of technologies and organisation structures and the political processes involved in their selection. This section will be concerned with reviewing some of the relevant studies and commentaries.

Joan Woodward: a pioneer of links between technology and structure

Woodward (1958, 1965) is one of the well-known scholars who first focused on the implications of different forms of production processes for management behaviour and structure in organisations. She conducted an empirical survey of 100 firms in one small area of south-east England. One of the objectives of this research was to investigate how and why industrial organisations varied in structure and whether, as some management theorists of the 1940s and 1950s would have people believe, there were particular forms of structure that were associated with commercial success. In her survey she did indeed find variations in structure and success, but she could only begin to make sense of them when she grouped her surveyed organisations into the three technological groups of (a) unit and small batch, (b) large batch and mass and (c) process, which were derived from the eleven-point scale of production systems shown in Table 3.3. This classification was an elaboration of a division normally used by production engineers and was taken to reflect the complexity of the technology – that is, its inherent controllability and predictability – although Starbuck (1965) has argued that it is more a scale of smoothness or continuity than of complexity of production. The scale ranged from the production of custom-made unit articles, through the batch and mass production of standardised goods, to what Woodward saw as the technically most complex stage, namely the continuous flow production of dimensional products. She also included two residual categories for combined systems which did not fit into any of the other categories.

Table 3.3
The Classification of Production Systems Used by Woodward

A. *Integral products*		
	1.	Production of simple units to customers' orders (e.g. 'made-to-measure suits')
Unit and small batch production	2.	Production of technically complex units (e.g. prototypes for small units)
	3.	Fabrication of large equipment in stages (e.g. radio transmitting stations)
	4.	Production of small batches to customers' orders
Large batch and mass production	5.	Production of components in large batches
	6.	Production of large batches, assembly-line type
	7.	Mass production
B. *Dimensional products*		
Process production	8.	Intermittent production of chemicals in multi-purpose plant
	9.	Continuous production of liquids, gases and crystalline substances
C. *Combined systems*		
	10.	Production of standardised components in large batches subsequently assembled diversely
	11.	Process production of crystalline substances subsequently prepared for sale by standardised production methods

SOURCE: Woodward (1965), p. 39.

Grouping her organisations into the three main categories of unit and small batch, large batch and mass and process production allowed her to identify three trends of direct relevance to the relationship between technology and organisation structure. First, she found a linear relationship between a firm's technical complexity and such features of its formal organisation chart as the length of line of command, the span of control of the chief executive, and the ratio of managers to total personnel. Second, there was a curvilinear relationship between a firm's technical complexity and the extent to which it had, in Burns and Stalker's (1961) terms, an organic informal, or a more mechanistic formal, system of management (see Chapter 4). Third, Woodward found that firms were more successful financially when they conformed to the median organisational characteristics for their 'technology' group than when they diverged from it. Thus Woodward concluded that there was 'no one best way to manage', but that it was important to consider the nature of the technical context before deciding on appropriate forms of organisation. The classical principles of management, with their clear definitions of responsibility, seemed to be appropriate to firms with large batch or mass production systems but, perhaps not surprisingly, to be detrimental to success in both unit and process production.

Management control systems

The initial findings relating technology to organisation structures were particularly well supported at either ends of the technology scale, but the relationships were less clear-cut in the middle areas of large batch and mass production, where it appeared to Woodward that there was more scope for managerial choice between options. With these types of production,

> physical work flow did not impose rigid restrictions with the result that technology did not so much determine organization as define the limits within which it could be determined. The separation of production administration from production operations, rationalisation of production processes, and attempts to push back the physical limitations of production resulted in the emergence of a control system that depended in part on the physical work and in part on top management policy. (Woodward, 1965, p. 185)

This observation led Woodward and her team, now established at Imperial College, to conduct further investigations into the way in which management control systems were developed. They adopted Eilon's definition of a management control system as encompassing the activities of planning, co-ordinating, monitoring and providing feedback about progress in achieving the task of the organisation (Eilon, 1962). A four-fold typology of control systems was developed in terms of variations on two dimensions (Reeves and Woodward, 1970). The first dimension was the degree to which control was exercised personally or indirectly. At one end of this scale one would have personal, hierarchical control of the owner–manager who decides what should be done and monitors progress. At the other end are the sort of bureaucratic and technical systems of control found in complex programmes for production planning and cost control or built into the production processes and operated through mechanical or electronic devices. The second dimension was the degree to which the control systems were integrated or fragmented. At the integrated end were firms where all the standards set for the product (e.g. cost, delivery, quality) and the adjustment mechanisms when one or other standard was being underachieved, were built into a single, integrated system of managerial control. This is clearly more feasible with automated and programmable production systems or those under the control of a very few people. In contrast, at the fragmented end were firms where such standards were set and controlled relatively independently by different departments. Some fragmentation of control was also noted in establishments where many different products were made for different markets.

Putting these two scales together, Reeves and Woodward identified four categories of control and suggested that the normal processes of industrial and technical development were such that firms started in the first cell with a single, integrated system of personal control, developed and monitored by an entrepreneur who personally resolved conflicts between time, quality and cost. As the business grows with increased specialisation, delegation and fragmentation, the second cell becomes the norm in which controls are still essentially personal through direct supervision but are now more fragmented, with different departments being responsible for different aspects of production. With the post-war growth of production engineering and operational research techniques, process control and mainframe computerisation, administrative controls proliferate and control systems become more mechanised and automated – but still fragmented. This characterised the third cell. Only with integrated data processing and computer-aided programming and design – in short, 'the new technology' – can a masterplan be developed into the single, integrated, impersonal control systems of the fourth cell.

When Woodward's original 100 firms were classified into one of the four categories, it was found that 75 per cent of unit and small batch firms fell into the first cell, and 95 per cent of process firms into the fourth. But the large batch and mass production firms were not so neatly accounted for, with 35 per cent falling into the second and 40 per cent falling into the third. It seemed that the similarities of social structure which Woodward had noted between unit and process production firms could be attributed to some extent to the fact that both could operate integrated control systems, the one through personal administration, the other through automation, whereas people in the middle ranges felt constantly harassed by different sectors of a fragmented system. This harassment was graphically illustrated in a study by Reeves and Turner in which they compared the nature of control systems in three firms, as summarised in Table 3.4. Similar degrees of chaos were found in the

Table 3.4
Relationship between Production System, Information Handling and Behaviour in Three Factories Studied by Reeves and Turner

Hollington	*Rose Engineering*	*Mass Bespoke*
Manufacturing	Manufacturing	Manufacturing
Large, complex electronic equipment	Precise hydraulic equipment	Men's bespoke suits
500 employees	700 employees	1000+ employees
Batch production	Batch production	Batch/mass production

1. Hollington and Rose Engineering had similar systems for planning and control of production which were much more complex than Mass Bespoke. In the first two factories there were continual crises caused by shortages; much energy devoted to progress-chasing; and a lack of complete knowledge about the state of play in the different versions of progress held by different functions. There was more certainty and less chaotic revisions in the suit factory.

2. The complexity of their production systems was a function of (a) their market position and how it was interpreted by management, and (b) the nature of their products. In the first two factories there was a much larger number of products, production operations, components and production sequences than in the third. There was also greater uncertainty about the market.

3. Underlying procedures could be detected as a basic strategy for controlling manufacture in the first two factories, including

- checking overall load on the factory by crude aggregate means
- preparing a notional production programme to allow preparatory work to be scheduled
- revising a notional programme as new information becomes available
- creating a list of priority work and updating it as new information becomes available
- coping with shortages, bottlenecks and late deliveries on an *ad hoc* basis

4. The problem of collecting and collating information in complex batch production systems is great. The existence of different sets of information is not just a manifestation of poor communications; the complexity of the situation *makes complete communication impossible* (given limited resources of time, money, etc.). The inability to gather all the necessary information in each of the two batch production factories is a good example of *limited knowledge/ bounded rationality*. Complete consensus on what information is required, let alone on its content, is unlikely to occur. This situation may be aggravated by the ability of some people to use power to get their own set of information accepted.

SOURCE: from Reeves and Turner (1972).

planning and control systems of two of the firms: Hollington electronics, making discrete batches of heavy electronic equipment from a large number of components, and Rose engineering, also engaged in component manufacture of enginering products. The planning and control information in these plants was subject to constant review and amendment. Much energy was devoted to progress-chasing the 'current most important order', in the absence of hard information on either production capacity or the 'relative importance' of other orders. Reeves and Turner compared this apparently chaotic system to the much calmer situation they found in the third factory, which was engaged in supplying weekly batches of mass produced suits from a factory where both the capacity and the number required each week were known. Scheduling and control were therefore comparatively easy. They explained the relative chaos of the batch engineering plants in terms of their diverse and fluctuating markets and the nature of their products. They pointed out, for example, that in scheduling nine jobs on to three machines, with three operators per job, there were millions of ways of completing this task. Thus complete agreement on what to do was almost impossible. There was, in their terms, a 'variable disjunction of information'. It is precisely these sorts of production situation which are greatly improved by the new micro-electronic technology which facilitates easy updating and realignment of different parameters. The form of planning and control system that was found to be characteristic of the Hollington and Rose batch production situations is likely to become less common with the adoption of new techniques.

Technology and relations between functions

Woodward also gave some thought to the implications of different technical systems for relations between departments; that is, to the horizontal as well as the vertical dimensions of structure (Chapter 5). Thinking overall about the flow of work in different contexts, she suggested that in unit production the key central function was development, in the sense that it was here that most money would be made or lost, because it is often the idea of a product and a conviction that the firm could make it, rather than the product itself, which is sold to the customer. Consequently marketing people have to be technically competent, but it is the development engineers who are the elite. In large batch and mass production the functions can be much more independent, with no clear elite and with considerable tensions between departments, not least because of the fragmented control system. Nonetheless, in Woodward's view the key activity is efficient production. In process production sales usually assume greater importance since once the system is in production it is vital to ensure a smoothly expanding market. There are usually fewer tensions between departments, not least because co-ordination of production is largely achieved automatically. Woodward relates an anecdote about Standard Oil of New Jersey, who at the beginning of the twentieth century distributed kerosene lamps free of charge to Chinese peasants in order to obtain a market for kerosene which was a by-product of a new refining process.

Woodward and her team at Imperial College were thus significant in popularising the idea that organisation structures should be designed to fit the constraints posed by the technology. Although her concerns with control as an intervening variable showed that she did not adhere to a strictly deterministic view of the relationship, there is little doubt that she was more excited by the discovery of the link than she was in discussing the limitations of her analysis or why particular technologies were chosen.

Support for a direct link between technology and organisation structure was not confined to Woodward's work. Burns and Stalker (1961) highlighted the importance of characteristics of technology and markets as sources of uncertainty and complexity which, they argued, could be best accommodated through developments in organic (for high uncertainty) or mechanistic (for low uncertainty) forms of organisation (see Chapter 4). Coincidentally with Woodward and Burns, others (notably James Thompson and Charles Perrow) were studying organisations in the USA and coming to similar conclusions.

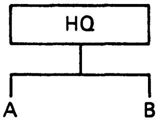
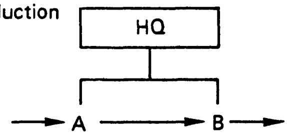
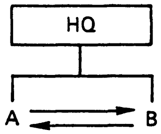
James Thompson: technology, interdependence and co-ordination

Thompson's classification of production systems is based on the nature of the linkages between various parts of the organisation. It is summarised in Figure 3.2. At the simplest level, there is what he calls 'mediating' technology, wherein the units are linked together by virtue of sharing a common resource from, or being subject to common constraints which are controlled by, a single headquarters. Thus the manufacturers of different components which will be assembled into an aeroplane are all subject to the common constraint of overall weight. Similarly, the branches of a supermarket chain are subject to the common constraint of the availability of their own brand name of baked beans and the administrative procedures of headquarters. Such technologies, Thompson suggests, are operated by units with pooled interdependence, each working separately but giving a discrete contribution to the whole. Transfers between the units can be handled in a co-ordinated and standardised way which lends itself to bureaucratisation and the impersonal application of rules.

At a more complex level of interdependence, long-linked technologies require operating units to be linked to one another in serial interdependence in which the outputs of one unit become the inputs of another. This is typical of many mass production assembly plants where, Thompson argued, co-ordination is best achieved through planning systems as well as rules and procedures. This point is reminiscent of Woodward's work on control systems for large batch and mass production firms.

The third form of production process Thompson calls intensive technology. This involves using a variety of techniques to achieve a change in a specific

FIGURE 3.2
The Classification of Technology, Interdependence and Co-ordination Used by Thompson

Technology	Interdependence	Co-ordination through	Likely strategies
Mediating, e.g. banks, post office	Pooled 	Standardisation	Expand populations served
Long-linked e.g. mass production assembly line	Sequential 	Plans, schedules	Vertical integration
Intensive, e.g. prototype production	Reciprocal 	Mutual adjustment/ feedback	Foster commitment and loyalty within company and from customers and suppliers

SOURCE: adapted from Thompson (1967)

object. The selection, combination and order of application of these techniques are determined by feedback from the object itself and between the people involved. The best way to co-ordinate such activities, Thompson argues, is to place heavy reliance on feedback and mutual adjustment between the parts and the object. This is a characteristic of organisations involved in providing health services, in renovating old buildings and in the development of military strategy.

Thompson was concerned with the way firms attempt to gain as much control as possible over those things that are necessary for the generation of their products but which, if uncontrolled, represent significant sources of uncertainty. He documented the ways in which firms tried to organise the acquisition of their inputs and the disposal of their outputs, so as to minimise the control that others have over them. He discussed ways of buffering inputs (e.g. through stockpiling or the constant recruitment and training of personnel). He was also concerned with ways of smoothing the production process itself through progressive planned maintenance, systems for the allocation of priorities, as with the distinction in the UK postal service between first or second class mail or, in other contexts, the maintenance of significant inventories of finished product.

Technology and corporate strategy

Thompson's concern with the way people in organisations seek to control significant sources of uncertainty leads him to suggest how the particular characteristics of an organisation's technical system are important when making decisions about expansion and development. Thus, he argued, long-linked technologies lend themselves to vertical integration, whereby a firm incorporates control over input and output units. Mediating technologies, on the other hand, can benefit greatly from an expansion of the populations they serve, while organisations with intensive technologies should give consideration to incorporating the objects of their work. Thompson also focused attention on the nature of product (especially their concreteness or versatility and abstraction) and the adaptability of the technology as being important sources of constraints and opportunities when it comes to decisions about corporate strategies. Thompson and Bates (1957) used these two dimensions as a basis for suggesting how senior executives could diagnose where they should concentrate their policy attention. For example, a highly concrete product and a low adaptability technology, as in organisations like TB hospitals or coal mines, meant, they suggested, that attention must be paid to possible avenues of diversification should product markets disappear. On the other hand, manufacturing organisations with concrete products but adaptable technologies need to be especially concerned with the decision about when to shift products.

Charles Perrow: the characteristics of raw materials

Whereas Woodward and Thompson were important in focusing attention on the implications of different forms of production or transformation process, Perrow concentrated on the inputs to the transformation processes (Perrow, 1967, 1970). He became particularly interested in the implications for people and structure of differences in two basic dimensions of inputs; (a) the degree to which raw materials used in an organisation were standardised, and (b) the nature of the response when non-standard raw materials were encountered.

The degree of standardisation of the raw materials

The purity and testability of inputs and the frequency with which production workers have to cope with exceptions to the norm in their raw materials are questions that can be asked equally of the feedstock entering an industrial chemicals plant, the microchips entering an electronic assembly factory, the components entering a mechanical engineering jobbing shop, and the clients entering a counselling service. The replies one gets are important considerations in the planning and operation of the organisation. They have a bearing on the following sorts of question. Would more emphasis on the search for alternative materials or alternative testing procedures be worth while? What sort of people, in terms of qualifications and experience, should be selected and recruited for the preparation and handling of the raw materials? How should clauses of the contract between supplier and user be phrased with regard to specifying quality and delivery? How should stores and inventory control be structured to relate to production, and where, if anywhere, should input quality testing be located?

The nature of the responses when non-standard raw materials are encountered

Perrow's second dimension concerns how exceptions are dealt with, if and when they are encountered. Are the problems that account for their sub-standardness sufficiently well understood to be handled by standardised procedures; in other words, can highly programmed responses follow the discovery of an inadequacy in the raw materials? For example, if a batch of chemical feedstock was not of the required strength, it is likely that standard operating instructions exist which specify the circumstances for rejection and the circumstances for specific changes to be made in the content or strength of mix. Similarly, standard operating procedures specify reactions to the identification of sub-standard components in mass production. Alternatively, the reasons for inadequacy may be neither so well understood nor so amenable to immediate action. A great deal of 'searching' may then be required to find a solution to the problems posed by non-standard raw materials. Such is often the case in prototype or unit production of a high specification product like an aeroplane engine. Here particular metal pieces may be specified and yet their properties under different points of stress be difficult to determine. If they are found to be inadequate, then the process and product engineers have to decide what to do. Should they refashion the components themselves, treat them with some chemical, request that they be made of an alternative material, rethink the whole design of that particular sub-assembly, or any combination of these strategies?

The extreme end of non-standard search procedures is found in organisations where the raw materials do not respond in a uniform fashion to screening tests, or indeed for which there are no known screening tests. A patient facing a doctor may not be easily categorised as needing a particular sort of treatment, and there may have to be a great deal of investigation to establish the nature of his condition. Where materials or processes are just being developed, as in the case of contemporary bioengineering, there is often a lot of searching required into the nature of the raw material's uncharted variability. In the early days of the commercial manufacture of microchips, 'yield' was a big problem largely because it was often not clear to production that chips were sub-specification until they had been incorporated into the assembly of the final product.

The more general implications of differences in the types of response to non-standard raw materials can be seen from the following questions. What sort of investment should a company make in gathering and processing information on raw materials and the reasons for their deviation from a specified norm? To what extent are comprehensive standard operating instructions appropriate in the stocking and production areas of the plant? What sort of people, in terms of qualifications and experience, should be employed to detect and to rectify deviations in raw materials? What in-house training is required to facilitate the development of discretionary judgement? How can changes in scientific and engineering know-how be monitored so that people in a company will know when, if at all, it is appropriate to increase standardisation in production procedures?

If the two dimensions of variability and search are put together, a four-cell model can be constructed. Perrow provides a convincing argument that organisations falling into each of these four cells are most appropriately structured in different ways. Whereas, he argues, a formal mechanistic hierarchy is appropriate for routine production where there is little variability and minimal search, a greater degree of informality is needed to cope with non-routine prototype development with high variability and extensive search requirements. These ideas are taken up again in Chapter 5.

Technology, structure and size

Further support for links between technology and organisation structure came from studies by others such as Hall (1962), Hage and Aiken (1967, 1969) and Khandwalla (1974). Hage and Aiken conducted a study of sixteen health and welfare agencies in the USA. They found significant relationships between the routineness of the technology and the degree of centralisation, formalisation and specialisation. By the time of the publication of their work, a debate had developed as to the relative priority between technology, as advocated by Woodward, Thompson and Perrow, and size, as advocated by Pugh and Blau and their colleagues (see Chapter 5). However, as Hickson, Pugh and Pheysey (1969) pointed out, it is likely that the relationship between production technology and structure will be strongest in those areas most in contact with the operations technology. Thus variations in the number of personnel and their form of organisation on inspection and maintenance was found to be highly related to type of technology, whereas this relationship was not found for indirect specialist functions. Arguably, therefore, the smaller the organisation, the more its structure will be pervaded by technological effects, whereas the larger the organisation, the less pervading will be the effects of technology. In larger organisations specialists and administrators will be 'buffered' from the effects of the technical core by the sorts of standard procedure and formalised paperwork which, all other things being equal, are associated with increases in size.

Management structure and new technology

Before leaving this discussion of the role of technology it is worth noting that the three main studies discussed in this section, namely Woodward, Thompson and Perrow, all pre-dated the operational introduction of new technology. To date most of the work in this area has focused on its implications for work organisation, but some comments in relation to management structure can be made. Underlying the relationships between technology and organisation structure suggested by Woodward, Thompson and Perrow is a concern for uncertainty and complexity. A common strand of argument is that characteristics of the technology pose uncertainties or create complexities which can somehow be coped with through the development of appropriate management structures: for example, by fostering flexible working relationships between specialists, maintaining buffer stocks of raw materials, and placing more or less emphasis on the different forms of administrative, technological, hierarchical and output systems of control. The fascinating importance of developments in new technology is that they may lead to a reduction in uncertainty and complexity precisely because they can facilitate the collection, interpretation and analysis of a mass of hitherto disparate information. Thus these developments in microelectronic technology may lead to a reduction in the emphasis on organisational forms as tools for coping with complexity and uncertainty, and an increase in the significance of personal networks of highly committed groups. This is the scenario presented by Drucker (1989), in a book entitled *The New Realities*. But this line of argument must be temporarily suspended until Chapter 5 in order to conduct an analysis of the 'environment' in a similar way to that made of 'technology'. In this way a fuller picture will be created from which to continue the discussion.