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TECHNICAL INNOVATION IN INDUSTRIAL PRODUCTION

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SUMMARY

New techniques in manufacturing, popularly referred to as mechanization and automation, have been a preoccupation of social and economic theorists since the industrial revolution.

A selection of relevant literature is reviewed, including the neo-classical economic treatment of technical change. This incorporates alterations to the mathematical production function and an associated increase in the efficiency with which the factors of production are converted into output. Other work emphasises the role of research and development and the process of diffusion, whereby new production techniques are propagated throughout industry. Some sociological writings attach importance to the type of production technology and its effect on the organisational structure and social relations within the factory.

Nine detailed case studies are undertaken of examples of industrial innovation in the rubber, automobile, vehicle components, confectionery and clothing industries. The old and new techniques are compared for a range of variables, including capital equipment, labour employed, raw materials used, space requirements and energy consumption, which in most cases exhibit significant change with the innovation. The rate of output, labour productivity, product quality, maintenance requirements and other aspects are also examined.

The process by which the change in production method was achieved is documented, including the development of new equipment and the strategy of its introduction into the factory, where appropriate. The firm, its environment, and the attitude of different sectors of the workforce are all seen to play a part in determining the motives for and consequences which flow from the innovations.

The traditional association of technical progress with its labour-saving aspect, though an accurate enough description of the cases investigated, is clearly seen to afford an inadequate perspective for the proper understanding of this complex phenomenon, which also induces change in a wide range of other social, economic and technical variables.

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"I have no data yet. It is a capital
mistake to theorise before one has
data. Insensibly one begins to twist
facts to suit theories, instead of
theories to suit facts"

- Sherlock Holmes

A Scandal in Bohemia

Chapter One

INTRODUCTION

Technical change has long been a subject for popular speculation on the future of society. In its most commonly conceived forms, industrial mechanization and automation, it has been seen both as heralding an age of leisure for the vast majority of the population, and as a harbinger of mass unemployment.

A preoccupation with the topic has existed ever since ancient Greek society, when Aristotle commented on the possibility of replacing manual labour in weaving by automatic looms. Wider practical experience of the issues raised by technical innovation had to await the industrial revolution, and the social consequences quickly became apparent as matters of public concern. The textile industry in England pioneered

industrial mechanization, and foremost among the early reactions to the burgeoning application of new machinery were those of the Luddites, whose strong opposition arose from the direct threat it posed to their employment. However, the industrialisation of manufacturing techniques continued, with sporadic but largely ineffectual protest.

Mechanization entered a new and more expansive phase when the motor car magnate Henry Ford introduced the first assembly line in 1913, heavily based on the time and motion principles of 'scientific management' developed by Taylor and Gilbreth. It is in this particular production method that the modern debate on technical change has its origins, because the pinnacle of task rationalisation and division of labour which it then represented enabled productivity increases, and the consequent elimination of labour from the production process, to be achieved on a hitherto impossible scale.

Subsequent important developments in manufacturing technology include the application of feed-back control in the 1930s, whereby certain parameters in an industrial process are monitored and corrective action taken if their variability exceeds the planned limits. This permits equipment to operate automatically, further decreases the requirement for direct labour in production, and has important effects upon the nature of the tasks performed by those operators who remain.

The Automation Debate - a technical balance has always

Much of the concern about mechanization and automation inevitably focusses on its employment consequences. The fact that many industrial innovations displace labour is indisputable; mechanized devices replace human physical effort, automatic control systems take over what was formerly monitored by a machine operator, and the resulting increases in productivity dictate that fewer workers are required.

However, it is also beyond argument that technical innovation creates new products, employment and even entire industrial sectors. A substantial proportion of current job functions in the advanced economies hardly existed 20 years ago, including most of those in the electronics and related industries. The question, therefore, is one of balance - determining to what extent the job-creating effects of technical change offset the labour-saving ones.

The best estimate perhaps comes from long term historical trends. An enormous amount of technological progress has obviously taken place since the industrial revolution, yet no severe structural mis-match of the supply and demand for workers is evident; the proportion of the labour force without employment has shown no dramatic rises which cannot be explained by wider economic trends. Although it is unreliable to extrapolate this, particularly in view of the accelerating rate at which technical

change is occurring, the numerical balance has always been roughly maintained.

This analysis, however, fails to incorporate two important facets of the problem. Firstly, the approximate quantitative equivalence of labour supply and demand says nothing about the mobility of the workforce between different industrial sectors, and secondly, it takes no account of skills.

In fact, as pointed out, there has been a steady growth of new industries based on advanced technologies, which are regularly recruiting staff as they expand. On the other hand, some long-established UK industries are in sharp decline (both through technological obsolescence and foreign competition), and over recent decades they have shed labour at a considerable rate.

Workers so displaced are not or cannot immediately be taken up by those firms experiencing growth, and the reason for this leads directly to the remaining problem of skills. Although geographical considerations of labour mobility are also an important cause of the pool of 'frictional unemployed' (that is, those whose job loss is a temporary condition of the process of labour re-deployment) a considerable number will have no employment future; they do not have and are unlikely to acquire the new skills demand in the sectors of growth.

Even within one industry, technical change can be argued to have varying effects on the skill levels

of the workforce. On the one hand, the greater complexity of machinery requires more skilled maintenance, and on the other, mechanization and the precise sequential programming of modern manufacturing operations reduces the direct operators' duties to the level of repetitive servitude to the production line.

At a more generalised level, the employment statistics of western countries show a consistent shift of labour from manufacturing to the service sector of the economy, just as in previous decades manufacturing overtook agriculture and other primary production. In the USA, the service sector already employs more than manufacturing industry. These trends further complicate the issue of matching skill availability with requirements, and have prompted a related discussion on the so-called 'post-industrial society' and the future of work.

The rapid expansion of high technology industries which have a large service sector component, such as computing, has revitalised the subject of automation and skills in recent years (N.E.D.O. 1980; MacTaggart 1981). With the increasing manufacturing applications of microprocessors, electronic warehouses, industrial robots and similar devices, the whole topic is again open for renewed debate.

Technical Change and the Social Sciences

Outwith the mainstream automation debate, industrial technology has long been a major theme of sociology. Much of the literature has concentrated on identifying types of production techniques, correlating these categories with the social conditions within the factory, and analysing the effect upon workers' experiences and responses. The most common types of classification distinguish a craft or unit production method (where every product item is constructed individually), batch production, mass production (essentially a 'batch' of great length, typified by the automobile assembly line) and process production, which involves forming a continuous stream of undifferentiated output.

These studies do not present the full picture in the sense that the organisational and social differences which they highlight are essentially static - they compare varying degrees of mechanization and automation in quite separate factories and industries. They rarely concentrate on the effect which technical change as a process has on a specified group of workers which experienced both the old and new production methods.

Much of this type of research relies perhaps too heavily on technology as a determinant of the social and other conditions in the factory. Many non-technical variables are also bound to affect the

work environment and the social factors which are being investigated, and these too must be considered.

Economic theory, in its treatment of industrial production, also covers the effects of technical change and the alterations to the mathematical production function which it causes. It distinguishes between labour-saving, capital-saving and neutral technical advance. The input of economics to the more general subject of the implications of technical change is of an abstract nature, and difficult to substantiate empirically. In particular, it falls between the tendencies to see it either as describing in aggregate form the national economy, or as being applicable to the conditions of individual firms and the levels of production technology which they variously employ. The difficulty (or impossibility) of achieving systematic and compatible measurements for output, capital, and the other factors of production imposes limitations on its practical usefulness for understanding the wider issues associated with technical change, although it certainly makes an important contribution.

Outline of the Present Study

The limitations of the various approaches to the topic of innovation outlined above suggest that there is scope for further investigation, but from different perspectives. One such possibility is the case study

method, which affords the opportunity to examine in detail, for an individual production system, as many relevant variables for which data can feasibly be gathered. The method of research is discussed more fully in Chapter 5, but one of the main features of case studies is the interdisciplinary attitude to the problem which they require. This is necessary because the raw data tends to be highly unsystematic and of variable quality (consisting of interviews, observation, miscellaneous factory logs, and so on), by virtue of the close range at which the topic is being studied.

However, if properly carried out, case studies do permit the collection of data of a type and at a level which would otherwise be virtually inaccessible. Correctly interpreted, they are able to cast light on issues avoided or only tentatively addressed by the more aggregate and strictly disciplinary findings on technical change offered by economics and sociology.

The intention of the research documented in the following chapters was to trace a number of technical innovations in industrial production methods through the process of change, and in the course of this to compare a wide range of parameters as they stood before and after the innovation. These included factors relating to capital equipment, such as the amount and type of machinery used, its reliability, flexibility, and the space occupied.

Among the labour aspects considered are the numbers of workers employed both directly in production and in ancillary functions such as maintenance, their skills, the organisation of tasks, and health and safety considerations in the work environment. Technical change also has repercussions for the product, and seen in terms of it being the output from the production system, relevant variables are the nature of the product, the rate at which it is produced, the range of sizes available, and their quality.

In documenting the process of industrial innovation, the key aspects are the choice of technical solution, its development where original equipment is concerned, and a range of issues related to its introduction into the work place. These last include both obstacles and facilitating factors, such as worker responses, managerial attitudes, and engineering difficulties in achieving equipment which functions reliably.

Because individual instances of technical change were being investigated for a broad selection of social, economic and technical variables the case study method was chosen as the best practical approach.

This work is part of the first phase of the Technology Policy Unit's programme of research into industrial innovation. Whereas the present study is concerned with documenting and explaining the changes that technical innovation causes to a number of associated factors, a complementary project started at the same time focusses on a single aspect of advanced industrial technology, industrial robots (Zermeno 1980). These devices, otherwise known as programmable handling machines, can be usefully employed in many industries, including welding, paint spraying, the loading of presses, and component assembly. One of the main areas of investigation is the low rate of diffusion exhibited by industrial robots, which is surprising in view of their versatility and virtually universal applicability. A continuation of this research is also underway.

Subsequent work at the Technology Policy Unit has included single case studies of industrial innovation (Dickson 1980) and an analysis of the diffusion of microelectronic applications in production (Bessant et al 1980). Other studies currently being undertaken include the effect of technical change on work organisation and job satisfaction, a case study of a single major investment in new production facilities and a new car model by a large automobile firm, automation in the chemical

industry, and the recent history of British government policy towards innovation in various industries.

A history of solid state physics, forming part of a three-country project, follows on from completed work on the history and impact of semiconductor electronics (Braun et al, 1978).

Chapter Two

HISTORY AND DEFINITION OF TERMS

Much confusion exists among academics, industrialists and policy-makers in the use of terms related to the advancement of industrial production methods. The section which follows is intended to illustrate the historical evolution of these terms and to clarify definitions as they will be used in this thesis.

2.1 TECHNOLOGY AND TECHNIQUE

The original meaning of technology was confined to knowledge about industrial practices and methods (Layton 1977, p199; Freeman 1977, p225). Technology was utilised through the employment of techniques which represent the realisation of this knowledge in physical terms.

Recent custom, however, has tended to employ technology, at the expense of technique, to represent both the knowledge and its means of practical implementation. Thus E. Mesthene says,

"we have found it more useful to define technology as tools in a general sense, including machines, but also including such intellectual tools as computer languages and contemporary analytic and mathematical techniques"
(1970, p25)

Technology is also used to describe engineering hardware alone, and is even restricted to only its most advanced manifestations, e.g., "industrial technology - that is, new machines and processes and the advent of factory automation" (Mesthene, p26).

Yet some economists have advocated retaining the distinction between technology and technique. Thus,

"Technology is the social pool of knowledge of the industrial arts Technological knowledge may be used to produce either more knowledge or ordinary goods and services. A method of producing a given good or service is a technique"
(Schmookler 1966, pp 1,2),

and

"Technology is society's pool of knowledge regarding the industrial arts. It consists of knowledge used by industry regarding the principles of physical and social phenomena, knowledge regarding the application of these principles to production, and knowledge regarding the day-to-day operations of production A technique is a utilized method of production"
(Mansfield 1968 , pp 10,11)

This distinction is now becoming more widely accepted (Johnson 1975, p17; Freeman 1977, p226; Layton, p199) and is retained in what

follows as providing a more useful insight than the broader definitions of technology which are sometimes used.

A further definition of technique is employed by some French writers (Ellul 1954; Meynaud 1964, pp 9, 22-24), to mean the application of method in the carrying out of tasks. Thus technique in this form is present in all aspects of human life, and is characterised by a continuing "rationalisation" of many types of operation, not merely industrial. It arises in part from difficulties of translation (*la technique* has a wider meaning than its English equivalent), and is inappropriate for the present purposes.

2.2 TECHNOLOGICAL AND TECHNICAL CHANGE

Even before these terms came into general use in economics, the essential importance of the concept was of course recognised. So when Schumpeter in 1928 (p31) said, "what we, unscientifically, call economic progress means essentially putting productive resources to uses hitherto untried in practice, and withdrawing them from uses they have served so far", he is in all but name referring to technical progress. Even earlier, Marx discusses the consequences of improvements in industrial machinery in 1867 (see 1954, Chapter XV).

The expressions technological change and technical change are very often used synonymously, principally

by economists to explain the gain accruing to the economy through the embodiment, in the means of industrial production, of advances in human knowledge.

However, a separation of meaning is desirable and necessary, and follows logically from the technology-technique distinction elaborated above. Technological change, or more accurately technological progress (since technological regression, or society-wide loss of knowledge, is assumed to be highly unlikely), therefore describes any increase in the knowledge of possible industrial practices.

A technical change, or change in technique, represents an alteration of the actual method of production employed. Thus the application of new technology in the form of industrial technique is called technical innovation, one form of technical change (Schmookler, pp 2,3; Mansfield 1968, p11).

Technical change has a meaning wider than that as a response to an increase in technological knowledge. It may also mean a shift, at a constant level of technology, from one set of techniques to another, through the substitution of the factors of production. At any given state of knowledge there will be several methods of producing a given output, and economic considerations may dictate, for example, a change from a labour intensive to a capital intensive method of production, as a result of increasing costs of labour relative to capital. Such an alteration is also known as a technical change, though not as technical

progress (Freeman 1977, p227; Schmookler, p2 note; Salter 1966, p5).

The two forms of technical change (through technological advance and factor substitution) are, however, difficult to distinguish in practice and often occur simultaneously in industrial innovation (Norris & Vaizey 1973, p24; Rosenberg 1976, p65).

2.3 MECHANIZATION AND AUTOMATION

Many differences of meaning are associated with the use of these two words. Although most writers regard automation as being more sophisticated than mechanization, this distinction is not consistently employed in the literature. Thus Blauner, by saying that "continuous-process technology is the most highly mechanized of the various forms of manufacturing" (1964, p125), implies that some of the most advanced industrial processes are to be called mechanization. Conversely, in 1936 Harder described automation as the "automatic handling of parts between progressive production processes" (Goodman 1957, p24), a definition which is quite restricted compared with current usage. Furthermore, automation is sometimes regarded as a specialised form of mechanization, as by Bright in his detailed classification of industrial machinery into 17 "levels of mechanization", the upper echelons of which may be called automated (1958, p188). Others suggest the reverse - "low levels of automation involve

"mechanization" of the physical effort part of the job, leaving the worker only the control function to perform" (D&R Elliot 1966, p44).

The diversity of the above definitions indicates a need for the clarification of terms before they can be usefully employed.

Mechanization. The authoritative dictionary definition of mechanization, though now somewhat dated (1933), is the act of "making or rendering mechanical". Mechanical means "acting, worked or produced by a machine or mechanism often in contrast to what is produced by hand-labour" (O.E.D., pp 284-6).

The idea of replacing human effort by mechanical effort is central to many interpretations of the word. Thus in 1929 Kimball writes, "By (mechanization) is meant the doing of the world's work by power-driven machinery instead of by the use of handicraft methods aided by manpower and animal power" (p295). The Elliots (1976, pp 44,219) similarly emphasise this aspect, as does Buckingham, thus, "mechanization means the use of machines to perform work. Sometimes mechanization substituted machinery for animal or human muscle" (1961, p15).

Yet other definitions of mechanization have concentrated on its economic effects. Blauner (1964, p36) writes that the level of mechanization is indicated by the ratio of total capital investment to the number of production workers. Another such interpretation

calls mechanization "any technical change which increases output per worker (or man-hour)" (Jaffe and Froomkin 1968, p17).

Automation. The possibility of machinery operating without human intervention has been recognised and expressed for many centuries. Aristotle wrote of a "condition that each instrument could do its own work, at the word of command or by intelligent anticipation, as if a shuttle should weave by itself ..." (Chapter IV; Barker 1958, p10; see also Ross 1949, p240).

It has been suggested that the origin of feedback control, essential to autonomous working, lies in three separate lines of pre-industrial technology - the water clock, thermostat, and a mechanism for controlling windmills (Mayr, 1970). Others take the first automatic control device to be the pressure cooker, devised in 1680 by a Frenchman, Denis Papin (Macmillan 1956, p8; for more similar examples see Buckingham, pp 26-7). Perhaps a better known early device was James Watt's centrifugal governor, designed in 1788, which regulated the speed of a drive shaft powered by his steam engine. Larger scale industrial automation, in the form of automatically controlled processes, has been present since the early 1930's in power stations, oil refineries, and certain chemical manufacturing processes (Salter, p25; Blauner, p124).

The word "automation" appears to have entered the English language in 1936 ("automatic" is a much older word) when it was used in the United States by Delmar S. Harder, in his definition quoted above (Goodman 1957, p24; Goodman 1958, p1; June et al 1955, p5). Other sources give its origin in print to be 1948, again from Harder (Burchfield 1972; Bullock & Stallybrass 1977). It was also claimed later to be a contraction of the word "automatization" coined by John T. Diebold, again in the U.S.A. (June et al, p5; Einzig 1956, pp 1,2). Whatever its beginnings, the word started to enter widespread use in Britain in the 1950s (D.S.I.R. 1956 , piii; Mortimer 1971, p28).

The subject of automation has been the target of voluminous outpourings in popular and academic literature, and consequently an immense number of varied definitions of the term exists. Restricting oneself to industrial automation in the production process (because the word is often used nowadays to include the effects of information processing and cybernetics in the office and the service sector, thus taking it beyond the concern of the present work), it is possible to classify a selection of these definitions of automation.

Firstly, probably the majority of writers emphasise the importance of feed-back control and self-regulation of the machinery. John Diebold, one of the most prominent early exponents of automation, comes into this category (June et al, p5). A report

by the Diebold Group to the U.S. government calls automation "the performance of work by automatically controlled machines or systems" (1965). In more detail Jaffe and Froomkin write of automation,

"This term should be reserved for that type of production process utilizing the automatic or feedback principle, in which a control mechanism triggers an operation after taking into account what has happened. The feedback principle generally distinguishes automation from mechanization".

The ultimate development is said to be a closed-loop process (Jaffe and Froomkin, p18).

Sir Leon Bagrit's BBC Reith Lectures, while not purporting to define automation, nevertheless view it as "a concept through which a machine-system is caused to operate with maximum efficiency by means of adequate measurement, observation and control of its behaviour" (Bagrit 1965, p13). Dennis Gabor (1970, p48) and J.K. Galbraith both similarly note the requirement for control with feedback : "an industrial process which provides data from its own operations and feeds this back usually through a computer to controls which fully govern the process" (1974, p239).

Lastly, the Oxford Dictionary definition of automation also requires self-regulating control to be present, describing it as "automatic control of the manufacture of a product through a number of successive stages; the application of automatic control to any branch of industry or science" (Burchfield, p159).

A second category of definitions requires the integration of several separate branches of engineering to achieve a substitute for both human physical effort and decision-making. In this vein Aaronson says "automation is the substitution of mechanical, pneumatic, hydraulic, electric and electronic devices for human organs of decision and effort" (quoted in June et al, p5, and Buckingham, p15). This definition includes effort devices (conveyors, motors) and decision devices (computers). The Department of Scientific and Industrial Research and the Trades Union Congress have used a definition meaning the merging of three separate technologies: automatic machinery, automatic process control, and the automatic processing of data (D.S.I.R. 1956 ; Mortimer, p28). Mann and Hoffman (1960) note that "there is not agreement on a single manufacturing process or mechanical complex called automation", but most automated processes exhibit:

- "1. More frequent use of automatic equipment.
2. Greater mechanization of transfer operations and combination of work units.
3. The use of multiple, closed-loop feedback systems as controls to achieve greater unity of all parts of the production process" (p3).

This importance of the integration of many devices into an inter-connected system is also mentioned by Goodman (1957, p24) and Diebold:

"Automation requires us to view the production process as an integrated system and not as a series of individual steps divided according to the most economic

distribution of human skills - or even "difficult of individual machines" (1955).

By way of a third category of definitions, a few writers, unlike the first group, do not insist that self-regulation is essential, although it may be present - it is sufficient that the machine is automatic in the literal sense of "self-acting under conditions fixed for it, going of itself" (O.E.D., p574). Thus the Elliots divide automation into various levels, only the higher of which are "self-correcting and self-controlling" (p44). Goodman has carried out one of the most comprehensive surveys of the semantics of automation, and his lengthy definition is worth quoting in full:

"Automation is the technology of automatic working in which the handling methods, the processes and the design of the processed material are integrated to utilize as fully as is economically justifiable the mechanization of thought and effort, in order to achieve an automatic and in some cases a self-regulating chain of processes" (1957, p26; 1958, p2).

A final aspect of automation is its consequences in terms of practical economics, and a definition similar to that quoted earlier for mechanization also exists:

"What matters for us is that automation, whether in the broadest or narrowest sense of the term, is a technological method that tends to reduce current production costs in terms of man-hours per unit of output" (Einzig, p2).

From the above will be appreciated the difficulty of deciding at what point mechanization and automation have been achieved in a given industrial process. Furthermore, many manufacturing processes involve a series of separate operations which will in most cases differ in the degree of mechanization or automatic control which they individually employ. Therefore any definitions which are to be useful in a practical classification of industrial techniques will perhaps be better to express the idea that manufacturing processes can exhibit mechanization and automation to varying degrees rather than that they are absolutely present or absolutely absent. In this light, the following definitions are employed in the remainder of the thesis.

1. The technology as knowledge, technique as practice, distinction elaborated earlier is accepted.
2. A technological innovation is therefore an addition to the stock of knowledge of the possibilities in industrial practice.
3. A technical innovation is the practical realization in a working device of a technological innovation.
4. The degree of mechanization of an industrial operation is the extent to which it dispenses with human intervention in the form of physical effort essential to its normal functioning.

5. The degree of automation of an industrial operation is the extent to which it dispenses with human intervention in the form of monitoring and control essential to its normal functioning.

The definition of automation therefore subsumes mechanization. By way of examples, definition 4 would classify a manually-loaded press as partial mechanization; and definition 5 will exclude a conveyor belt which, while operating automatically in the sense of autonomously, does not represent automation because it requires no monitoring and control in its normal operation.

Chapter Three

THE ECONOMICS OF TECHNOLOGICAL CHANGE

Neo-classical economics offers an elaborate theory of production, in which the idea of technological change plays an important part.

It is mathematically based, and identifies a continuum of technological levels purporting to represent advances in human knowledge and the way these are embodied in industrial practices. In this way, it is used to explain how industrial techniques vary between individual factories, and the way in which technological progress can advance the efficiencies of manufacturing processes and entire national economies.

The theory distinguishes several different categories of change, each consequent upon different adjustments to capital, labour and the other inputs to the production process. There are also other relevant economic writings.

3.1 THE PRODUCTION FUNCTION

The production function is an expression of the relationship between the inputs and output, and between the inputs themselves, in the production process. Outputs represent the end products of the industrial process, and inputs consist of the factors of production; that is, land, labour, capital, energy and raw materials. These are often classified into simply two aggregate factors, labour and capital.

The most widely used production function is that of the Cobb-Douglas type (Cobb, 1928, p139):

$$Q = AL^{\alpha}K^{\beta} \quad *$$

Where Q is output produced, L is a measure of labour employed, K is a measure of capital employed, A is a scale factor whose magnitude indicates the efficiency of the production process in converting inputs into outputs, α is the partial elasticity of production (output) with respect to labour ($\alpha = (dQ/dL) \cdot (L/Q)$), and β is the partial elasticity of production with respect to capital ($\beta = (dQ/dK) \cdot (K/Q)$). A, α and β are constants for a given state of technology, and are to be empirically ascertained (Brown, 1968, pp31-33).

* This is the unrestricted two-factor form of the production function. The restricted form, where $\alpha + \beta = 1$, is also commonly employed (Brown, 1968, p31).

This type of production function has a number of important characteristics.

If output is to be increased, capital and labour requirements also increase. The marginal products ((dQ/dL) and (dQ/dK)) are therefore positive (Dernberg, 1972, p316; Brown, 1968, p32).

Furthermore, it exhibits diminishing marginal productivity of inputs (capital and labour). That is, if one factor input is held constant, an increase in the other will yield diminishing increases in output. This is true when α and β are each less than unity, which is normally the case (Brown, 1968, p32n).

The function is homogeneous of degree $\alpha+\beta$. The degree of homogeneity of a production function is a measure of the amount by which output increases for a given increase in inputs. As mentioned, there are two forms of the Cobb-Douglas production function, restricted and unrestricted. In the restricted form the factor exponents, α and β , sum to 1, and as inputs are increased output increases in the same proportion. This is known as constant returns to scale. The unrestricted form imposes no such limitation on α and β . If their sum is greater than 1, then economies of scale obtain, i.e. as inputs are increased the corresponding increase in output is proportionately greater. Conversely, if their sum is less than 1, diseconomies of scale are said to exist. In summary:

$\alpha + \beta < 1$: diseconomies of scale

$\alpha + \beta = 1$: constant returns to scale

$\alpha + \beta > 1$: economies of scale

A further characteristic associated with homogeneity is that least-cost factor proportions are unaltered by an increase in output (Lipsey, 1971, p224).

Isoquant Analysis

The production function permits a given level of output to be achieved by varying quantities of inputs. This is illustrated graphically in Fig.3.1.

The curved lines are isoquants (joining points of equal quantity of output) which indicate how varying amounts of labour and capital can be used to produce the same level of output. The shape of the curve (asymptotic to the K and L axes) is a consequence of the previously noted characteristic of decreasing marginal productivity.

Figure 3.1 is a two-dimensional representation of what is properly a continuous three-dimensional surface. The third axis measures output, and a convex production surface rises from the origin, and from both the K and L axes. The successive isoquants are on this surface at increasing heights above the K-L plane, as Fig.3.2 shows (Allen, 1950, p285). Most analysis, however, can be done on the two-dimensional isoquant diagram.

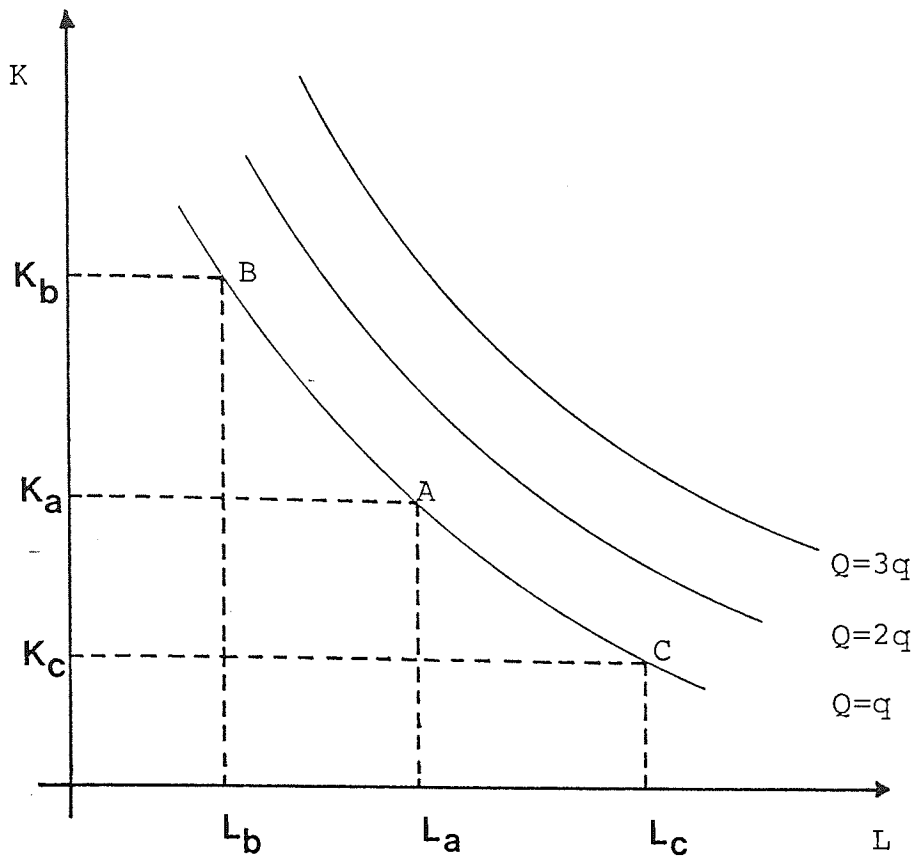
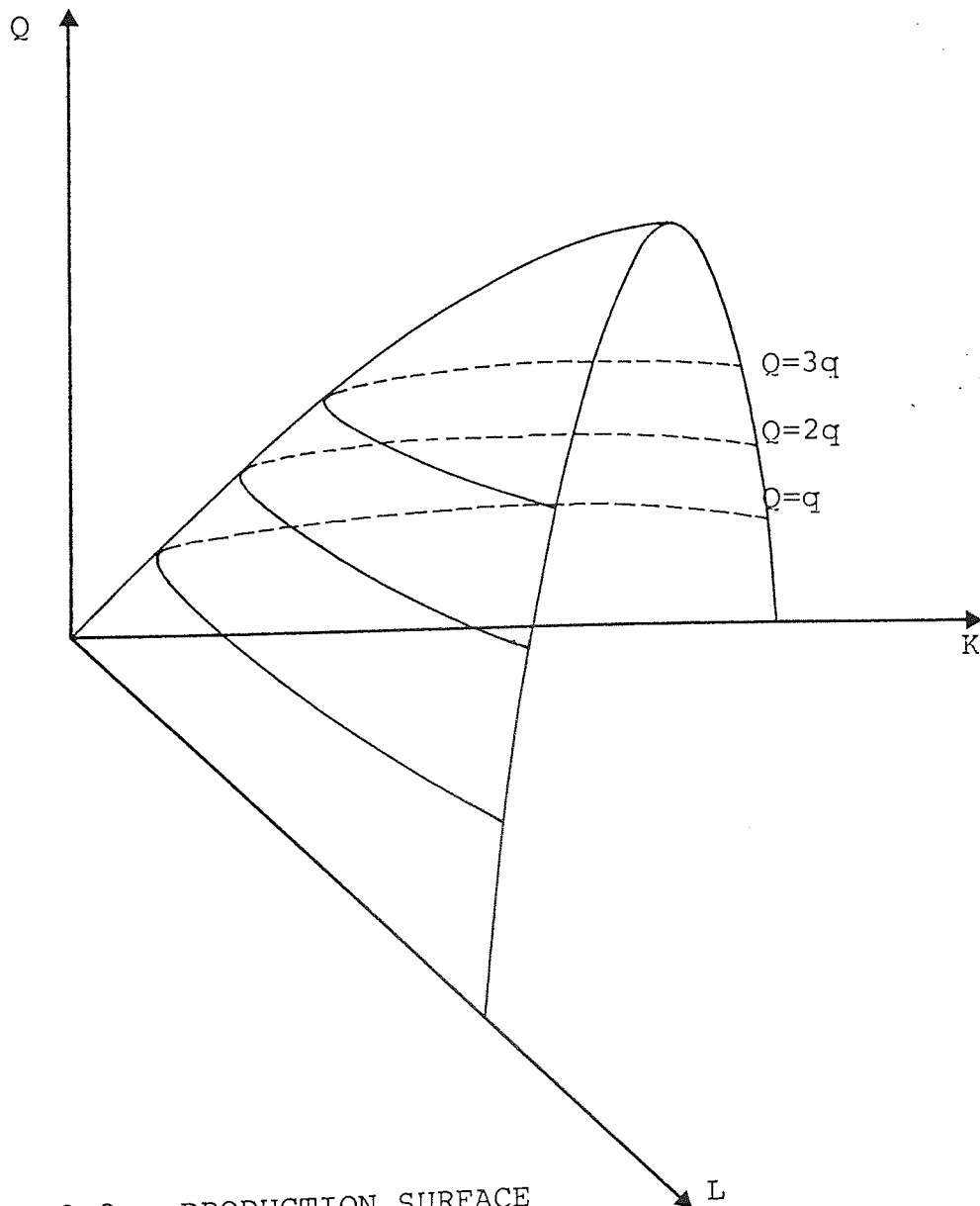


FIG.3.1 : ISOQUANT ANALYSIS



PRODUCTION SURFACE

Returning to Fig.3.1, a firm producing an output of q units and operating at point A employs K_A units of capital and L_A units of labour. Without altering output it can move to point B (on the same isoquant) by reducing its labour input to L_B and increasing its capital input to K_B . This new operating point, B, is said to be more capital-intensive than point A.

Converse changes in inputs result in a movement towards point C, which is more labour-intensive (less capital-intensive) than point A*. This phenomenon of movement along an isoquant is known as factor substitution. Similar adjustments could be made by a firm operating at another level of output, such as $2q$ or $3q$, although in practice not all points on the isoquant are attainable because of indivisibilities present in the factors of production.

There are two mathematical parameters associated with the concept of factor substitution. Firstly, the marginal rate of substitution of capital for labour is defined to be the derivative of capital with respect to labour, dK/dL . This is equal to the slope of the tangent to the isoquant, and can also be understood as being the ratio of the marginal product of labour to the marginal product of capital:

$$MRS_{KL} = \frac{MPL}{MPK} = \frac{dQ/dL}{dQ/dK} = \frac{dK}{dL}$$

* There is an additional definition of labour and capital intensity elaborated later (page 46).

Similarly, the marginal rate of substitution of labour for capital is the reciprocal, dL/dK .

A concept related to the marginal rate of substitution is the elasticity of substitution. This is a measure of the ease with which one factor can be substituted for the other at a constant output, and relates to a proportional change in the ratio in which factors are employed, to the corresponding proportional change in the marginal rate of substitution between factors, or their relative marginal products* (Brown, 1968, p18; Blaug, 1963, p90n; Bannock, 1972, p139; Salter, 1966, p34).

The elasticity of substitution of capital for labour is defined thus:

$$\begin{aligned}\sigma_{KL} &= \frac{\text{Proportional Change in } K/L}{\text{Proportional Change in } MRS_{KL}} \\ &= \frac{d\left(\frac{K}{L}\right) / \left(\frac{K}{L}\right)}{d\left(\frac{dK}{dL}\right) / \left(\frac{dK}{dL}\right)} \\ &= \frac{d\left(\frac{K}{L}\right) \cdot \left(\frac{dK}{dL}\right)}{\left(\frac{K}{L}\right) \cdot d\left(\frac{dK}{dL}\right)}\end{aligned}$$

Similarly, the elasticity of substitution of labour for capital is represented by:

$$\sigma_{LK} = \frac{d\left(\frac{L}{K}\right) \cdot \left(\frac{dL}{dK}\right)}{\left(\frac{L}{K}\right) \cdot d\left(\frac{dL}{dK}\right)}$$

* This can also be thought of as the relative factor price ratio, since factors are paid the value of their marginal products under perfect competition.

Elasticity of substitution can take any positive value, between 0 and ∞ , and is in inverse proportion to the degree of curvature of the isoquants.

For the Cobb-Douglas production function the two elasticities are equal, and are unity, for all combinations of capital and labour and for all values of α and β (Brown, 1968, p36).

Only one point on the isoquant is economically optimal at a given factor price ratio, and this is determined by the point of tangency of an isocost line, which represents all combinations of labour and capital which a firm could acquire for a given outlay. The slope of the isocost line reflects the relative factor prices, and is derived from a budget equation of the following form:

$$C = c_L L + c_K K$$

where C is total cost, c_L is the unit cost of labour, c_K is the unit cost of capital, L is a measure of the amount of labour employed, and K is a measure of the amount of capital employed.

The isocost lines are superimposed on the isoquant diagram, as indicated in Fig.3.3.

For a total outlay of c_1 a firm is unable to produce an output of q , since the isocost line ($C=c_1$) does not meet the appropriate isoquant at any point. For an outlay of c_3 , a firm can produce an output of q in two combinations of capital and labour inputs: at point Y , employing k_B units of

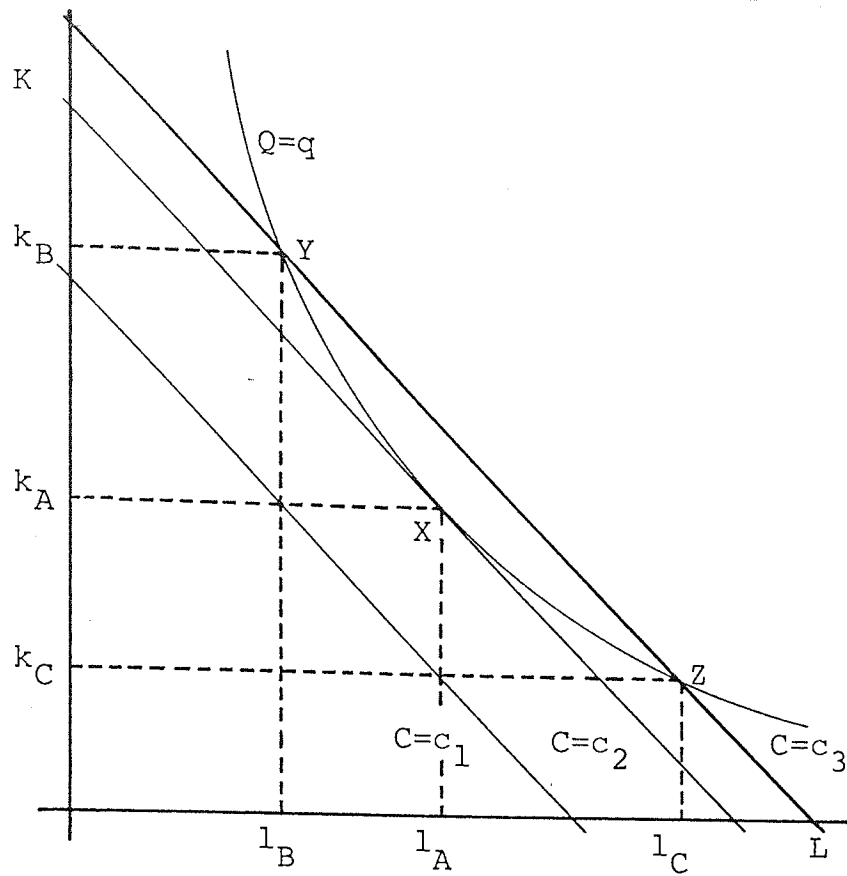


FIG.3.3 : ISOCOST LINES

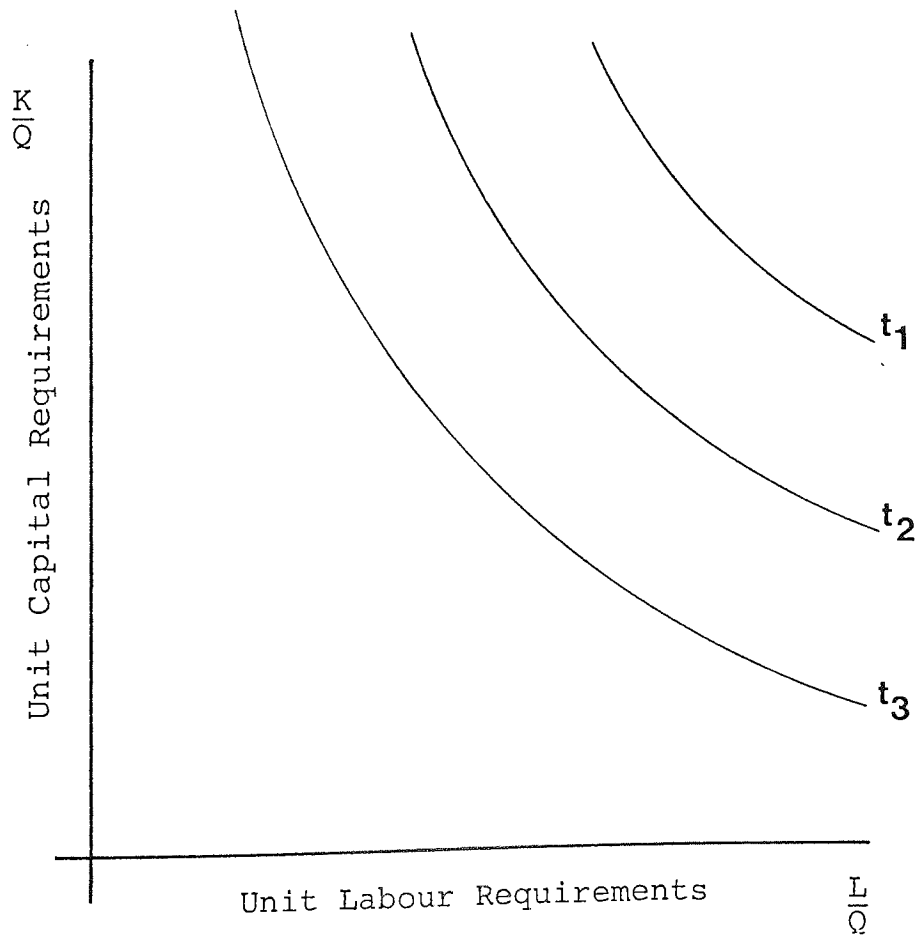


FIG.3.4 : STATE-OF-TECHNOLOGY CURVES

capital and l_B units of labour; or at point Z, employing k_C units of capital and l_C units of labour.

However, neither of these is economically optimal because it is possible to move along the isoquant to achieve a lower level of total cost, in the case of Y by substituting labour for capital, in the case of Z by substituting capital for labour.

The point of tangency, X, therefore represents the least cost combination of capital and labour which will produce an output of q . At this point the highest possible factor productivity is achieved.

An alteration of relative factor prices would change the slope of the isocost line and hence shift the least-cost point of optimality away from X.

3.2 TECHNOLOGICAL CHANGE AND THE PRODUCTION FUNCTION

Technological change, or an alteration in the state of knowledge of industrial practices, has important implications for the production function, involving changes in a number of the variables.

Technological change is best represented diagrammatically by transforming the previously illustrated isoquant diagram (Fig.3.1) to eliminate the effect of variations in output. The axes now represent capital and labour requirements per unit of output. Mathematically these are given by the expressions K/Q and L/Q , the inverses of the average

product of capital and labour respectively, and hence measures of factor productivity (Salter, p22).

If we now make the assumption of constant returns to scale (i.e. that unit factor requirements do not vary with output), then the entire production function at a given state of technology, for all outputs and all combinations of labour and capital, is represented by a single curve (Mansfield, 1968, p14).

Movement to a different curve closer to the origin therefore represents a shift to a new production function which is more technically advanced than the previous one, because factor inputs per unit of output are reduced at all points on the curve (Reddaway, 1977). In Fig.3.4 the production function represented by the curve t_3 is more technically efficient than t_2 , which is in turn more efficient than t_1 .

Neutral Technological Change

Fig.3.4 illustrates a special case of technological change known as neutral technological progress (if the frontier of technical possibilities moves over time from t_1 through t_2 to t_3). In this instance, the curve has moved towards the origin in equal proportions at all points : that is, the marginal rate of substitution is unchanged at all combinations of capital and labour. In terms of the production

equation, $Q = AL^\alpha K^\beta$, the parameter A has increased.

A second type of neutral technological change has also been identified (Brown, 1968, pp13,21,39). This involves a change in the degree of returns to scale obtaining in a production process, when this is a consequence of a change in the technical methods of production (it could also be a consequence of other causes). In mathematical terms, if the sum of the elasticities α and β increases such that the ratio α/β remains constant, then there has occurred a neutral technological gain. Again, the marginal rate of substitution between factors remains constant.

An example of such would be a constant-returns process being technologically transformed to an increasing returns process, from $\alpha+\beta = 1$ to $\alpha+\beta > 1$, with the ratio α/β the same in both instances. This is illustrated graphically in Figs. 3.5 and 3.6.

Non-Neutral Technological Change

The more general case of technological change is known as non-neutral or factor-biased, and is represented graphically by a skewed movement of the curve towards the origin, i.e. it moves closer to one axis than to the other. It is therefore of two types; capital using (or labour saving) when the curve moves closest towards the capital axis, and labour using (or capital saving) when it moves closest towards the labour axis. In terms of the

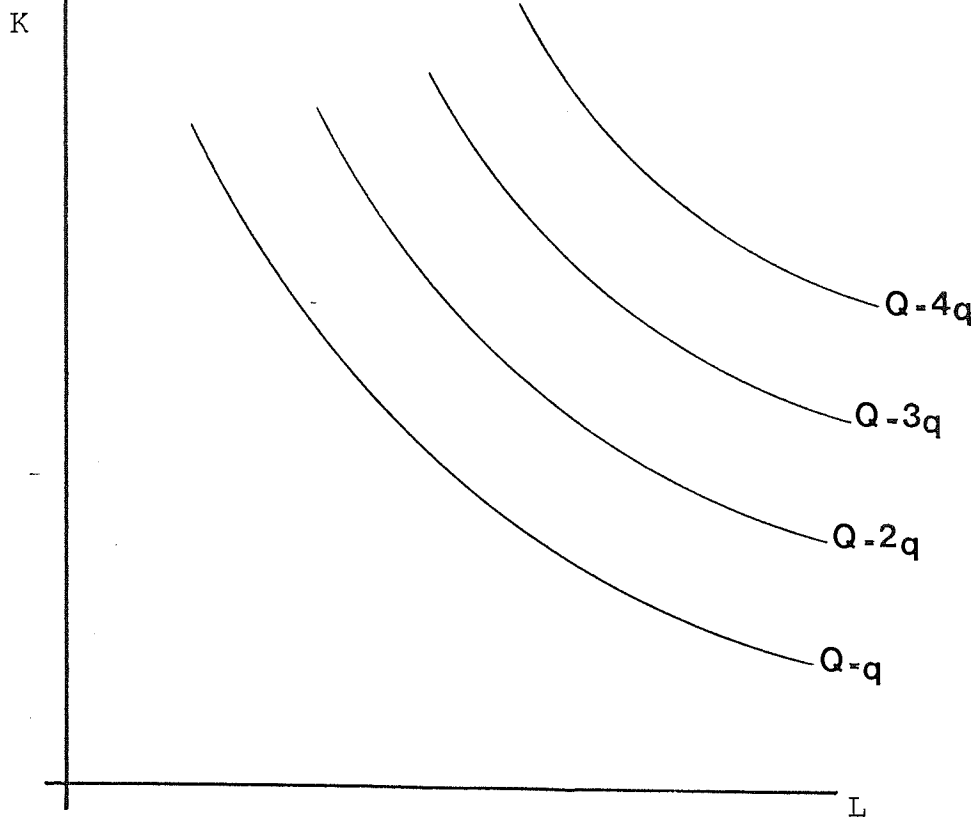


FIG.3.5 : CONSTANT RETURNS TO SCALE

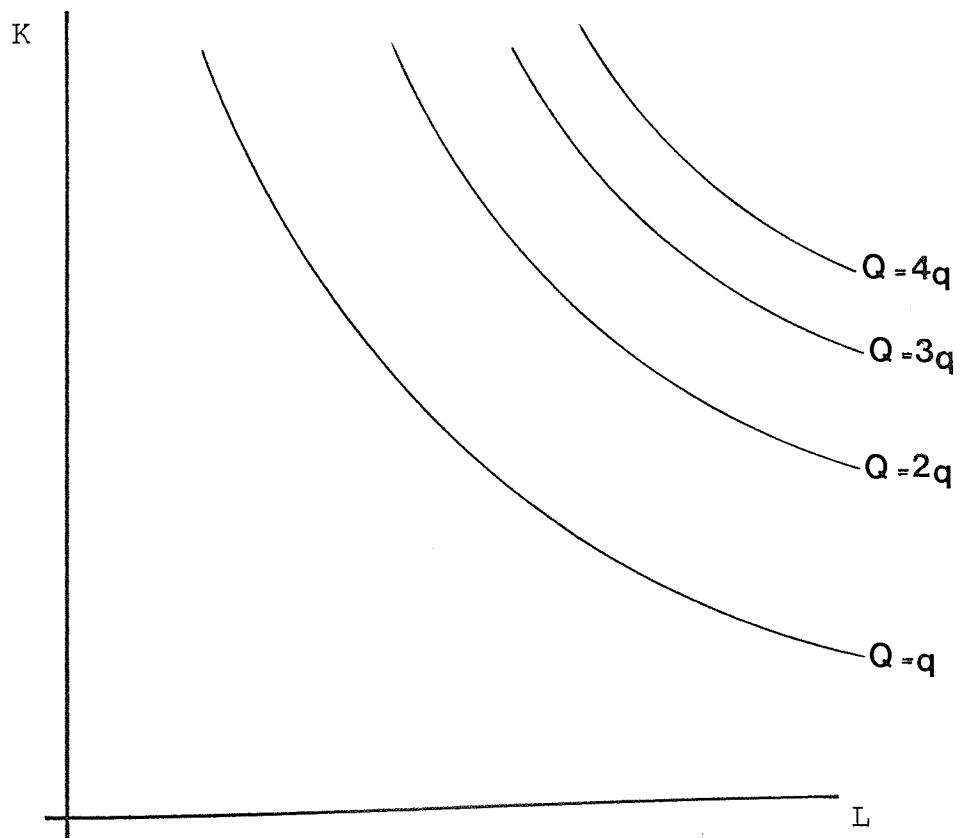


FIG.3.6 : INCREASING RETURNS TO SCALE

production function, this requires an increase in the coefficient A and a change in the ratio of the partial elasticities of production, α/β .

If β rises relative to α , then the change is of the labour-saving type (the marginal product of capital has risen), and if α rises relative to β then the change is of the capital-saving type (the marginal product of labour has risen).

It is apparent from Figs 3.7 and 3.8 that the marginal rate of substitution of capital for labour (dK/dL) is altered in a non-neutral technological change - in Fig. 3.7 (labour saving technical progress) it is decreased from curve A to curve B, and in Fig. 3.8 (capital saving) it is increased from C to D (Brown, 1968, pp22-3, 40-1).

The extent to which a curve is biased towards the capital (or labour) axis is a measure of the capital (or labour) intensity of the production process. Thus the technology represented by the curve B is more capital intensive (and more technically advanced) than that represented by curve A, because at constant factor proportions (e.g. at points a and b) the marginal rate of substitution of capital for labour is lower on curve B. Similarly, curve D is more labour intensive than C because the marginal rate of substitution of labour for capital is lower on D (and the marginal rate of substitution of K for L is higher).

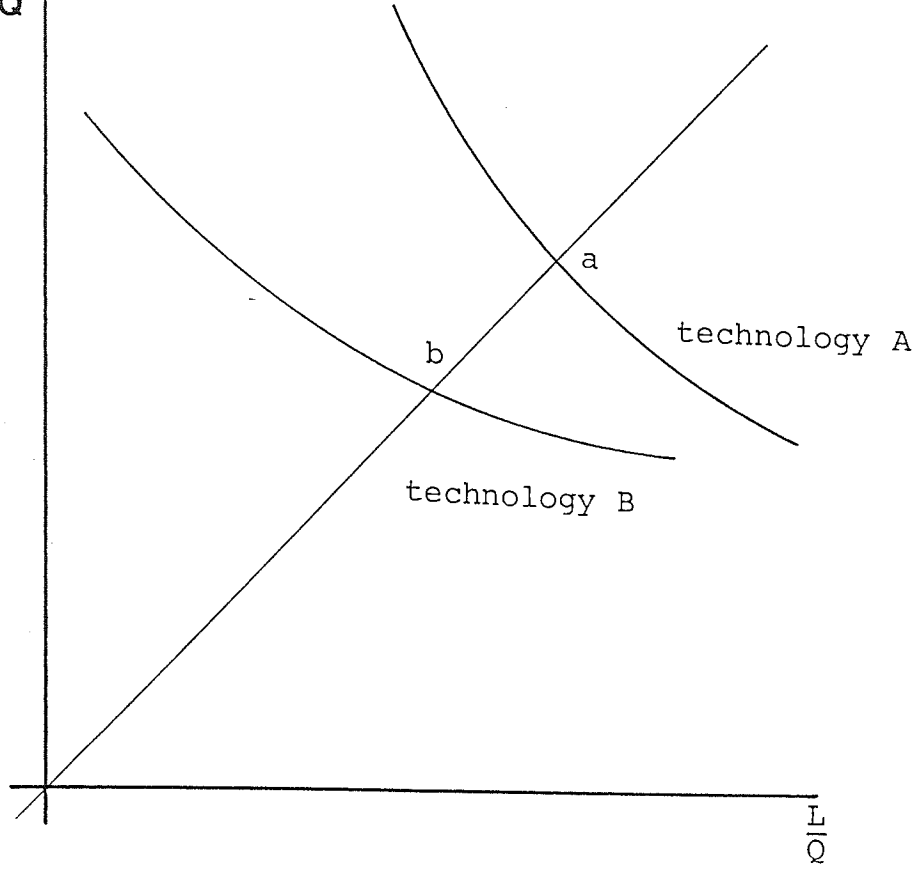


FIG.3.7 : LABOUR-SAVING TECHNICAL PROGRESS.

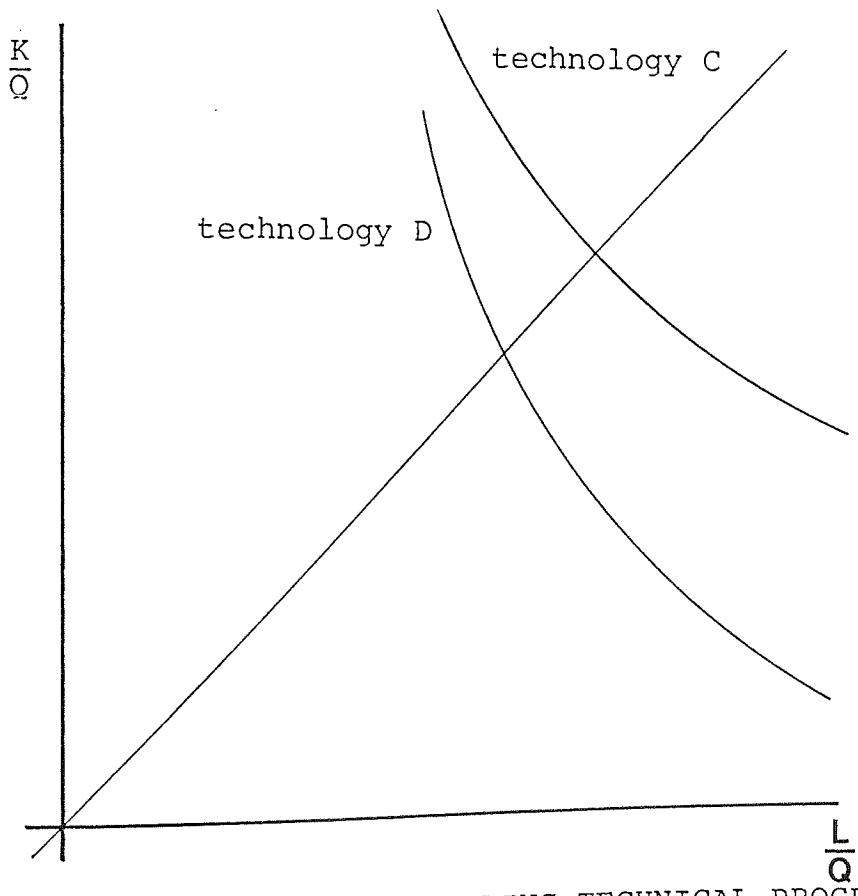


FIG.3.8 : CAPITAL-SAVING TECHNICAL PROGRESS

This definition of factor intensity does not conflict with that advanced earlier (page 38). In this instance we are concerned with the capital intensity of a complete technology, whereas previously we were comparing different points on the same isoquant. So although curve B (Fig.3.7) is more capital intensive than curve A in terms of the marginal rate of substitution, some points on curve B will be more or less capital intensive than others on the same curve in terms of the K/L ratio.

For continuing technological progress, successive curves moving towards the origin must not cross at any point, since this would represent technological retrogression over part of the production function (Salter, 1966, pp 21-3, 27-9).

An important consequence of factor-biased technological change is its effect on the point of optimality, as determined by the point of tangency of an isocost line (see page 40). It is apparent from Fig.3.9 that when the marginal rate of substitution changes with technological progress, and the ruling factor price ratio (as indicated by the gradient of the isocost line) remains constant, then the least-cost factor proportions are altered.

Thus for labour-saving technological progress as illustrated in Fig.3.9, the K/L ratio is increased at optimality, in a movement from point A on curve t_1

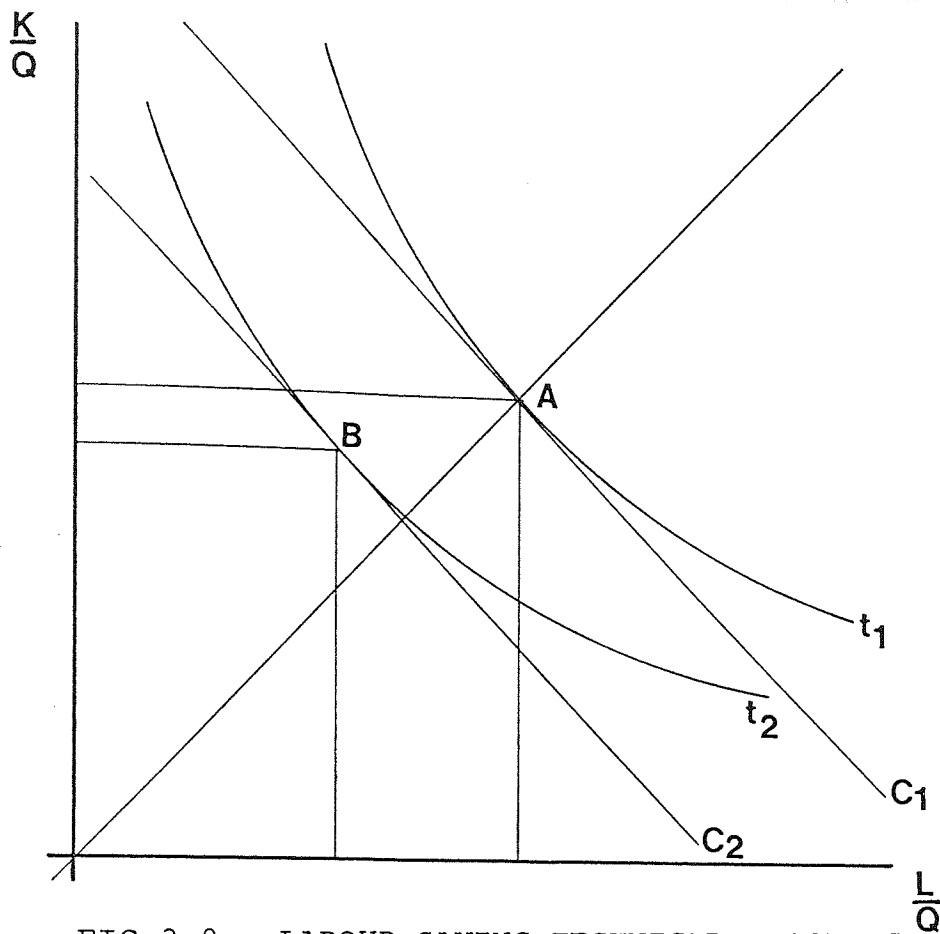
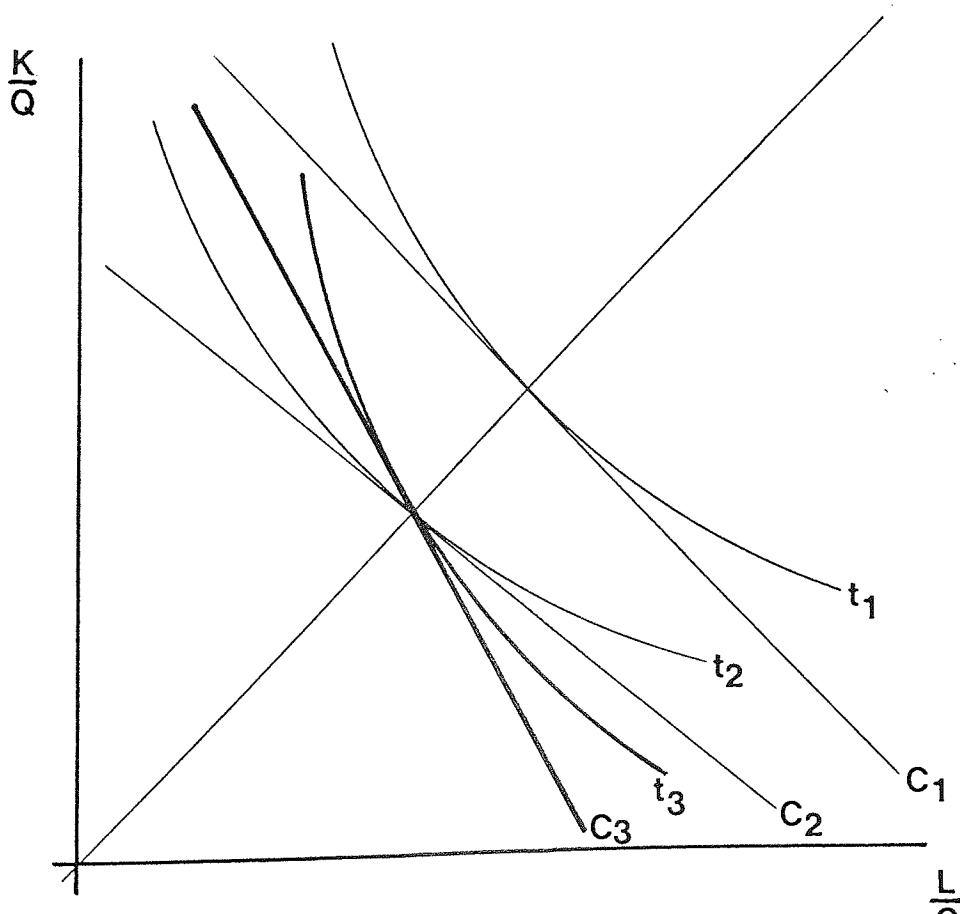


FIG.3.9 : LABOUR-SAVING TECHNICAL PROGRESS AND ISOCOSTS



t_1 to t_2 = labour-saving technical progress
 t_1 to t_3 = capital-saving technical progress

FIG.3.10 : FACTOR-BIASED TECHNICAL PROGRESS AT CONSTANT FACTOR PROPORTIONS

to point B on curve t_2^* . This is the situation as it applies to the individual firm operating in the market, where the factor price ratio is given for the firm, and is outside its control.

However, we can also consider technological change at constant factor proportions, i.e. the K/L ratio remaining unchanged. In this case factor-biassed technological progress is depicted by a change in the marginal rate of substitution at optimality, and hence a change in the factor price ratio[†]. The concept is illustrated in Fig.3.10.

It is apparent that a labour saving technological gain rises the marginal rate of substitution of labour for capital at a given capital-labour ratio, and conversely for a capital-saving technological gain. This is the Hicks-Robinson definition of factor-biassed technological change, and is applicable to the economy as a whole, where (in the short term) factor proportions are constant and relative factor prices may be altered by market forces. Thus in this approach, a labour-saving technological change does not save labour in terms of quantity employed, but rather reduces labour's share of total income, and hence the wage rate.

* See Blaug (1963, p88 and Fig.1). His exposition employs K and L as the axes' labels, whereas K/Q and L/Q are employed here, but they are directly comparable.

† The gradient of the tangent to the curve = marginal rate of substitution = factor price ratio, see pages 38 and 40.

The above two definitions are not in conflict, and the graphical analysis employed above can incorporate both effects on the same system of curves.

Changes in the elasticity of substitution between capital and labour (σ) can also result in a non-neutral technological change. However, for the Cobb-Douglas production function employed here, σ is always equal to unity. Other production functions may not share this restriction (Brown, 1968, pp 22, 40-1).

3.3 OTHER RELEVANT ECONOMIC THEORY

The foregoing theory of neo-classical economics is mainly used at the macro-level in analyses of national economies (e.g. Solow 1957; Salter 1966; Wragg 1978), but although attempts have been made to apply it to the situation of real firms, it has been the target of criticism for its abstract nature (Blaug 1974).

It requires, for instance, that the factors of production be infinitely divisible, and so able to be freely substituted as changes occur in their relative prices. This is transparently impossible. At the very minimum, labour must be hired in multiples of one. Furthermore, the division of labour makes many industrial tasks interdependent, dictating that recruitment and lay-off of staff occurs

en masse. In the prevailing socio-economic climate, they are not equally easily accomplished.

The theory also assumes the operation of simple market forces to determine the supply and demand for labour and capital, which must be suspect. In the inflation-prone economies of the OECD countries, for instance, wage rates are rarely forced down by market pressures, as the hypothesis implies.

Yet other aspects of conventional production theory lay it open to some doubt, such as its assumption of a free flow of knowledge. Certainly much is available through the patent literature, which has been estimated to contain 75% of the useful technical information on process development (Baines et al 1969), and is encouraged as a mechanism for the diffusion of innovations (Patent Office, 1974). Schmookler (1966) believes that avoiding patenting valuable inventions to preserve secrecy is rare. Some limited findings suggest that the contrary may be more widespread than commonly imagined (MacTaggart 1976), and a patent adviser in one high-technology industry claims that only processes and devices which are detectable are patented; the most sensitive information invariably remains on companies' internal registers of trade secrets (Donaldson 1980). In the last resort, however, the matter of how much industrial knowledge remains (at least initially) with the discoverers can only be a matter for speculation.

When such information is freely available, it occasions no surprise to find that the rate of imitation tends to be faster for innovations which are profitable, and require a comparatively low level of investment for their realisation (Mansfield 1961).

A separate body of theory exists to explain the diffusion of innovations, that is, how new industrial techniques (or products) spread throughout the economy, and so consolidate technical progress into the stock of society's industrial practices. This is essentially peripheral to the study of individual cases of technical change, but for examples of such studies see Griliches (1957), Utterback (1974), Warner (1974), Hough (1975), Zermeno (1979), Zermeno et al (1979).

The diffusion of innovations and the widespread implementation of technical advances is closely linked to economic growth, and its importance for developing countries is widely recognised, despite controversy over the rate at which advanced techniques should be introduced (Scientific American, 1963; Baldwin 1972; Stewart 1973; Cooper 1973; Ahmad 1980).

Among the more advanced western countries, comparative economic performance is often attributed to productivity (an indicator of the state of industrial technology), particularly in the light of the UK's recent experience (Melman 1955; Cairncross 1977;

Sargent 1979; Pavitt 1979, 1980). The chain of cause and effect in respect of national economic progress is extended further back by other writers, who see a direct relationship between expenditure on research and development and growth (Mansfield 1972; Merrett 1981).

In addition to explanatory theories of technical change, a substantial body of economic literature is devoted to its consequences. The effects range from the most common concern, unemployment (Kondratieff 1926; Freeman 1977; Moseley 1979; Rothwell et al 1979), to capital formation (Weintraub 1939) and restrictive practices (Weinstein 1965).

One final group of literature, which may be categorised as innovation studies, requires to be mentioned. These include analyses of investment decisions (Carter et al 1958), comparative studies of success and failure in innovation (S.P.R.U. 1972), reviews of factors promoting innovation (Carter et al 1957; A.C.A.R.D. 1978; Comerford 1979; I.M.E. 1979), and lastly more general innovation models (Abernathy 1978; Haustein et al 1979).

Chapter Four

SOCIAL THEORY OF INDUSTRIAL TECHNOLOGY

A wide range of sociological theory covers the subject of industrial technology and how it relates to various social variables. Most writings have tended to deal with the way a given production system influences the pattern of social relations within the factory, and workers' behaviour. However, the clear implication is that technical change injects a dynamic element into the situation, setting off a cascade of consequences for factory organisation, workers' job experiences, and industrial relations. The main trends in organisational and social research on industrial topics are outlined in what follows.

4.1 TECHNOLOGY AND INDUSTRIAL ORGANIZATION

Woodward (1958, 1965) has found that technical methods of production determine the organisation and human relations within factories; "... the main conclusion reached through this research project was that the existence of the link between technology and social structure first postulated by Thorstein Veblen (1904) can be demonstrated empirically" (1965, p50).

In a survey of 100 manufacturing firms in south east England she identifies technical methods as being the main distinguishing factor, and isolates three main groups: small batch and unit production; large batch and mass production; and process production. Three main organisational criteria were used to define the differences between the technological groups, viz., (1) the number of levels of authority in the management hierarchy increased with technical complexity (from unit to process), (2) the span of control* of the first line supervisor reached its

* 'Span of control' is indicated by the number of people reporting to an individual. The management 'line' refers to the vertical hierarchy of control and authority within the firm. The first line supervisors are thus those whose managerial position is one level above factory operatives. Management 'staff', in contrast, are appended horizontally to the line at various levels and are organisationally outwith the main hierarchy, e.g. personnel functions, finance.

peak in mass production and then decreased, (3) the ratio of managers and supervisory staff to total personnel was to a certain extent dependent on the size of the firm, but the general trend was of increasing managerial staff with technical advance.

Other variations with technology are elaborated in Woodward's later work (1965) thus; (4) the span of control of the chief executive increased with technical complexity, as did the incidence of 'management by committee', (5) labour costs as a proportion of turnover decreased with technical complexity, (6) the qualifications of managerial and supervisory staff increased with technical complexity, (7) the ratio of direct to indirect labour decreased with technical complexity.

As indicated above the span of control of first line supervisors peaked in mass production. A number of other organisational factors exhibited such a relationship to technology. Thus unit and process firms were similar in having a higher proportion of skilled labour, more flexible work rates, more verbal communications, and less specialisation of management functions compared with mass production.

Many of these similarities are related to the type of management system employed - mass production tended to be bureaucratic (or 'mechanistic', to use the terminology of Burns and Stalker (1961)), process and unit were non-bureaucratic or 'organic'. The

reason for this was found in the nature of the 'central problem' in each of the production systems. In unit this is product development, in process it is marketing, and both require the ability to innovate and the implication of organisational flexibility. Mass production, by contrast, has as its central problem the efficiency of production itself, and a bureaucratic organisation with rigidly defined roles is the most suitable.

Burns and Stalker's organisational models are not specifically related to technology, but to the general environment in which the firm operates. The mechanistic organisation is most suitable for conditions of market stability and constant technical methods of production. The organic organisation, characterised by the lack of a rigorously defined hierarchy or task delineation, is more appropriate to instability in the environment.

Sayles (1958) has, like Woodward, found organisational similarities at the extremes of technical complexity. His analysis is of the role of the informal work group and suggests that in craft industries socially cohesive work groups are formed under the influence of a common craft identity, membership of a community, and opportunities for social interaction at work. Although process workers lack an occupational community, they are, unlike craft workers, functionally interdependent, and this tends to promote a work group identity. By comparison,

machine-minding and assembly-line technologies, with their rigid job definition and controlled work pace, do not permit social interaction and thus inhibit the formation of informal groups.

4.2 TECHNOLOGY AND THE EXPERIENCE OF WORK

Woodward's discussion of different production technologies goes further than merely the organisational consequences. She relates technology quite directly to the worker's subjective experience on the job: "there appear to be considerable differences between production systems in the extent to which the 'situational demands' create conditions conducive to human happiness" (1958, p30). In particular, mass production severely restricts the possibilities for job satisfaction and does not provide an outlet for the workers' desire to belong to a stable work group.

Blauner's study of alienation takes a similar position: "I attempt to show that the worker's relation to the technological organisation of the work process and in the social organisation of the factory determines whether or not he characteristically experiences in that work a sense of control rather than domination" (1964, pvii). These two writers therefore lay heavy emphasis on technology determining the workers' reactions.

Sayles, however, offers an alternative approach which lays more emphasis on the importance of the informal organisation of the work place as mediating between the technology and the workers' reaction to it (1958). His identification of a link between production technology and the informal group has been taken up by the socio-technical systems school, as outlined by Rice: "The concept of socio-technical system arose from the consideration that any production system requires both a technological organization - equipment and process layout - and a work organization relating to each other those who carry out the necessary tasks. The technological demands place limits on the type of work organization possible, but a work organization has social and psychological properties of its own that are independent of technology" (1958).

Thus socio-technical systems theory maintains that although technology, the formal organisation, and individual workers' outlooks are systematically related, no one factor is of predominant importance. It is a species of open systems theory, in which the organisation is considered as a system operating within an environment which influences it. Technology is the mechanism by which inputs to the system from the environment (e.g. the market for raw materials) are converted into outputs discharged to the environment (the market for finished goods).

Trist and others (1951, 1963) have applied socio-technical systems theory to the coal-mining

industry, where they examined the transition from traditional working techniques to the conventional long wall method of mining. The old 'single-place working' incorporated small, self-selected, and largely autonomous teams with all the necessary skills to perform the complete process of coal extraction. The longwall method was an attempt to rationalise work organisation, but it had detrimental social and economic consequences, including loss of output. It involved job specialisation, breaking up of work groups, tighter control, and splitting the extraction operation into three shifts performing coal cutting, conveyor loading, and roof propping as separate tasks. These had previously all been done by one work group.

The central problem with operating the new technology is seen to be related to two points; that it requires the breakdown of tasks, and that overall efficiency depends on the synchronisation of all tasks (because one shift cannot operate without the previous shift completing its work). So there exists a situation of extreme interdependence of tasks but without an overall integrating group.

In later work, Trist (1963) advocates the 'composite longwall method' as a means of overcoming these difficulties. Although retaining three shifts, this involves no strict division of tasks between the shifts, and permits work group autonomy and flexibility in worker deployment. It was found to

be superior in three ways: (a) greater output per work cycle was achieved, (b) it employed less ancillary labour, and (c) less breakdown and loss of the work cycle occurred. According to Emery and Trist (1969) there is a second set of reasons for the superiority of the composite system, related to miners' psychological needs, such as that for solidarity under dangerous conditions.

Trist also makes generalisations from coal mining to other industries, and this illustrates a principal weakness of socio-technical systems theory, its implicit assumption of a universal set of needs on the part of the worker.

This criticism is the starting point for an alternative approach, the social action perspective, which lays emphasis on the attitudes or 'orientations' which the worker brings to his job as being the prime determinant of his reaction to the conditions of work. The study by Goldthorpe and others (1966, 1968) of the 'affluent' car workers at a factory unusually free from industrial dispute illuminates this. Goldthorpe directs criticism at what he sees as a theoretical weakness in earlier studies:

"(a) too great a weight has been given to technology as a determinant of attitudes and behaviour in the work situation, and
(b) too little attention has been paid to the prior orientations which workers have towards employment, and which in turn influence their choice of job, the meaning they give to work and their definition of the work situation"
(1966, p228).

In his earlier study Goldthorpe looks at the car assembler in relation to three aspects of his employment; the job itself, the shop-floor group, and the firm.

The assembler and his job. His findings were similar to those of previous researchers in this area; the operators experienced deprivation at work (boredom, fatigue) caused by the nature of assembly-line tasks, and they had an 'instrumental' (pecuniary) attachment to work. However, Goldthorpe differs in his interpretation of the last point. Workers are not instrumental in attitude because of their experience on the assembly-line. Rather, they are in an assembly-line job because of their instrumental orientation, which is a significant difference.

The assembler and the shop-floor group. Previous studies demonstrated that the work group is broken down by technology, and took this to be a source of dissatisfaction. As a substitute, a closer and more informal relationship with the supervisor was sought. Goldthorpe's results are contrary, because although he confirmed that cohesive groups were not present, it was found that the workers were not concerned about it. Furthermore, he substantiated the fact that relations with the supervisors were good, but this was seen to be a consequence of infrequent rather than frequent contact.

The assembler and the firm. Earlier studies showed high levels of dissatisfaction with the firm,

and the workers exhibiting unco-operative and unpredictable behaviour. Again, Goldthorpe's findings are to the contrary. Absenteeism, labour turnover and the work accident rate were low, implying high morale and attachment to the firm; the workers had favourable attitudes towards the employer; and there was little tendency to express employer-worker relations in oppositional terms.

The later survey (1968) was expanded to include a chemicals plant (process production) and a ball bearings factory (batch production). Goldthorpe's findings can be briefly summarised as follows: job satisfaction and the degree of social interaction at work are functions of the production technology employed, in agreement with previous research, but industrial opinions and behaviour are not. Rather, they are a function of a variable attitude to work*.

These results have important implications for the other approaches elaborated earlier. Thus for the technological determinism propounded by Woodward, the antagonism suggested to be the consequence of pressure and stress on the workers in mass production was not in evidence. In a determinist line of argument workers behaviour would be found to be a function of technology, which Goldthorpe's evidence denies.

* Goldthorpe identifies two other attitudes to work in wider society in addition to 'instrumental', viz. 'solidaristic' and 'bureaucratic'.

They also refute the socio-technical systems theorists in so far as the latter neglect the actors and their attitudes, by concentrating on the system. It should be noted that this instrumental attitude is empirically discovered, rather than assumed, as are workers' motivations and needs in many other studies, particularly those of the organisational psychologists, such as Mayo and McGregor.

Goldthorpe's work has been criticised by Daniel (1969) on methodological and empirical grounds. Daniel's own research has found that the factors which attract a person to a job are not directly equatable with those which keep him there. In more detail, he discovered that attraction and attachment to the job derived mainly from wages and conditions, that job satisfaction derived mainly from problem-solving and learning, and leaving the job arose mainly from frustrated promotion ambitions. Thus he claims that hire-purchase commitments and numbers of children become determinants of behaviour, more than any basic 'orientation to work'.

However, the importance of attitudes has been upheld by other writers. Ingham (1970), for instance, in an attempt to test the so-called 'size effect' in industrial organisations, that as size increases worker commitment decreases (indicated by absenteeism and labour turnover), discovered a similar rate of turnover in large and small firms. The large firms had employees of an instrumental

and economic inclination, and small firms had workers whose attitude was expressive and non-economic. The similarity in labour turnover was due to the fact that in both cases there was a high degree of congruence between the workers' expectations and their situation.

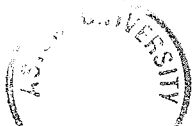
In the same school as Goldthorpe and Ingham, Wedderburn and Crompton (1972) surveyed workers' attitudes inside one company which employed a variety of production technologies. They found a general approval of working conditions but criticism of management-worker relations. However, an important distinction arose between tradesmen and general workers, who had different reasons for adopting these attitudes.

Tradesmen tended to find their work interesting, were conscious of the worth of their own skills, and exhibited a degree of solidarity. General workers, on the other hand, had no coherent group identity, and they indulged in 'constraint evasive behaviour' (i.e. 'non co-operation') which varied with job interest and the supervisor relationship. In an analysis performed irrespective of the various works within the company, they looked at four categories of tasks (similar man-machine systems) and found them to be clearly differentiated in terms of feelings about supervision and interest in the work. This represents a partial return to technological determinism, but with the important disclaimer that

it applies only to semi-skilled workers. In fact, throughout the study they emphasise that it is between general workers and tradesmen that the important distinctions lie, not between different groups of general workers.

Again in a similar vein, Beynon and Blackburn (1972) stress the importance of orientation to work and examine variations within a single food factory employing both men and women. However, they also concede technology to have a significant bearing upon the attitudes and behaviour of individual workers, and in their findings point out that, at least for one category of workers, "the relationship between dominantly instrumental orientations and workplace behaviour is far from straightforward" (p159), hence their caution in generalising from Goldthorpe's conclusions: "In the Luton study* it seems that orientations are attributed with a permanence that remains unaffected by experience of work. Whatever the particular features of the Luton situation, it would be unwise to introduce a priori into other studies similar assumptions about the relationship of orientations to work experience" (p159).

* The factories examined by Goldthorpe et al were in the Luton area.



4.3 ALIENATION

The concept of worker alienation is central to the social theory of industrial life. It is said to exist where the worker owns neither the capital involved in production nor the final product. His labour often results not in a discrete unit of output, but in a small contribution towards a larger item, and the worker may not himself be able to use or afford what he produces. There exists in addition a physical separation between the workplace and home*. Such objective conditions may lead to subjective estrangement, frustration and boredom.

This basic definition of alienation is employed by many writers, and is related to a distinct philosophy of work embodying the idea of self-fulfillment. Thus for Marx industrial labour was alienated because it became a commodity sold in a market rather than a means of self-expression:

"... in his work ... (the worker) does not affirm but denies himself, does not feel content but unhappy, does not develop freely his physical and mental energy but mortifies his body and ruins his mind... It is therefore not the satisfaction of a need; it is merely the means to satisfy needs external to it ... it is the loss of his self" (1844, pp 110-111).

* This is to be compared with craft working or subsistence agriculture, where the worker owns his tools, product, and often also his workplace. The workplace and home are usually congruent.

This idea is taken up by modern organisational psychologists in the notion of self-actualising man, put forward by Maslow (1954) and elaborated later by others (McGregor, Argyris, Likert). Maslow's theory of motivation rests on a hierarchy of five classes of human needs; in ascending order these are physiological, safety, social, ego and self-actualisation. Only when the lower order needs are satisfied or 'reduced', do the higher ones come into play as motivating agents, and when the lower ones are largely reduced they cease to affect behaviour. An alienated worker is thus not permitted to realise his full potential by self-actualisation because his lower needs are not satisfied in the work environment.

Seeman (1959) has surveyed the use of the term 'alienation' by a wide range of writers, and Blauner (1964) uses his categories in an attempt to relate the degree of alienation with the types of technology employed in production. He adopts four dimensions of alienation in a wide survey of American workers in the printing, textile, automobile and chemical industries. These are characterised by differing production styles (craft, mass, and process) and the degree of alienation identified in each case is different. The general relationship which he describes is illustrated by the now-famous 'inverted-U' curve.

As might be expected alienation was lowest in the traditional craft of printing. Textiles and the

automobile industry, both engaged in mass production, differ in that textile production has an associated occupational culture and tradition lacking in the other. Both exhibit the derogation of individual skill, but in different ways; in textiles the redundancy of the workers' skill has come solely through technical advance, whereas in the automobile industry it is through the rationalisation and division of labour. In the automated chemical industry, however, skill returns in the context of maintenance and monitoring. There also exists a degree of unpredictability in the process, flexibility in work rhythm and increasing social contact which combine to reduce the alienating tendencies of sophisticated technology.

Blauner's survey is useful in pointing out the lack of homogeneity in the industrial environment and the worker's experience of it, but a number of criticisms can be levelled against it. Firstly, as Fox (1971, p75) points out, he emphasises only the personal experience aspect of alienation and neglects others, such as the structure of control in the factory. Other criticisms include, as is said of Woodward, that the analysis of the relationship between technology and work experience is too deterministic. He fails to give an account of how differences in the social background, personality and attitudes of the workforce could result in different responses to alienating conditions, implying

that all workers would react in a similar way (Silverman 1970, p182). This essentially brings the argument back to Goldthorpe (1966, 1968), whose car workers are alienated in Blauner's terms, yet remain strongly attached to their jobs.

4.4 TECHNOLOGY AND INDUSTRIAL RELATIONS

It is clear that there will be some link between the workers' experiences at work and the state of industrial relations in the factory, and many of the previously mentioned writers take this up.

Woodward (1965) found that industrial relations were best in process production technology. This is attributed to a number of factors. Firstly, the relatively low proportion of the company's turnover which comprises wages implies that there will be more scope for flexibility in wage bargaining. Close personal relationships between supervisors and subordinates are encouraged by the small work groups, limited spans of control, and the high proportions of managerial staff which characterise the organisation of process production. Thus she claims, "personal relationships develop which blur the edges of role relationships and make both role conflict and innovation easier to deal with" (p233).

In addition there exists an inverse relation between productivity and effort, that is, in a monitoring operation the staff have to work hardest

when something has gone wrong. Her contention is that human beings respond automatically to crises. Lastly, high technology industries are said to employ 'more sophisticated' managers, who have a more intellectual and less emotional attitude to problems than the equivalent staff in batch production.

A number of criticisms can be levelled at these arguments. As for the point about supervisor relations, close personal contact with the supervisor enforced by the organisational structure will only result in harmonious relations if the worker obtains satisfaction from it. Goldthorpe's car factory displayed good industrial relations partly because workers had infrequent contact with supervisors, which was what they wanted. Although the latter production technology (mass) differs from what Woodward is discussing (process), Goldthorpe's results are at variance with other mass production findings, such as those of Walker and Guest (1952), implying a similar possibility for variation between process plants.

Woodward's assumption that workers respond automatically to crises must be regarded as suspect. It is likely to be a function of the degree of commitment towards the firm, rather than a universal human reaction. The last reason advocated for good employee relations in process industries is interesting in that it appears to extend technological determinism to cover managerial (in addition to

worker) behaviour.

The later study by Goldthorpe et al (1968) of three companies at Luton encompassed different technologies in Woodward's sense (batch, mass and process) and also different categories of workers - craftsmen, setters, machine-operators, assemblers and process workers. All three firms had good industrial relations and attitudes to the firm, which one would expect to vary if Woodward's propositions were the case. This, as noted earlier, is attributed to a fairly consistent instrumental attitude to work. Such financial expectations were largely fulfilled in that remuneration was generally regarded as being better than elsewhere, and a consequently favourable outlook on the employer had a positive effect on industrial relations: "The attachment of the majority of (car) assemblers to their firm may be of an essentially economic kind: but this, it seems, does not prevent it from being one of relatively high functional effectiveness" (1966, p237).

In fact, some conflict with the employers did exist, but this was restricted to matters directly related to the 'effort bargain'. It did not concern manpower deployment, job rights, work rules or discipline which, as Goldthorpe notes, are often the cause of disputes elsewhere.

As a cautionary note on Goldthorpe's findings, it should be pointed out that he found little evidence of trade union activity among workers, although

most were inactive members, which perhaps again emphasises the distinctive nature of the plants which he studied.

Killingsworth (1960) points out that some industries are so highly automated that the effectiveness of strike action is reduced. For example, if many employees are engaged in routine maintenance much non-critical work can be postponed for the duration of a strike. He cites telephone, gas and electricity industries, but a similar situation can be conceived of in a highly automated process plant, where management could temporarily take over monitoring functions. He also notes that with the widespread increase in automation, job security has come very much to the fore as a negotiating issue.

Touraine (1965) examined the effect of automation on a traditional strategy employed by labour which gives them a degree of control over management's wishes - that of restriction of output, or 'idling'. Such action is co-ordinated by the informal work group to limit the work pace where payment is by results (piece-work). Several examples of this are found in the Hawthorne experiments performed by Mayo (1945) and others, who point out the social stigma attached to being a 'rate-buster'. However, with increasing mechanization and the introduction of continuous line working this device can no longer be used, since work pace is often regulated entirely by the machine. Furthermore, as automation advances

to process-type technologies, the effort involved becomes a condition of the periodic demands placed upon the monitoring staff by crises as they arise. Touraine writes: "The link between production and wages is loosened and the wage level is fixed by comparison with other categories The worker or the technician ... himself shapes the image of a 'fair job' or a 'fair wage'" (p110).

Chapter Five

METHOD OF RESEARCH

Given that the investigation was to analyse in detail the motives for technical innovations in industrial production methods, the processes by which they were effected, and the consequences which then followed, it was clear that empirical research would be necessary on real instances of such innovation. Although a substantial body of material exists in the literature, very little of it is in sufficient depth to illuminate the micro-level phenomena which are involved in individual technical choices. Even less coverage was found to have been given to the complete process of innovation, from the inception of the idea to its realisation in working production machinery installed in a factory.

Selection of Research Method

With the necessity in mind for original data on actual examples of technical change in real industrial situations, two methods of research seemed appropriate for consideration; either the study could attempt to form a general picture of the status of a production technique in the industry as a whole, or it could examine in detail very specific industrial innovations in the form of case studies. Although the two are not mutually exclusive, it is clear that each requires different techniques, which rules out a unified approach to achieve both results.

In the first case, a statistically significant selection of firms in the relevant industrial sector must be included, and for most sectors this will be a large number. This fact almost certainly precludes individual visits, and implies resort to a questionnaire form of data collection. Difficulties with this approach abound (Goode and Hatt 1952; Oppenheim 1968) and centre mainly on the fact that there is of necessity only limited interaction between the researcher and the subject; usually written questions eliciting written answers, and little else. It is unlikely to be feasible to follow up all questionnaires with even a telephone conversation. This leaves the method open to wide variation in the quality of results, which can only be speculated upon. For example, some conscientious respondents will doubtless

go to considerable lengths to check figures and other data prior to completing the forms, but it is equally apparent that others will regard it as a task of low priority, and supply superficial answers. It will be difficult for the researcher to distinguish such inconsistency in the quality of data from the written responses.

A further problem with postal research is that there is a trade-off to be resolved between the desire to obtain as much information as possible, tending to lengthen the questionnaire, and the negative effect this is likely to have on the response rate. A shorter form is more likely to be completed by a busy executive than is a long one, but it will inevitably contain less useful data. Questionnaire response therefore tends to be erratic, and has also been found to be affected by apparently irrelevant variables, such as whether or not first class post is used. There is the further problem of correctly identifying the person to whom the questionnaire should be addressed.

A second possible research method, which was the one finally adopted, avoids some of the difficulties of the postal approach at the expense of some of its advantages. It employs visits to participating firms to interview several respondents (unlike the single one to whom a questionnaire is normally sent). This permits a very full response to be obtained; replies can be scrutinised and supplementary points or

explanations requested, and a proper dialogue established on the topic being investigated. Because more than one person is usually seen, there is a greater likelihood of eliminating the personal bias to which data from a single respondent is suspect. Another major advantage is that a visit affords the opportunity to inspect in person the production equipment which is under investigation, and to observe the work environment, so the researcher is not wholly reliant on interviewees for data.

Although both research approaches could be performed separately by the individually appropriate methods, it was clear that each was a large task in itself. The latter strategy, that of carrying out a number of detailed case studies of particular innovations in production techniques, was chosen.

Case Study Approach

A major contribution of case studies to the furtherance of knowledge of industrial or other problems lies in the great detail of information at the micro-level which they can furnish.

The topic with which this particular study is concerned, technical innovation in industrial production, highlights another significant aspect of the case study method; it is interdisciplinary. The subject is complex and has, as the preceding literature review illustrates, been approached from a

variety of conventional subject disciplines.

Firstly, it has inevitable economic consequences. In terms of systems theory, technical change is the principal vehicle by which economic units advance their efficiency in transforming inputs (of whatever type; raw materials, semi-produced goods, information, energy, human effort, etc.) into output. This applies to units of all sizes, from individual machine tools to national economies.

A social factor is also inextricably involved in industrial innovation. The largest part of industrial sociology addresses itself to the problems of human beings and their relations with technical systems, and even although technical change is not explicitly discussed in some of the major studies, it has undoubtedly made an important contribution to the underlying social and organisational structures of a factory.

Human psychology is also closely related in that it forms the basis for social behaviour (an important aspect of the industrial scene) and attempts to describe the individual's reaction to the industrial environment. As long as humans remain an important part of production systems, and in the majority of cases that will be true for the foreseeable future, psychology will continue to have relevance.

Management theory, in some respects a pseudo-science in that it is often an amalgam of sociology, psychology, organisation theory and production

economics used as an instrument to pursue corporate goals, also has a contribution to make on the subject of technical change.

Industrial innovations also have legal implications. Among them, patent law controls the diffusion of innovations, and industrial safety and health legislation imposes restrictions on the technical options available to firms installing new equipment.

The various branches of engineering are often excluded from social scientific analyses of industrial problems, but this is bound to limit the perspective gained. It is the embodiment of advances in engineering technology in industrial systems which provides the starting point from which the social, economic and other consequences of technical change flow.

Recent developments in production technology have even promoted an interdisciplinary approach within the engineering sector itself, as skills in electronics, fluidics and mechanics are combined in machinery of ever-increasing complexity.

The foregoing illustrates the multitude of individual disciplines which already purport to tackle the subject of industrial innovation in one form or another, and demonstrates the complexity of a subject which is approachable from such a variety of viewpoints.

The micro-level nature of case studies, implying gathering data in situ about very localised phenomena

under very specific conditions, makes the interdisciplinary approach almost inevitable, and certainly the most efficient. In analysing events at such close quarters, no clear separation into the generalised and highly structured paradigms of economics, sociology, engineering or other branches of knowledge, is immediately apparent.

Put in straightforward terms, it is not possible to discuss with a press shop foreman the economics of technological change as related to a new press under his supervision. Questions and conversation will certainly touch on a wide range of related social and technical issues, such as industrial relations, machine outputs and the job functions of individuals in his charge. So in these circumstances, it is inappropriate to adopt a rigorous disciplinarian attitude which would mean ignoring a large body of original data.

In some respects, case studies are better seen as an art form; the judgement of the researcher plays an important part in arriving at a coherent analysis of information from disparate sources, in extracting the essence from the detail.

The above therefore implies a liberal interpretation of method. However, one methodological approach of an interdisciplinary nature has become more widely accepted - that of technology assessment (TA).

Despite a continuing debate as to whether TA has or has not a coherent methodology, and over its alleged ideological biases, it does offer a framework within which much interdisciplinary research into the effects of technology has been performed. Although the present research was not carried out as a TA, it has much in common, in that it is also attempting to evaluate the consequences of new technology.

Technology assessment offers greater scope than conventional disciplines for accommodating opinions, probabilities and other so-called 'soft' data which are inevitably encountered in this type of research, and virtually all such assessments are carried out in case study form. (A fuller discussion of TA, its method, and the issues it raises, is provided in Appendix 1).

The main problem with the case study approach is that of generalising from the results, and of the wider significance which can be attached to very specific findings. The normal investigative approach in the social and natural sciences requires results which are of wider relevance than the merely local conditions in which the study took place. This is more difficult to achieve with case studies, which are individually of less significance than wider sample-based research. Their depth of analysis, however, is able to cast further light on macro-effects which are already understood in part.

The case study approach to evaluating complex problems is further validated by criticisms made of more conventional research. Wright Mills (1959) attacks the detached empirical methods upon which much social analysis is based, resulting in the study of problems "only within the curiously self-imposed limitations of their arbitrary epistemology" (p65). Methodological inhibition, he says, encourages "a pronounced tendency to confuse whatever is to be studied with the set of methods suggested for its study".

Giner (1972, Chap.1,2) gives examples of qualitative (rather than statistical) analyses in sociological research, which avoid conventional hypothesis formulation and theorising, and he points out that the descriptive approach is widespread. Heclo (1972) more explicitly endorses the case study method.

For critical views of the more rigorous methods of enquiry in the natural sciences, and the processes which lead to a strict demarcation of disciplines, see Kuhn (1962), Crombie (1963) and Hagstrom (1965). Bradbury (1969), however, makes the additional point that research outwith the natural sciences can benefit from their approach to problems: "Social studies and sociology ... are not open to experiment under laboratory conditions but are pursued with the aid of scientific method" (p63).

A series of case studies of technological issues is given in Braun et al (1979), and more specifically

about industrial innovation, in Christensen (1968) and Rijnsdorp (1979).

Selection of the Innovations

The type of industrial research envisaged, involving detailed examination of specific industrial processes down to the level of individual machines, is almost wholly dependent upon industrial firms for data.

Although the equipment can be examined in manufacturers' workshops or in production engineering research laboratories, it is only in working factories that a proper appreciation of the industrial techniques and their associated phenomena is obtained. This reliance on outside bodies does mean that the programme of research is somewhat vulnerable, in the degree that assistance is or is not forthcoming.

Requests for help were put to a number of firms with which the Technology Policy Unit already had contact, and a positive response was obtained from one of those for an extensive survey over a retrospective period of time. It was originally envisaged that all the empirical work would be undertaken within this large group of companies, which would assist in selecting a number of key innovations in production methods for detailed study.

Subsequent events, however, resulted in a rapid changeover of key staff in the firm which had initiated the co-operation, and in the last resort

only one case study was carried out in that particular company.

A round of more widespread applications was made by letter to other firms in various industries. These were addressed to a known contact, or failing that, the technical director, requesting the opportunity to examine a recent innovation and interview the relevant personnel. An undertaking of confidentiality with respect to the data for individual firms was given and found to be necessary, so none of the participating companies are identified.

The response rate was under 50% which is perhaps not surprising given that quite a high level of involvement was being requested. To conduct a detailed case study requires a series of visits and interviews, and not all firms are prepared to devote the time, or disclose the information.

In the end, nine major case studies were carried out in five British industries, and a number of less detailed studies in a further three industries. The five main industrial categories, as defined by the Standard Industrial Classification (C.S.O., 1968), are as follows:

- Order III - Food, Drink and Tobacco
- Order IX - Electrical Engineering
- Order XI - Vehicles
- Order XV - Clothing and footwear
- Order XIX - Other Manufacturing Industries

The degree of co-operation offered varied greatly. One firm agreed to the researcher working in one of its departments for a period of several months, yielding five case studies, and at the other extreme a single day visit was supplemented by subsequent telephone interviews.

Methods of Data Collection

The methods employed varied somewhat between the firms, depending mainly on the degree of co-operation which each was prepared to offer. In all cases, a preliminary meeting with a key member of staff who had close involvement with the innovation was arranged.

This took the form of a partly structured interview; a list of topics on which comment was required provided the basis for the conversation, but the format was flexible and could be departed from if the interviewee had particularly strong views or wished to comment at length on any one aspect.

This initial contact usually centred on acquiring a preliminary understanding of the product, the production process, the changes which constituted the innovation, the motivation to make the change, and how it had been achieved. Subsequent interviews were necessary in most cases, often with different and more specialist personnel, to pursue in detail the consequences of the innovation, how they compared with expectations, and other aspects of the issue.

These included what changes, if any, had occurred in the factors listed in Appendix 2.

The respondents replies were either immediately written down or tape-recorded for later transcription. The type of personnel interviewed varied from case to case, but overall included executive decision-makers responsible for the innovation, technical staff who implemented and sometimes designed the chosen technical solution, industrial engineering (work study) staff, accountants, production managers, foremen and trades union representatives.

Apart from the interview results, additional data was obtained on the firms and the innovations from published annual reports and accounts, press reports, and internal company reports, where available. Other documents from the firm, such as machine manuals and job specification sheets, provided more details of production techniques. Further information was also found in published articles on the particular engineering processes, or was available from the equipment manufacturers, if the production machinery was sold on the commercial market.

In one case, a firm in the rubber industry made available detailed computer print-outs of costings and energy consumption.

Results Obtained

The response of interviewees varied widely, as might be expected, from forthright disclosure of information and admission of errors to reluctance to reveal certain key facts. Some of the respondents readily accepted the presence of a tape recorder, others refused, and yet others admitted that they would give less full replies if their remarks were recorded in this way.

Staff in the technical and engineering research departments were found to be the best source of information on the comparison of the old and new production techniques, and often on the motivation to change. Even although they would not have made the investment decision themselves, their technical evaluations were one of the main inputs to the decision-makers.

Production foremen were often the best source for details on machine reliability, task specification of the operators, and general running conditions and problems. They usually proved more likely to admit difficulties and inadequacies than higher management. One interesting point to emerge from the automobile industry was that personnel management staff are not always those most closely involved in manning negotiations about new equipment. In that instance, a chief design engineer took the responsibility because only he could properly evaluate where manual

labour was required.

It was not possible to obtain all the details requested. This was anticipated, and in carrying out the case studies the expectation was that although few of them would be able individually to cover all of the aspects of technical innovation itemised above and in Appendix 2, they would do so when taken together. All the main factors are, in fact, addressed in the combined results.

There are several reasons for this variability in the data. Sometimes the only individual who could answer certain questions was inaccessible, and on other occasions the information was available but confidential, so not disclosed. In several instances, the data was kept but difficult to retrieve, and in the case of at least one large company, records had been destroyed.

Groups of companies are particularly susceptible to the last two effects. A central records office may be physically distant from the point of production, and the large amount of information which it has to accumulate necessitate periodic rejection.

A surprising finding was that one very large company did not note the results obtained from its capital investment programmes. There was no record of how, for instance, actual production rates compared with those anticipated when the decision to invest was taken. In what was quite probably a false economy, measures to save on overheads had resulted

in the elimination of 'non-productive functions', including record-keeping.

Where records do exist, there are often inconsistencies between plants, and over different time periods, making comparisons difficult.

Despite these restrictions, it is clear that the bulk of the data would have been impossible to obtain had the alternative strategy of a questionnaire method been adopted. Interpretation and elaboration of many of the points raised was necessary, and impractical to carry out except by personal interview.

Processing of Data

The information was obtained, as outlined, in a partially structured form. At one extreme, the computer print-outs from the rubber manufacturer allowed different cost items and energy consumption to be averaged over a three month period, so obtaining quite accurate figures for those items.

At the other extreme, the sometimes contrary opinions of the various individuals involved in the innovation had to be resolved, and some consensus obtained by further discussion or personal observation. A degree of caution must therefore be observed in interpreting these results.

The factory in which the five rubber case studies were carried out had a system of cost centres to which charges were made according to the consumption

of services. A cost centre might be a single large piece of production machinery, a part of a larger process, or a bank of smaller machines. Services included electricity, gas, water and steam, and were provided throughout the factory on a network of pipes and cables, which was metered at each cost centre. In this way, an accurate evaluation of running costs based on actual consumption was obtained.

Maintenance services and spare parts used were in some instances also logged in this way. The system of cost centres additionally recorded the output from the appropriate machine(s), and so permitted the calculation of, for example, maintenance costs per unit of output.

Information obtained in less concrete form from the interviews and conversations was organised under the appropriate topics which served as notes to guide the discussions. This separation cannot always be done in a rigorous fashion, because certain matters are relevant to more than one of the aspects of the innovation being studied. For instance, job specification (the nature of the task performed by an employee) will have a bearing on work satisfaction, health and safety, and wages.

Presentation of Case Studies

The details of the innovations examined and the results obtained are presented in Chapters 6 and 7. The layout of these chapters is somewhat unconventional,

and a few explanatory notes are necessary.

Chapter 6 contains five case studies performed in one firm in the rubber industry, and Chapter 7 has four from miscellaneous industries. Since many of the case studies are individually too short to make up a chapter on their own they are grouped together as indicated, each one occupying a separate section within the appropriate chapter.

A standard layout is almost consistently employed throughout, to record the results in a manner which facilitates comparison between them. The format for the presentation of each case study is set out below.

1. The Industry
2. The Firm
3. General Process Description
4. Old Method
5. Motivation to Change
6. Development
7. New Method
8. Comparison of Old and New Methods
 - a. Capital Equipment
 - b. Labour
 - c. Raw Material
 - d. Energy
 - e. Space
 - f. Output
 - g. Economics
 - h. Work Organisation

- i. Health and Safety
- j. Management

Table of Comparative Data

9. Implementation

10. Conclusions on Case Study

Table of Advantages and Disadvantages

Because of the previously noted inconsistencies in the availability of data, not every section is present for each case study. In the five from the rubber industry, there is clearly no point in repeating the industry and firm sections, which are therefore grouped together at the beginning of Chapter 6. The layouts of the remaining case studies, however, are virtually identical.

The first table in each case study, in the comparison section, contrasts those aspects of the old and new method which have numerical importance. From the preceding comparison several factors emerge as being the salient points of contrast between the new and old processes. These are presented in the second table, which gives their approximate relative importance, and are listed under the headings 'Advantages' and 'Disadvantages'. Although this is obviously a matter of subjective judgement on the part of factory personnel and the researcher, and raises the point that advantages to management may not be the same thing as advantages to the work force, it is nevertheless included as providing a useful summary of the conclusions on each case study.

Chapter Six

INNOVATION IN THE TYRE INDUSTRY

This first set of case studies of technical innovation in industrial production methods comes from one large plant in the tyre industry. Tyre production is a complex process employing many separate industrial techniques, most of which are long-established and have been the subject of piecemeal alteration over a period of decades.

This unco-ordinated approach to innovation, though having proved adequate in the past, is being increasingly questioned, and radical and highly automated solutions to production problems are currently under consideration by the world's leading manufacturers.

These envisaged developments are still the subject of much secrecy, and include the wholesale

transformation of what has traditionally been a collection of several labour-intensive operations into something akin to continuous flow production. This ultimate goal remains unrealised, and although several positive advances have been made in the newest factories, it will certainly be costly and difficult to achieve in full.

Mounting economic difficulties faced by the industry, including falling demand, changing market structure, and increasing raw material prices, have prompted this intensive research effort into new production methods designed to reduce costs. The innovations described here are each a part of this overall process.

The Tyre Industry

The tyre industry may be succinctly described as a dual-market oligopoly. The two markets are represented by the fact that manufacturers distribute their products in two separate ways; as direct sales of replacement tyres to drivers and garages, and negotiated large volume contracts with car makers. The latter market is the most important, but has lower profit margins. The oligopoly arises from the fact that the industry is highly concentrated in its manufacturing operations, and is thus dominated world-wide by a few large companies which account for a large proportion of its output.

The market for replacement tyres has slumped by 13% from 1972 to 1978 (F.T. 14.11.1978), on account of a number of factors. Most important of these is the fact that radial tyres, which are replacing cross-ply tyres to an increasing degree, have a life-time considerably extended, by between 50% and 100%. An expected rise in the length of the average car journey has not materialised, probably because of increasing petrol prices, and this also reduces the projected tyre demand upon which capital investment programmes were based. Lastly, the problems in this market are compounded for Western European manufacturers by an influx of cheaper tyres from East Europe and elsewhere.

The second tyre market, those purchased by car manufacturers for installation on new cars, is affected firstly by the substantial increase in foreign-made cars sold in Britain. Between 1974 and 1978 registrations of imported new cars rose from 28% to 49% of the U.K. total, and this figure continues to rise (Trade and Industry 9.2.1979).

The result of this is over-capacity in the tyre industry, which has the facilities to produce more tyres than the market demands. Estimates vary between countries, but it is a world-wide problem and the figure for the U.K. probably lies in the range 20% to 25% (F.T. 14.11.1978; Guardian 31.3.1979; Business Week 28.8.1978).

Consequently, price competition between manufacturers

is high.

The rubber industry as a whole has recently experienced considerable economic difficulties, and within this the tyre firms have probably suffered most. In the period 1976 to 1979 the average profit in the U.K. rubber industry dropped from 8.7% to 5%, and average profit margins from 6.6% to 3.8% (F.T. 24.4.1980). A fall in tyre profits over this period is displayed by all leading firms.

Firms manufacturing tyres are almost all very large industrial concerns which incorporate most of the stages of manufacture from the production of rubber through to the finished and tested tyre, often even including ownership of the rubber plantations. A wide variety of industrial processes is therefore carried out within one company, and many of these will be on a single site.

The level of automation in the industry is generally low, and labour constitutes about one-third of total manufacturing costs. This labour-intensity is at its peak in the tyre-building operation, which has defied mechanization for many years and this is only now on the verge of being achieved.

A superficial account of the whole rubber and tyre production sequence will serve to place in context the five specific process innovations which are examined in detail (Section 6.1).

The Firm

The firm in which the following five case studies were undertaken is, like the majority of tyre manufacturers, a large multinational company, with substantial British operations.

Under the Standard Industrial Classification (C.S.O. 1968, p31) the factory in question has specifications as follows:

S.I.C. Order XI - Other Manufacturing Industries
Minimum List Heading 491 - Rubber
Sub-division 1 - Tyres and Tubes

The company as a whole manufactures a wider range of goods than those produced at this establishment, but they largely fall within Minimum List Heading 491.

Around the period of the investigation the company was exhibiting an annual growth rate in U.K. sales of about 7%. However only 45% of U.K. sales at that time were tyres, and the proportion is declining. The tyre industry as a whole is undergoing a contraction and that is reflected in this particular company, whose tyre sales have slackened off, and operating profits in the tyre division have noticeably fallen.

The company's U.K. employees make up just under one half of its world total, and the figures reveal a gradual contraction in the five years prior to the study. Over a longer period, this trend is

more pronounced in the factory investigated, which lost 25% of its labour force over the eight year period up to 1978. The figure currently stands at around 4600. This steady labour loss reflects product diversification and a shift away from a heavy reliance on tyre production.

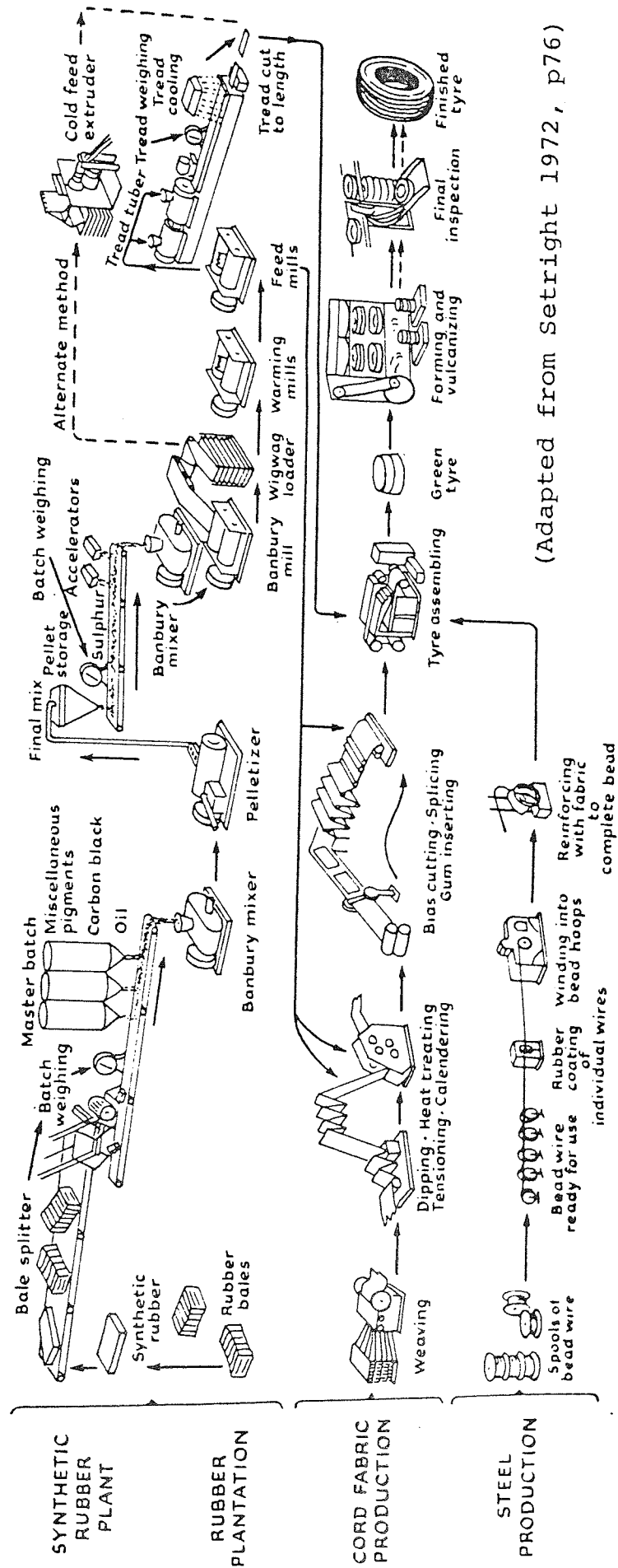
6.1 TYRE PRODUCTION

Three separate production lines for rubber, cord fabric, and wire beading, all converge at the operation of assembling the tyre (see Fig.6.1).

First, rubber from both synthetic (nowadays the slightly higher proportion) and natural sources is delivered to the plant in the form of bales, granulated particles, or powder. After preliminary treatment it is mixed with chemical ingredients such as pigments, reinforcers and anti-oxidants, and is then masticated in a process known as "compounding", to produce a fluid gum stock.

The gum is next milled in a "calender", a machine consisting of two large rollers rotating in opposite directions, with a narrow and variable gap between them. A warmed mass of rubber introduced to this gap is forced through and emerges as a thin sheet of rubber which is drawn off. Finally, the material is cut into a long band and forced through the nozzle of an extruder under high pressure. The shape of the nozzle die varies, depending on the cross-section required in the extruded strip, which will be cut into lengths to form the tyre sidewalls and tread, as yet unpatterned.

The second of the parallel production lines makes rayon, nylon, or even steel textile fabric. The thread is woven into a sheet and dipped in rubber latex, before being calendered to impregnate



(Adapted from Setright 1972, p76)

FIG. 6.1 : TYRE MANUFACTURE

the rubber into the cord. The result is a rolled-up strip of rubberised fabric, more resistant to stretch than would be a sheet of pure rubber with similar thickness. The roll is lastly diagonally dissected on a bias-cutter, or "banner", which leaves the cord running at the desired angle across the fabric.

The last and smallest line produces the steel wire beading used to provide a semi-rigid rim for attaching the finished tyre to the wheel. The wire is extruded with rubber to provide it with a coating, and several such strands come together to form a spiralled hoop.

The three basic materials used in building the tyre are now ready: extruded rubber strips to form treads and sidewalls; bias-cut rubberised fabric for inside the tyre body; and rubber coated wire hoops used to make the inner rim.

Tyres are assembled individually by a skilled operator working at a single station, the centre-piece of which is a revolving drum with its axis horizontal. First, alternate layers of bias-cut plies are wrapped around the drum, one on top of the other, with the cords running alternately in opposite directions. An adhesive solution is used to bind the plies. (This is the method for cross-ply tyres: radial-ply tyre assembly is not radically different). Next, the bead wires are attached and the edges of the plies wrapped around them to link firmly the tyre body and the bead rim. The final

assembly operations are the attachment of the side-walls and the tread strip, all using a naphtha solution to make the rubber sufficiently tacky to adhere. Great care is required in joining the two chamfered ends of the tread strip.

The result of this process is an assembled "green cover". It approximates in shape and size to the final tyre, but lacks any patterning on its surface. This latter is achieved by the process of vulcanisation. The green cover is first painted, then inserted into a split toroidal mould bearing the reverse imprint of the finished tyre. It is pressed against the inside of the die by the inflation of a diaphragm and is "cured" under conditions of high temperature and pressure. This activates the chemical hardeners and other additives introduced at the beginning, and imprints the tread and other tyre surface markings. This process takes from 10 to 480 minutes depending upon the size of tyre.

The finished tyre is now ready for inspection and trimming to remove superfluous thin rubber protrusions which result from the moulding process.

At the factory investigated, new production techniques had either recently been or were in the process of being introduced in five of the above operations. In the case of four of these, the older technique was still in use on similar operations elsewhere in

the factory, so providing a useful current comparison.

The five operations are:

1. Extrusion of tread and sidewall rubber
2. Batching of bias-cut rubberised fabric
3. Painting of green covers
4. Moulding and vulcanisation of green covers
5. Trimming of moulded tyres

6.2 RUBBER EXTRUSION

The process of extrusion of rubber compounds involves forcing a continuous stream of the material through an aperture or die to produce long strips of rubber with a desired cross-section. Compound is fed into the extruder and is caught up in a screw, which masticates it and propels it forward to the die, sometimes through a pre-former. Dies can be changed to produce extrudates of different cross-sections, and this is done quite frequently on an average shift.

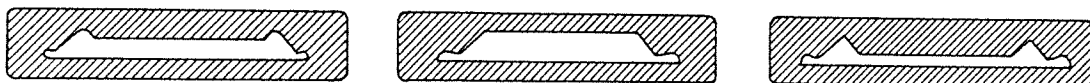


FIG.6.2: THREE EXAMPLES OF EXTRUDER DIE APERTURES.

Often the extruded strips from two or even three extruders are conveyed together to be superimposed while they are still warm and tacky after leaving the die, to produce a layered tread or sidewall as required. This is all done while the strips are in motion on conveyor belts, and they are carried forward to be cooled, then cut up into sections of appropriate length and weight.

Old Method - Warm Feed Extrusion

This is a long-established technique for producing strip rubber, and requires several operations to be performed prior to extrusion. Rubber, mixed with the other ingredients and supplied by the compound preparation department, is first warmed and rolled into a pliable condition in a masticating mill. It is then transferred to a feed mill, from which it is cut off in a continuous strip by blades against which the mill drums rotate. Residue rubber, which has not been properly cut or is otherwise unsuitable for extrusion (e.g., by having cooled below a workable temperature), is re-masticated on a third mill. The strip of rubber cut from the feed mill is conveyed on overhead rollers and fed continuously into the extruder while still warm.

In the factory in question the warm feed extruder was being used to produce a two-layered tread with undertread, the main tread being extruded and the undertread simply cut as a continuous strip directly from the rotating drum of a fourth mill. Extrusion is not necessary to produce rubber strips of simple cross-section.

Motivation to Change

The technique of warm feed extrusion is unsatisfactory in that it requires considerable processing

of the rubber compound prior to extrusion, as the extruders in use are capable of handling only rubber which has been warmed and masticated into a soft and pliable condition. Compound which has not been brought to this state cannot be extruded in a regular and cohesive strip of acceptable quality.

The four mills and associated conveyors which are essentially ancillary to the extrusion process take up more floor space than the extruder which they supply, and they require additional operators.

New Method - Cold Feed Extrusion

The more recent development of cold feed extrusion has completely dispensed with the array of mills previously used to heat and roll the rubber prior to its being extruded. Instead, bales of rubber sheeting arriving from the compound preparation department are automatically cut into disjointed strips and fed directly to the extruder. This type of extruder has a considerably longer screw and in travelling along the length of this the compound is compressed and heated, so arriving at the die in a sufficiently pliable condition for smooth extrusion. The long screw requires a higher energy input to ensure full plastication of the rubber, and in practice this process tends to be used on synthetic compounds which are easier to break down than natural ones, and which are used for tyre side-walls rather than treads. However,

there is no obstacle in principle to cold feed extrusion being used for both.

Adjacent to the older warm feed extruder, the firm concerned had a complex of four cold feed extruders connected to two conveyor systems. A simplified plan view of this is illustrated in Fig.6.3.

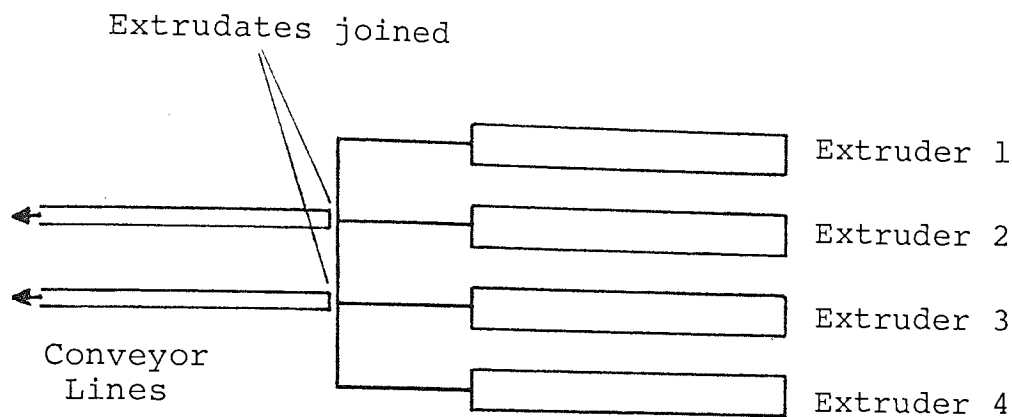


FIG. 6.3: COLD FEED EXTRUDER COMPLEX

These could be operated in a number of combinations : single layered extrusion on extruder 2, line A, or extruder 3, line B; double-layered extrusion on extruders 1 and 2, line A, etc; triple layered extrusion on extruders 1, 2 and 3, line A, etc. For the purposes of comparison with the warm feed two-layered extrusion, the cold feed complex is considered as being run on two extruders and one conveyor line only, to produce a two-piece sidewall

Comparison of Old and New Methods

Throughout this section refer to Table 6.1.
Capital Equipment. Technical details are elaborated

earlier in the individual process descriptions. An immediate point of contrast emerges in the machinery employed by the two processes. To make a similar product on one conveyor line, the new process requires merely two extruders, compared with the single extruder and four mills of the old. The number of stages in the production of extruded rubber is therefore considerably reduced. When the entire complex of four cold-feed extruders is considered as a whole (rather than just the two taken for the purposes of comparison with the warm feed), its superior flexibility over the warm feed becomes clear. It can run many permutations from one to four extruders on one or two conveyors, some of these combinations simultaneously. The warm feed extruder, in contrast, can run only one extrudate, with the option of an additional calender-cut layer, such as the undertread in the example quoted. In the existing arrangement, however, the warm feed extruder is able to cope with larger extrudate cross-sections and so is superior in that respect. The reliability of the newer system is somewhat less than the old, on account of its greater complexity. All the equipment employed can be purchased from outside manufacturers and used in unmodified form.

Labour. The manning levels of the two operations are quite different. Whereas the warm feed extrusion requires six operators (one machine operator, one assistant machine operator, two mill operators, two

weigh/stack/service operators) the cold feed requires only two (one machine operator and one batching operator, who mutually assist). This lower number is largely accounted for by the absence of mills in the cold feed extrusion.

The skill levels of the two sets of workers are not substantially disparate; although the cold feed personnel are required to operate and monitor a central control console which the warm feed extruder does not have, their other duties (clearing of waste rubber, changing dies, batching up, etc.) are similar and in many cases identical.

Raw Material. In current practice, although this is not essential, the two types of extruder tend to be used for different raw materials. Synthetic rubber is generally employed in the cold feed extruder because it is softer and thus easier to extrude without heating, whereas the harder natural rubbers benefit from mastication in the mills which precede extrusion in the warm feed method. However, some natural rubbers are quite amenable to cold feed extrusion.

Energy. Services (electricity, gas, steam, cooling water, and pressurised air) are supplied throughout the factory on a fixed network of pipes and cables, and metered when drawn off. It is therefore possible to make an estimate of the consumption of these services in relation to output (see Table 6.1). The

extruders and mills are electrically powered and require cooling water. Steam is used to warm extruders prior to their operation, in which they are pneumatically controlled. Although different services are used to differing degrees in the two processes, the net cost of services to each are fairly similar.

Space. The floor space occupied by the older warm feed extruder and its associated mills is over twice that of the two cold feed extruders with which it is being compared. Extra area is also required for the working space of the additional operators which the warm feed process employs.

Output. In the current operating arrangement the two systems are making slightly different products, and it is possible only to minimise but not eliminate these differences. The closest similarity is achieved when the warm feed machine produces a two-piece layered tyre tread, and the cold feed produces a two-piece layered tyre sidewall.

The two processes are roughly similar in conveyor line speed and extrusion rate (17 to 18 metres/minute), and become even more so when the target output rate is calculated. This differs from the extrusion rate because (a) some of the extrudate at the beginning and end of each run is not usable, (b) time is spent on start up, shut down, and die and compound changes, and (c) a small further reduction is necessary

to take account of workers' personal time allowance (variable, depending on gang size).

On both machines, the length of a production run is generally a small fraction of a shift; i.e. extruder dies, and consequently the shapes of the extrudates, can be changed within 4 to 10 minutes, and this is done quite frequently on an average shift. The quality of the extrudate does not radically differ between warm and cold feed.

Economics. Although the output rate of the warm feed is 3% higher, the much lower manning levels on the cold feed permit it to achieve an output per worker nearly three times that of the warm feed.

The costs of services and maintenance have been averaged over a typical three month period from factory accounting records, and these are presented in Table 6.1. The newer process is 8% cheaper in its consumption of services, but its maintenance requirements cost 57% more over the period in question.

Work Organisation. Both processes are quite similar in this respect, in that the operators each have several varied tasks to perform in starting up, running, and shutting down several production batches in every shift. There is substantial scope for worker interaction, and very often the requirement for mutual assistance between operators on both warm and cold feed extrusion. A single foreman supervises all

TABLE 6.1: COMPARISON OF WARM FEED AND COLD FEED RUBBER EXTRUSION

	WARM FEED	COLD FEED
Capital Equipment	4 Mills 1 Extruder 1 Conveyor Line	2 Extruders 1 Conveyor Line
Product	Two-piece layered tyre tread	Two-piece layered tyre sidewall
Manning	6	2
Line Speed (metres/min.)	18.0	16.8
Average Output (metres/min.)	12.3	11.9
Output per Worker (metres/min.)	2.05	5.95
Services (in decreasing order of expense incurred per Standard Hour*)	1. Electricity 2. Steam 3. Water 4. Gas	Steam Electricity Air Water
Services Cost per Standard Hour* (£)	1.42	1.30
Maintenance Cost per Standard Hour* (£)	2.27	3.55

* Standard Hour is the unit of output employed in factory accounts

extrusion, and shift work is employed to cover 24 hour factory operations.

Health and Safety. Two problem areas are prominent. Firstly, the most likely sources of danger lie in the running conveyor belt, which is common to both methods, and in the rotating mills of the warm feed. Since the latter are eliminated in the newer process, it can be said to be in some degree safer. Secondly, prepared rubber compound contains some additives which have been demonstrated to be detrimental to human health. In the calendering stage of warm feed extrusion the mills are open to the atmosphere and volatile ingredients can escape during warming. Any hazard which they might cause is therefore not present to the same degree in the cold feed technique, which omits this prior warming.

Conclusions on Rubber Extrusion

An analysis of the innovation of the cold feed technique must have as its starting point the simplification or streamlining of the process of rubber extrusion, by the elimination of certain stages which were previously necessary. It is from this essential development that the various advantages of the newer method over the older warm feed extrusion derive, although the resultant benefits may be of more economic importance than the changes in process

organisation themselves (see Table 6.2).

TABLE 6.2: ADVANTAGES AND DISADVANTAGES OF COLD FEED WITH RESPECT TO WARM FEED RUBBER EXTRUSION

ADVANTAGES

1. Labour force reduction
2. Output per worker increased
3. Process simplification
4. Production flexibility increased
5. Floor space economy

DISADVANTAGES

1. Maintenance costs increased
2. Product size limitation
3. Some limitation on raw material

Thus the substantial reduction in the numbers of workers employed is largely attributable to the elimination of the calendering stage prior to extrusion, and the consequent dispensation with the operators of mills and their associated service workers. Since output rates are virtually unchanged between the two processes, the large increase in output per worker results almost entirely from this labour reduction. The economy of floor space achieved in the new process

also follows from the removal of the requirement for mills.

The final main advantage is inherent not in cold feed extrusion as such, but in the particularly flexible arrangement of the extruder complex installed in this factory - its capability to interchange and run together several extrudates on two conveyor lines. Against this benefit must be set the limitations on the extrudate which cold feed technology can produce, being to some extent confined to softer rubber compounds and smaller cross-sectional areas. The principal disadvantage of the new process, however, lies in the increased cost of maintaining the more sophisticated capital equipment which it employs.

Cold feed extrusion therefore emerges quite clearly as a major labour-saving improvement to an existing process, with several substantial ancillary benefits, and a smaller number of disadvantages.

6.3 BATCHING OF BIAS-CUT RUBBERISED FABRIC

Rubberised fabric consists of a weave of rayon or nylon cord which has been put through rollers and impregnated on both sides with rubber. The weave is usually made up almost entirely of warp cords with a thin weft to bind them. As a result its resistance to stretching (an important requirement when it is used in tyre-building) is highly directional and is very weak along the line of the weft. To counter the problems which this poses, the fabric is cut into sections or "plies" with a "bias", which means that the cords lie at an angle to take maximum advantage from the stronger warp.

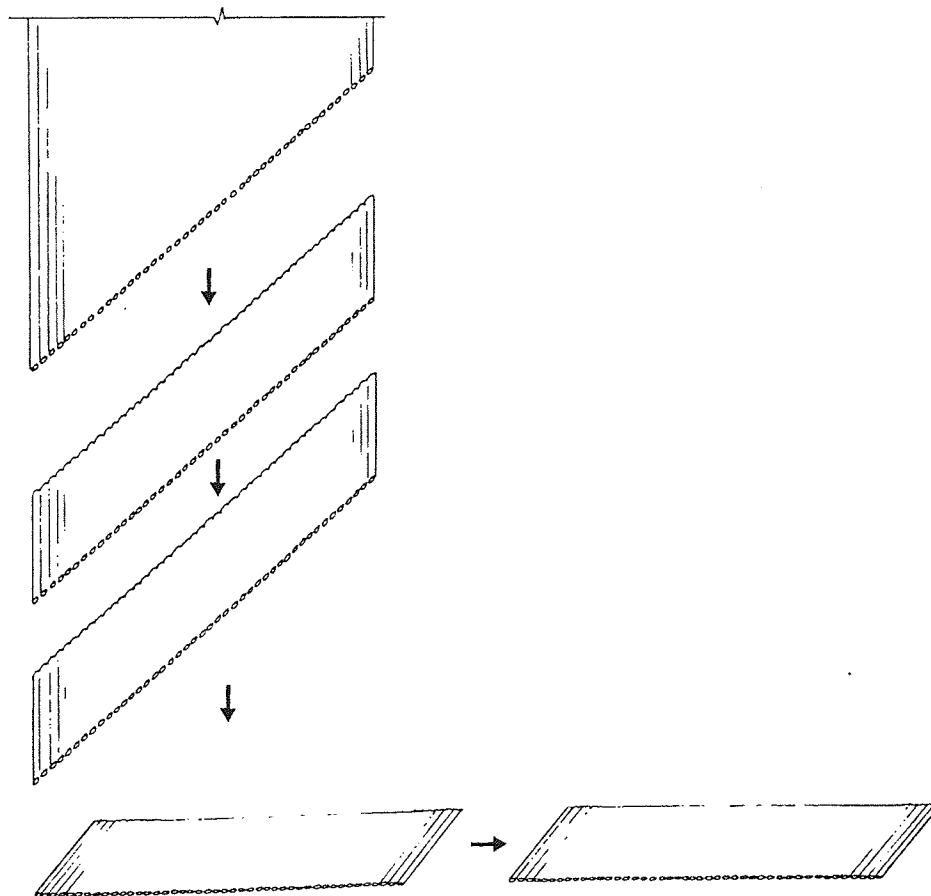


FIG.6.4 : RUBBERISED FABRIC CUT IN PLYES

The rubberised fabric arrives at the bias-cutter, known also as a "banner", in wide rolls, the layers of which are interleaved with white cloth to keep the rubber surfaces apart and avoid them sticking. It is then unreeled from the spindle and passes onto a flat conveyor which carries it under the bias-cutter. This device consists of a sharp blade mounted in a frame, and it automatically cuts off a strip or ply of a preset width and angle of bias, which is between approximately 50° and 90° . A photovoltaic cell detects when the ply has been removed, and signals the next cutting operation. The plies are thus spaced apart and delivered to the batching-up station. Up to this point the old and new processes are identical; it is the subsequent operation which differs.

After leaving the banner the plies have to be joined end to end to form a roll of fabric which is much narrower than the one from which the plies are cut, and which has the cords lying diagonally across it at the correct bias angle. Only in this form is it ready to be used in tyre assembly.

Old Method - S.P. Tables

In order to batch up the cut fabric, the plies are conveyed to an operator who must remove manually each one and place it on another short conveyor belt which leads to an S.P. (Special Product) type batching table. On the conveyor he joins it with a slight

overlap to the end of the previously removed ply with a hand-held rolling device, which consolidates and thus seals the tacky rubber at the point of overlap. It is then rolled forward on the operation of a pedal control (this conveyor moves incrementally, and only on command) onto a spool to await the attachment of the next ply. The rubberised fabric layers are interleaved with plastic sheeting to prevent adhesion, and the fully loaded spool is stored until required.

The operator's duties also include changing the batching cartridge when the spool is full, and changing the width and bias angle of the ply cut off by the banner. There is the option of batching up simultaneously on the other side of the main conveyor, but this is not normally used because of limitations on the speed of the bias-cutter, which cannot usually produce enough work for two batchers. There is also a further batching position at a different point on the conveyor.

Motivation to Change

The chief incentive for altering the technique of batching is that the S.P. method is ergonomically inefficient, and unnecessarily strenuous for the operator. Without complete automation it is not possible to reduce the labour input because only one operator is involved, and so this is not a relevant factor in this instance. However, by rationalising

the layout, the operation can be brought closer to an arrangement where bias-cutting and the subsequent batching can be integrated and automated; that is, the job layout reaches a point where the total automation of each batch run is a more readily attainable possibility. It can thus pave the way for future developments, and at the same time ease the work of the operator.

New Method - Conti Unit

In this method the cut plies are carried to the end of the conveyor leading from the bias-cutter, and are held there until the operator is ready to receive them. By depressing a pedal, one ply is delivered directly to the work station via a transfer line, where the operator picks it up and attaches it to the previous one. Unlike in the old method, he need not move from his work station to perform this. After attachment, the ply is conveyed to a "Conti" (properly "Continental") batching unit, where it is rolled onto a spool in a manner similar to the S.P. batcher. As before, the operator's duties also involve changing ply width and bias angle on the banner between batches, and replacing the batching cartridge when full.

Comparison of Old and New Methods

Throughout this section refer to Table 6.3 .

Capital Equipment. Both techniques use a set of large rollers to unreel the rubberised fabric, a main conveyor belt with the banner bias cutter fixed across it, and the different batchers with their short conveyors. However the newer Conti system has in addition a transfer line between the main conveyor and the batching conveyor. This device can be regarded as a direct substitute for a large part of the operator's effort in the old method.

Labour. Under normal operating conditions a manning level of one is required by both systems. The older S.P. method has two extra batching stations, one of them an alternative (i.e. still only one operator is required, but he works at a different location), and the other an additional station for production runs with which one batching operator could not cope, but these are not the norm.

Skill levels as indicated by wage scale are exactly the same, but retraining would be necessary to transfer from one method to the other. The tasks are of a highly repetitive nature and neither lends itself to much scope for worker satisfaction.

Raw Materials. The nature of the material is the same in both cases - cord fabric which has been impregnated on either side with rubber. Dimensions will vary intentionally between batches in both methods. However the Conti machine is used to batch substantially

(on average over 40%) longer rolls than the older batcher.

Energy. Both consume only electricity. The new method is insignificantly more expensive in this respect, to produce a unit of output.

Space. The single Conti batcher is positioned compactly against the end of the conveyor. The older method requires more area for the operator to move around, and has the three S.P. batching tables protruding at right angles from the main conveyor into the adjoining floor space, which they occupy in a geometrically inefficient manner. Usually only one of these is in use at any one time, and so redundant equipment is unnecessarily taking up space.

Output. The nature of the product from each method is identical - rubberised fabric cut and rejoined into a continuous reel of pre-set width and cord bias angle. The last two factors will, of course, vary from batch to batch as different tyre sizes require different ply dimensions in their construction. The average width of one cut ply is very similar between the two, but because the Conti is used in cutting longer rolls it handles more cuts per roll than the S.P. batcher (on average 720 compared with 480). However, in any meaningful comparison the relevant factor is the number of cuts per unit time, after making allowances for the

differing frequencies of roll changing. When this is done the Conti emerges as having a 14% higher rate of batching than the S.P. machine.

The quality of the product is the same, since it is only the organisation of work which is altered by mechanical aids, not the process through which the fabric goes.

Economics. Output per worker is the same as the total system output, because both methods employ only one operator. In achieving its 14% higher output (300 more plies per 8 hour shift) the Conti unit incurs maintenance costs (engineers' labour plus parts) almost double (195%) those of the S.P. batcher. This is attributable to greater engineering complexity resulting from mechanizing part of the operator's former duties in manually transferring the plies. The cost of services in the form of electricity to power the machines is 4% higher in the new method, and is therefore unimportant in any comparison.

Work Organisation. The principal difference between the two methods lies in the task of the operator. In the older arrangement of S.P. batching tables he must physically carry the strip of fabric from the main conveyor to the batching station across the intervening floor space, and there commence the task of attaching it to the previous strip. He has to turn around to perform the operation. The newer Conti

TABLE 6.3: COMPARISON OF S.P. TABLE AND CONTI UNIT PLY BATCHING

	S.P. TABLE	CONTI UNIT
Capital Equipment	Fabric Rollers Banner Bias Cutter Conveyor 3 SP Batching Tables	Fabric Rollers Banner Bias Cutter Conveyor Transfer Device 1 Conti Batching Unit
Product	Batched Bias-Cut Fabric Plies of Varying Width	Batched Bias-Cut Fabric Plies of Varying Width
Manning	1	1
Average Fabric Roll Length (metres)	220	310
Average Ply Width (metres)	0.457	0.430
Average Output (plies/shift)	2200	2500
Output per Worker (plies/shift)	2200	2500
Services Cost per Standard Hour* (£)	0.53	0.55
Maintenance Cost per Standard Hour* (£)	2.86	5.57

* Standard Hour is the unit of output employed in factory accounts

system, on the other hand, effects this transfer between conveyors mechanically, at the press of a pedal. The operator stays standing at one work station, having no necessity to turn, and so the task is considerably less strenuous. Furthermore, because a limited number of plies can be held back after leaving the banner until they are required, the Conti unit is less stressful to the worker. In the other, he must return at very regular intervals to the main conveyor to pick up the next ply. Finally, the longer fabric rolls used mean that they have to be replaced less frequently on each shift (on average every 2.33 hours in the new method, and every 1.75 in the old).

Advantages to the operator from the re-organisation of work must be regarded as the main immediate benefit from this innovation.

Health and Safety. The only significant difference in this regard derives from the more ergonomically convenient layout of the operator's duties in the Conti method. In that sense it is not as stressful as the S.P. batching method, as detailed above.

Conclusions on Batching of Bias-Cut Rubberised Fabric

This innovation is clearly classifiable as mechanization rather than automation, since direct human participation and control is still required. It is to some degree labour-saving in that output per

worker is increased, but the more important characteristic, from which the increase in output results, is that the new method is considerably effort-saving from the operator's point of view. The ergonomics of the task of batching are much improved, and the frequency of fabric roll changing is substantially reduced. The reorganisation of the job layout necessary to achieve this provides another major advantage; it creates conditions under which further mechanization and automation can realistically take place at a later date.

As a final point, in obtaining these benefits a substantial penalty is incurred by the doubling of maintenance expenditure required by the more complex machinery used.

TABLE 6.4 : ADVANTAGES AND DISADVANTAGE OF CONTI UNIT WITH RESPECT TO S.P. TABLES PLY BATCHING

ADVANTAGES

1. Task ergonomics improved
2. Creates conditions for future automation
3. Output per worker increased
4. Floor space economy

DISADVANTAGE

1. Maintenance costs increased

6.4 PAINTING OF GREEN COVERS

After a tyre has been assembled from the various plies of fabric, extruded rubber strips, and wire beading of which it is constructed (see page 103), it is known as a "green cover". The term "green" refers to the fact that it has not been cured or vulcanised. In this form it has a toroidal shape similar to that of the finished tyre, but is wider and more flaccid, and lacks patterning on the tread. It requires one further operation prior to the process of vulcanisation, by which it assumes its final form; the whole surface of the green cover, inside and out, must be coated with a black paint.

Old Methods - Hand Painting and Spray Booths

The original procedure for painting green covers was laboriously to do each individually with hand-held mops. This was a highly labour-intensive and dirty operation.

There then followed a semi-manual arrangement of two painting booths side-by-side, constituting one work station. The operator first placed the green cover onto the turntable in the right-hand booth. The turntable was spun by depressing a pedal, and simultaneously a central jet sprayed the inside of the cover with paint. He next lifted the cover off and hung it on the hook in the second booth, where he sprayed one

side with a hand-held paint gun. The cover was then manually turned around to spray the other face.

A later refinement of this method used only one booth, with the turntable and an extra paint spray nozzle. Operation of the pedal spun the turntable to spray simultaneously half of the cover's inside and half of the outside. The cover was then inverted to complete the coating. Five such work stations were required to handle the volume of green covers produced by the tyre-builders.

Motivation to Change

Even the most advanced of the semi-manual methods described above is labour-intensive and heavily reliant on manual effort. Each green cover must be individually manhandled in the process, and this is a rather inconvenient arrangement. Furthermore, the system of a turntable and spray jets produces even at best a somewhat irregular coating of paint, and the rejection rate of covers which have to be repainted is undesirably high. This constitutes the principal reason for altering the method.

Lastly, the working environment of the spray booths is unhealthy by virtue of the quantities of airborne paint which can readily escape from the open fronts of the booths. Any inhalation of such paint is unhealthy and clearly unavoidable.

New Method - Ilmberger

One large mechanical complex, known as an "Ilmberger" unit, now replaces all the separate semi-manual work stations. An overhead conveyor with hooks carries the green covers from another part of the site where they were assembled. They are dropped onto a set of moving rollers and carried forward to be picked up two at a time by "chucks" which lift them by extending hooked arms underneath the rim to grip the cover. There are eight such chucks mounted on a turntable, and as it rotates the green covers are brought into an enclosed painting area where they are sprayed inside and out by sixteen nozzles. Each cover is independently revolved under the paint jets to ensure even coverage. The inside of the spraying area is washed down with water to avoid fumes, and this water is recycled to reclaim the paint which it has carried away.

After moving through the spraying area, the chucks drop the painted covers onto another bed of moving rollers, at the end of which an operator stacks them manually in racks for later transportation to another part of the factory where they are vulcanised.

Comparison of Old and New Methods

In this case, it was possible only to make a retrospective comparison of the Ilmberger with the

most advanced of the semi-manual techniques. Although the spray booths were still in the factory and could be directly inspected, the Ilmberger had taken over their functions entirely. However, since the numbers and types of green covers being handled in each instance are similar, and the new method had only recently replaced the old, such a comparison should be valid.

In the particular case of the impact on skills, a more extensive comparison of all of the old methods with the new is instructive, and is given in the conclusions on green cover painting.

Throughout this section refer to Table 6.5.

Capital Equipment. The particular semi-manual method being considered for comparison purposes employs five single booths, with pedal-operated turntables and paint spray nozzles. Paint reservoirs are located nearby. No mechanical aids in the handling of the green covers are employed.

The large Ilmberger unit is acquired externally, and requires a custom-made array of motorised rollers for transferring incoming and outgoing covers. The difference between the two methods regarding engineering complexity is obviously great - the Ilmberger assumes the tasks of the previous five operators, mechanizes the spraying, rotating, and all transfer operations except the final stacking, and integrates the complete sequence into something approaching a continual

process. A penalty in the form of greater susceptibility to mechanical defect is inevitable.

Although most production techniques which directly employ human labour have an advantage in terms of flexibility over a mechanised one (e.g. in this case the manual sprayers could cope with almost any tyre size), the Ilmberger is sufficiently versatile to handle a wide range of cover sizes and an irregular rate of flow from the conveyor.

Labour. The older method being considered here used five spraying operators per shift, on five booths. An additional $1\frac{1}{2}$ workers (i.e. two, one of whom spent half his time on other duties) of less skill were employed in delivery and transporting.

The Ilmberger currently uses four operators; one machine overseer, two to unload, and one to transport. It should be possible to reduce this to three if union agreement can be obtained.

The skills required in each method are different. The newest of the old methods involved the operators in considerable manual handling, but also required each to judge the quality of the paint coating. In the Ilmberger, only the supervisor has this function, the others being only handlers. The net effect is therefore that of de-skilling, as far as the direct workers are concerned.

The degree to which maintenance staff are employed is greater in the new process, as is the skill they

require.

Raw Materials. The material input for processing is the same in each method; tyres after assembly but prior to moulding, technically known as "green covers", and arriving in various sizes.

Energy. The Ilmberger is a considerably greater consumer of services than the spray booths, requiring electricity to power the transfer mechanisms and turntables, water for the recycling of the paint, and compressed air for the paint jets, of which there are more than in the old method. The latter, in contrast, has only an electrically driven turntable and two spray jets per booth.

Space. The comparative floor space occupied by the two techniques is difficult to ascertain, because the old method is no longer in use, and was performed at two separate locations. However, it appears likely that the five spraying booths and working space for the operators would occupy an approximately similar area of factory space to the Ilmberger and its arriving and departing conveyors.

Output. The nature of the output, painted green covers of varying size, is the same by both methods.

The output rate of the painting operation is governed not simply by what is theoretically achievable

by each of the methods, but also by one major external factor; the rate of the subsequent moulding through which each tyre goes. To avoid bottle-necks, the volume of output from painting is matched as closely as possible to the rate at which the covers are taken up for moulding, and this often involves under-utilisation of the painting capacity.

Each manual sprayer painted 500 to 600 green covers per shift, which gives 2500 to 3000 in total. The Ilmberger has a target output of 2770 covers per shift, which is the nominal rate for the subsequent moulding. However, although it could cope with up to 3000, the moulding target is not often achieved and an average of 2200 is typical.

The quality of results by the new method is much superior to that of the old. An even coating of paint can now be applied even to the awkward recesses inside the cover, and the variation in results which characterised the old method is largely eliminated.

Economics. The theoretical maximum output by both methods is the same, although the derived maximum output per worker differs on account of the differing labour numbers employed. It is 62% higher in the new method. However, because of the lower output rate achieved in practice by the new process, attributable to external economic variables, the Ilmberger's potential is not fully realised and the average output per worker is only 30% higher, still a significant amount.

Although fuller costings of the Ilmberger are available, they have been omitted because no similar records exist for the now ceased spray booth operations, and hence no useful comparison can be drawn.

Regarding maintenance costs, the Ilmberger assembly with its associated transfer mechanisms is clearly a much more complex system than were a few booths and spray guns. It therefore requires more maintenance and of a more sophisticated nature, which is consequently more expensive.

Work Organisation. This aspect remains the same for some of the workers, and has substantially changed for others. The manual tasks of stacking and transporting are required by both methods, although handling is only necessary at the end of the Ilmberger process. The natures of those jobs, however, are virtually identical.

The more skilled operators on each technique have quite different functions to perform. The single-place work of the sprayer at his booth has been replaced by a machine overseer who monitors the Ilmberger and conveyor operations, recharges paint reservoirs, and makes regular checks on the quality of painting applied to the covers.

Health and Safety. This constitutes the remaining major difference between the two techniques. Whereas the old method requires the operator physically to

TABLE 6.5 : COMPARISON OF SPRAY BOOTHS AND ILMBERGER GREEN COVER PAINTING

	SPRAY BOOTHS	ILMBERGER
Capital Equipment	5 Paint Spray Booths Stacking Racks	1 Ilmberger Paint Spray Unit 2 Conveyor Lines Stacking Racks
Product	Painted Green Covers in Various Sizes	Painted Green Covers in Various Sizes
Manning	6½	4
Maximum Output (covers/shift)	3000	3000
Average Output* (covers/shift)	2750	2200
Maximum Output per Worker (covers/shift)	462	750
Average Output per Worker* (covers/shift)	423	550

* Variable, dependent upon output required by subsequent operation

hold the spray gun and observe from close range the application of the paint, in the Ilmberger the painting operation is enclosed and out of direct sight of the personnel. Furthermore, running water carries away any paint which misses the target and so keeps the atmosphere relatively free of harmful vapours whose inhalation might be detrimental to health.

Management. Managerial control over the operation is simplified in the Ilmberger system, because tyres which previously were painted at several separate locations are now channelled through a single machine.

Conclusions on Painting of Green Covers

The first salient point emerging from the introduction of the Ilmberger painting device is that this single machine replaces five smaller work places in the old method. It can thus be said to focus the flow of tyre production at the stage of cover painting, by drawing together tyres of various sizes built at various locations within the factory.

Next, the operation has become largely mechanized. The older methods involved a high degree of manual handling in the transport of covers, placing them on turntables, removing, and stacking. This has been reduced to stacking at the end of the operation only.

The new method is labour-saving, and from this derives an increase in output per worker. However,

this aspect is secondary to the principal motive for the change, an increased consistency in the quality of the paint coating on the cover. The rejection rate is substantially reduced.

TABLE 6.6: ADVANTAGES AND DISADVANTAGES OF ILMBERGER WITH RESPECT TO SPRAY BOOTH GREEN COVER PAINTING

ADVANTAGES

1. Quality improved
2. Health aspect improved
3. Labour force reduction
4. Output per worker increased
5. Manual tasks reduced

DISADVANTAGES

1. Maintenance costs increased
2. Energy consumption increased

Finally, a major improvement in the working environment is achieved by the almost total enclosure of the spraying area and its being washed down to remove surplus paint. This greatly reduces the quantity of paint vapour inhaled by the operators. On the negative side, the complexity of the new equipment results in the inevitable economic penalties of

high maintenance costs, energy costs, and initial capital cost.

The effect of technical change on skills, as illustrated by this case study, is of particular interest. The sequence of innovations which culminates in the Ilmberger (see page 128) embodies a progressive elimination of skill in the operation in which the paint is applied:

1. Hand Mops
 - manual control of brush
 - manual paint application
2. Hand Spray Guns
 - manual control of gun
 - pneumatic paint application
3. Booth Spray Nozzles
 - pedal control
 - pneumatic paint application
4. Ilmberger
 - automatic control
 - pneumatic paint application

In the oldest method the operator's skill comprises two aspects; the application of an even coating of paint, and his judgement of the painting quality immediately after it has been applied. On the basis of this judgement he either passes the cover on to dry and be stacked, or he re-sprays any thin or unpainted areas. With the advent of the Ilmberger and the more advanced of the booth methods, the skill of manual paint application is lost. However, judgement of the quality of the paint layer remains a necessary function of the Ilmberger machine overseer. More

importantly, the skill requirement in maintenance is greatly increased. The final group of unskilled manual handlers are present in both methods.

Thus the skill consequences may be summarised as follows:

- several skilled paint application tasks disappear
- several skilled paint quality judgement tasks become a single such task for the new machine overseer
- some unskilled manual tasks remain unchanged
- maintenance skill requirements substantially increase

The next effect is therefore a relocation of the concentration of skills from production workers to maintenance crews, from direct to indirect labour.

6.5 MOULDING AND VULCANISATION OF GREEN COVERS

After the incipient tyre, or green cover, has been painted, it passes to another section of the factory for the subsequent operation in which it finally assumes the shape and tread imprint of a finished tyre. This moulding is done under high temperatures and pressures, and it simultaneously activates the process of vulcanisation, whereby chemical reactions take place between the rubber and the other agents (principally sulphur) with which it has been mixed at the compounding stage. In this way the tyre acquires the appropriate combination of rigidity and flexibility.

A large press is used, which contains a segmented metal mould bearing the reverse imprint of the tyre tread, sidewall markings, lettering, and other surface features. A green cover is inserted into the open mould, the press is closed, and then a "curing bag" is inflated inside the cover. The curing bag is also made of rubber and manufactured by the firm itself, and its function is to conform to the internal shape of the green cover and press it firmly against the interior of the mould to ensure an accurate reproduction of the pattern. This inflation is achieved firstly by steam, and then maintained by circulating hot water at 400 psi and 150°C. Steam at 143°C surrounds the exterior of the mould, totally

enclosed by the press, and the green cover is thus "cured" both from inside and out.

The curing time varies from 10 minutes for a small car tyre to over 70 minutes for an average truck tyre.

Old Method - McLloyd Press

In the first stage of this method the painted green cover must have its rubber curing bag inserted with the aid of a vacuum box, a device adjacent to the line of curing presses. The cover is placed inside the box and the lid closed. The deflated curing bag, which is similar in appearance and function to a tyre inner tube, is lubricated and pushed inside the cover with a plunger suspended from the roof. After insertion, the curing bag is inflated with compressed air. The vacuum box is then opened, and the cover containing its inflated curing bag is removed and transported on a trolley to a vacant curing press.

Here a short inflation pipe is fitted to the valve hole in the curing bag, and the cover and bag are loaded into the mould using lifting tackle. Once the cover is emplaced and centralised, the other end of the inflation pipe is attached to a fitting inside the mould through which it is inflated.

There are two mould cavities to hold two green covers in each press, positioned one above the other. The press lid is now shut, the segmented mould closes around the cover, and the process commences. During curing which in this case lasts just over an hour, the operator must monitor the temperatures, pressures, and cure times along the line of twelve presses for which he is responsible.

Fifteen minutes before the end of the cure, cold water circulates to cool the tyre and then the press opens automatically. The newly-formed tyre is unloaded by the hoist with manual guidance, and the water is drained from the curing bag. A service operator transports the tyre off to where the bag is extracted by a hook. A new cover is normally inserted within two minutes.

There are five sizes of mould used on the McLloyd press, and they are changed on occasion depending upon the size of the batch run. The curing bags require replacement every two months.

Motivation to Change

The McLloyd press requires a preliminary time- and effort-consuming operation prior to moulding; the insertion of a separate curing bag for each cover being processed. It would be desirable to eliminate this.

Next, the procedure by which the tyres are loaded into and unloaded from the press is somewhat clumsy, consisting of a primitive arrangement of lifting tackle requiring manual guidance for emplacement. This is a strenuous operation for the loading workers, particularly with the larger commercial vehicle tyres.

Lastly, the fact that the two moulds in each press are placed one above the other means that simultaneous loading is not possible. It was expected that a substantial increase in productivity would result from remedying the above deficiencies.

New Method - Shaw McNeill Bag-O-Matic Press

This technique obviates the necessity for the prior insertion of the curing bag in the vacuum box. The green cover is placed in a tray on the floor in front of the press, where it is lubricated using a hand mop.

Either automatically, or upon the operator pressing a switch, a loading chuck descends into the centre of the cover, opens out, and lifts it into position ready for insertion. (The chuck operates in a manner similar to that used in the Ilmberger green cover painter, 6.4). The operator pushes a second switch and the cover descends into the mould. The press this time contains as a fixture the curing

bag (or diaphragm) which in the older press has to be independently inserted. This diaphragm is inflated by steam at the same temperature and pressure as used in the McLloyd. In the meantime the chuck retracts and descends to pick up the next cover, which it holds until the press is ready to receive it.

The mould in this case is circumferentially rather than radially split, and when the press lid closes the upper mould segment descends onto the cover and curing commences. The steam used to inflate the diaphragm is replaced by hot water, and moulding and vulcanisation take around 50 minutes. After curing, the press opens automatically and the finished tyre and curing diaphragm rise out of the press. The deflated diaphragm is retracted while the tyre is supported on mechanical arms, prior to being ejected rearwards onto a continuously moving conveyor for transport to the final stage of manufacture.

A new cover is inserted within two minutes of the previous tyre being ejected. Each press holds two moulds side by side, which can be changed to accommodate a limited range of tyre sizes.

Comparison of Old and New Methods

Throughout this section refer to Table 6.7.

Capital Equipment. An important difference between the two methods is the fact that the older press requires an ancilliary item of capital equipment for inserting the curing bag (the vacuum box), and other equipment for the bag's later removal, which the newer press does not need on account of having a diaphragm permanently installed inside the mould.

The semi-manual loading arrangement of the older McLloyd is replaced by mechanical grippers known as chucks, and because the two moulds in each press are now side by side rather than superimposed, simultaneous loading is possible with the Bag-O-Matic. The conveyor of the new system replaces manual transport of the tyres on mobile racks.

The McLloyd machines are arranged in two lines each of 13 presses. Of the 26 in total, one was not working at the time of the investigation. They are about 20 years old. These 25 presses were served by two vacuum boxes. The first of the Shaw-McNeil Bag-O-Matic presses was installed in 1971 and although there were again two lines, this time of 10 presses each, six of the newest ones were not yet commissioned and another two not working. Thus 12 presses were in current operation.

Although the engineering reliability of the newer machinery is greater, its more complex control system requires specialised maintenance. Both types of presses are bought from outside suppliers.

Labour. The McLloyd presses require only one operator to supervise moulding on each of the two lines, because each press is normally at a different point in the one-hour process, and his main duties come at the beginning and end of the moulding sequence. A gang of six works on servicing (transport, fitting curing bags, removing curing bags), which gives a total of eight. This averages at one worker per 3.125 presses. The Bag-O-Matic lines again have one moulder per line, but only one service man for the 12 presses operational; an average of four presses per man.

The operators are roughly similar in grade, though since the Bag-O-Matic moulders have more responsibility and are required to operate a control panel they have a higher wage than their counterparts on the McLloyd presses. The job satisfaction of the moulder has probably increased on account of the greater complexity of the machinery of which he has control.

Raw Materials. These are the same between the two processes - painted green covers of various sizes, naphtha, silicone to lubricate the cover and diaphragm, stencils and chalk to mark the tyre, and other miscellaneous items. However the older presses with their separate curing bags use these up at a regular rate far in excess of the replacement frequency

of the Bag-O-Matics' fixed diaphragms. The cost of these diaphragms was only 13% of the McLloyd curing bags over a three month period.

Energy. Both methods are very heavy consumers of piped steam and hot water and this is the most expensive of all inputs, far exceeding even labour costs. They also require water, compressed air, and electricity. The vacuum box, present only in the McLloyd arrangement, uses electricity and air to a small degree.

Space. No precise figures were available on the floor space occupied by the two types of machine. However, as their main difference lies in the fact that the Bag-O-Matic presses have their two moulds arranged side by side rather than superimposed, and have a lengthy conveyor line which the McLloyds do not, it is apparent that the more advanced method takes up more room.

Output. At the time in question the McLloyd was producing 60 inch steel radial truck tyres, and the Bag-O-Matic a similar tyre of 63½ inches. As moulds can be varied the Bag-O-Matic can also produce the 60 inch tyre, and so the two are comparable.

Each press in both the old and new methods produces two tyres simultaneously. However, because of a shorter cure time in the Bag-O-Matic its output

rate is 33% greater than the McLloyd's. The quality of finished tyres is not significantly different.

Economics. Although there are less Bag-O-Matics and their total output is less than that of the older presses, they have a higher number of presses per operator, and consequently a much higher output per worker (71%).

Labour costs per standard hour reflect the greater productivity of the newer method. The McLloyd presses are more costly of labour in spite of the marginally more skilled (and hence more highly paid) workers employed in Bag-O-Matic moulding. Service costs per standard hour are lower in the newer presses largely on account of the shorter moulding time required. Maintenance costs for the Bag-O-Matics are marginally higher in spite of their greater reliability, on account of the complexity of maintenance work undertaken.

Work organisation. Several operations are eliminated by the newer process - the insertion of the curing bags in the covers and their later removal is no longer necessary; connection of the inflation pipe between the curing bags and the steam and water inlets is not required; the strenuous tasks of loading and unloading the older presses with lifting tackle disappear; and the manual removal of completed tyres on trolleys is replaced by a conveyor.

TABLE 6.7: COMPARISON OF McLLLOYD AND BAG-O-MATIC TYRE MOULDING

	McLLLOYD	BAG-O-MATIC
Capital Equipment	25 McLloyd Twin Presses 2 Vacuum Boxes Tyre Trolleys	12 Shaw-McNeil Bag-O-Matic Twin Presses 1 Conveyor Line
Product	60" Steel Radial Truck Tyres	63½" Steel Radial Truck Tyres
Manning	8	3
Presses per Worker	3.125	4
Cure Time (minutes)	62-71	48-54
Output per Press (tyres/shift)	12	16
Total Output (tyres/shift)	300	192
Output per Worker (tyres/shift)	37.5	64
Labour Cost per Standard Hour* (£)	6.98	3.72
Services Cost per Standard Hour* (£)	37.86	20.99
Maintenance Cost per Standard Hour* (£)	6.89	7.18

* Standard Hour is the unit of output employed in factory accounts

Health and Safety. The major improvement in this respect is the elimination of some strenuous handling tasks. In addition, when the tyres leave the mould they are hot and steaming, and give off rubber and chemical vapours until they cool. Since the new process avoids manual handling of tyres at this stage (they are carried off on a conveyor behind the presses) this is probably advantageous.

Management. There is no effect of any significance. One foreman oversees moulding on both types of press.

Conclusions on Moulding and Vulcanisation of Green Covers

The first point to emerge when comparing the two types of press is the simplification of the process in the Bag-O-Matic. It dispenses with the necessity to insert individual curing bags for every tyre, using a vacuum box, and instead has a fixed diaphragm which fulfills the same purpose. A direct benefit from this is a saving in raw materials, since the curing bags must regularly be replaced.

Another important advantage is a reduction in the number of workers required per press on account of the elimination of certain manual tasks, principally loading and unloading the tyres. When this is added to a reduced cure time for each green cover, the effect is a substantial increase in output per worker.

It should be noted that although substantial mechanization has occurred, the curing process itself is a largely automatic operation in both the old and new methods.

Concerning the capital equipment, in spite of the fact that the newer machines are more reliable, their greater mechanical and electrical complexity requires a higher level of maintenance, and this yields the only major disadvantage of the Bag-O-Matic.

In brief, this innovation affords a substantial increase in output per worker. This is achieved by raising the productivities both of capital, through the streamlining of the process, and of labour, through the mechanization of certain tasks.

TABLE 6.8: ADVANTAGES AND DISADVANTAGE OF BAG-O-MATIC WITH RESPECT TO McILLOYD TYRE MOULDING

ADVANTAGES

1. Process simplification
2. Labour force reduction
3. Product processing time reduced
4. Output per worker increased
5. Manual tasks reduced
6. Increased reliability of equipment
7. Reduced consumption of raw materials

DISADVANTAGE

1. Maintenance costs increased

6.6 TRIMMING OF MOULDED TYRES

During the process of moulding and vulcanisation the green cover is pressed firmly against the inside of the mould by the curing bag or diaphragm, to ensure that it fully reproduces the pattern of the tread and other surface markings. To avoid bare moulding all air must therefore be excluded from the space between the cover and the mould's interior, and this is achieved by a number of narrow vents drilled in the mould. After the air has been expelled through these vents a small amount of rubber, which is in a plastic condition due to the heat of moulding, enters, and hardens when the cover is cooled for removal. The tyre which results is therefore covered in many thin protrusions known as "spue pips", which are reproductions of these air holes. They must be cut off in a trimming process before the tyre is ready for use.

Certain modern tyres are made with a reduced number of pips and do not require trimming. In this case the mould is designed so that the spue forms in the gaps in the tread where it does not pose a problem. The majority of tyres, however, still need to be trimmed.

Old Method - Hand Trimming on Powered Tables

A large variety of tyres of mixed size and tread are brought by overhead conveyor from the moulding

shop to the trimming area. The tyres are manually removed from a storage conveyor and placed on a power-driven revolving metal table. Here the operator, wearing gloves, centres the tyre and trims the spue pips from one sidewall and half of the tread using a "V"-shaped manually held knife. He then turns the tyre over, centres it once more, and trims the other side and the remaining half of the tread in a similar manner.

The trimmed tyre is then removed, placed on an adjacent roller conveyor, and pushed towards a powered delivery conveyor which takes it to a loading bay. The operator has in addition a number of miscellaneous duties including marking the tyres with coloured chalk to denote the shift he is working, and regularly sharpening the tool blade.

Motivation to Change

The above method clearly involves the operator in much handling of the tyre, and it was expected that productivity would be improved by eliminating some of these manual tasks. Thus a desire to mechanize certain stages of the operation, and so increase output per worker, constitutes the principal motivation for the development which took place.

New Method - Auto-feed Trimming Machine

The Auto-feed machine has two work stations side by side, each of which holds one tyre for trimming. One operator works alternately at these two stations.

A tyre coming from the moulding shop is conveyed directly to the Auto-feed trimmer and enters one of the work stations, where it is held in front of the operator in a vertical position at about waist height. The operator directs alternate tyres into adjacent stations using a pedal. When in place, the tyre is made to spin rapidly by powered rollers against which it rests. The operator holds two knives, one in each hand, against the rotating tyre and it is thus trimmed of the spue pips. The depression of a pedal mechanically ejects the finished tyre onto a delivery conveyor and admits another to the same work station, while the operator moves over to the other station to trim the tyre which it holds. He therefore continually moves from one station to the other and back again in the course of his tasks. His duties also include sharpening the trimming tool, changing blades, and releasing tyres which have become inadvertently trapped.

Comparison of Old and New Methods

At the time of the investigation the Auto-feed had assumed the bulk of the load of tyre trimming

being done in that section of the factory. One of the older powered tables was still in regular use to deal with cross-ply tyres which were best done by that method, and so the process could be inspected and costed at current rates. However, output and other data are based on the arrangement as it existed when all tyres were trimmed using powered tables, as this affords the most realistic comparison.

Throughout this section refer to Table 6.9.

Capital Equipment. The four power-driven trimming turntables of the old method are replaced by two Auto-feed machines, which were developed internally to the firm. They are mechanically much more complex than the tables, having automatic loading, and ejection of tyres, and this is reflected in lesser reliability. Conveyor lines are used in both methods, but more extensively in the modern layout. Similarly, manually-held trimming knives are employed in both techniques; two per operator in the new, against one in the old. The flexibility of the new system is a little less, because it still requires certain sizes of tyres which cannot be accommodated by the Huntsville to be trimmed on a table.

Labour. Three men work on the trimming tables, but the two Auto-feed machines require only one operator each. The innovation therefore affords a manning level reduction of 33%, but also achieves an increase

in output as detailed later. There is no substantial difference in skill levels between the two processes, although the Auto-feed operators have more to do in that they must trim with two blades simultaneously. They are consequently more highly paid.

Raw Materials. Both systems have as their material input newly moulded tyres, after they have been cooled. However the Auto-feed is slightly restricted in the dimensions of tyres which it can accept. The only items consumed in the process are knife blades, which must be replaced about twice per shift.

Energy. Both techniques consume only electricity, and at the same rate, to drive the several motors used in rotating the turntables, tyres, and conveyor rollers.

Space. This factor is difficult to estimate accurately because the full layout of the old technique is no longer in existence. Although any difference between the two is unlikely to be great, the older was probably more extensive in area on account of the greater number number of operators and the larger work space they require in order manually to move the tyres to and from the tables.

Output. A substantial 53% increase in the total output rate is possible in the new method, and this is

achieved in practice by its handling tyres from a larger number of presses than did the old. The quality of trimming is quite acceptable by both techniques.

Economics. Output per worker exhibits a very significant increase in the Auto-feed, being 2.3 times that achieved on the turntables. This results both from an increase in the rate of output and a reduction in the labour required.

The cost of electricity consumed was identical over a three month period for the two methods. Maintenance costs for the Auto-feed are 97% greater than the older tables, reflecting the new machines' complexity and lower reliability.

Work Organisation. This aspect is substantially altered by the introduction of the Auto-feed machines. In the old method the operators manually transfer the tyres from a storage conveyor to the turntables for trimming, perform the operation, and then manually load them onto another conveyor.

The workers are therefore continually moving around in a fairly large and open work space. In the Auto-feed system worker movement is quite limited - only turning from one work station to the adjacent one and back again. This work area is partially enclosed, and there is little opportunity for worker interaction.

TABLE 6.9: COMPARISON OF POWERED TABLES AND AUTO-FEED TYRE TRIMMING

	POWERED TABLES	AUTO-FEED
Capital Equipment	4 Powered Trimming Tables Hand-held Knives 2 Conveyors Tyre Storage Racks	2 Auto-feed Trimming Machines Hand-held knives 2 Conveyors
Product	Trimmed Tyres in Various Sizes	Trimmed Tyres in Various Sizes
Manning	3	2
Total Output (tyres/shift)	1800	2750
Output per Worker (tyres/shift)	600	1375
Services Cost per Standard Hour* (£)	0.15	0.15
Maintenance Cost per Standard Hour* (£)	0.88	1.73

* Standard Hour is the unit of output employed in factory accounts

Health and Safety. The main difference in this regard is that the Auto-feed eliminates manual handling, which might be a strain with the larger tyre sizes.

Management. In that the Auto-feed system has a greater number of tyres channelled through a single point in the factory, rather than the diffuse arrangement of widely distributed turntables in different workshops, it may be said to increase managerial control by focussing production flow. This has the concomitant disadvantage that breakdowns will more readily result in the disruption of production.

Conclusions on Trimming of Moulded Tyres

As in the case of the Ilmberger for painting green covers, the installation of two Auto-feed tyre trimming machines serves to focus the flow of production at this final stage in the long sequence of operations which make up the tyre manufacturing process.

The manual handling before and after trimming, which was a time-consuming element of the old process, has been replaced by mechanized transfer, loading, and ejection devices. As a result, the operators can spend more time on trimming than before, and output per worker is more than doubled. This has the additional consequence of a reduction in strenuous work, but at the expense of the variety of tasks,

which is greater using the turntables.

TABLE 6.10: ADVANTAGES AND DISADVANTAGES OF AUTO-FEED WITH RESPECT TO POWERED TABLE TYRE TRIMMING

ADVANTAGES

1. Labour force reduction
2. Output per worker increased
3. Manual tasks reduced

DISADVANTAGES

1. Maintenance costs increased
2. Product size limitation

The principal disadvantage arising from this innovation is the increase in maintenance costs, almost universally associated with technically more sophisticated production methods. In this context it is interesting to note that a more fully automatic trimming machine had previously been installed but was not successful. Unlike the Auto-feed, this device had its own blades which automatically trimmed the tyres without human intervention. Although theoretically more efficient, its complexity required an excessive amount of maintenance, and it was ultimately removed. The final disadvantage of the

Auto-feed is the small limitation in tyre size it can handle, which necessitates the retention of one of the old powered tables.

In brief, the new method mechanizes certain transfer operations, reduces labour input, and increases output per worker, incurring the financial penalty of increased maintenance.

Chapter Seven

INNOVATION IN MISCELLANEOUS INDUSTRIES

This chapter documents examples of technical change in four different industries. A vehicle components firm devised a new method of producing battery cases and simultaneously re-designed the case itself. In the confectionery industry, a major UK manufacturer collaborated with a company specialising in food production equipment to build a novel plant for the moulding of confectionery centres. A large car firm greatly increased the output of its press lines by a combination of in-house mechanization and the purchase of commercially-available equipment. Lastly, a small garment component manufacturer was assisted to mechanize part of its production operations.

7.1 VEHICLE COMPONENTS INDUSTRY

An innovation in both a product and the technique of production occurred simultaneously in this case study. It took place in the mid 1960's, and so the following constitutes a retrospective analysis of a successful development which has now become a more widespread practice in the industry, latterly adopted by the company's competitors.

The Firm

The group to which this company belongs is a large multinational of British origin with share ownership widely spread among individuals, investment trusts, banks, and other companies.

It is a major world manufacturer of electrical hydraulic and mechanical equipment used in internal combustion, diesel, and gas turbine engines for road vehicles, trains, aircraft and ships. It also produces a wide range of industrial goods. Road vehicle equipment constitutes by far the largest share of the total.

Under the Standard Industrial Classification (C.S.O. 1968, p20) the factory in which the investigation took place has specifications as follows:

S.I.C. Order IX - Electrical Engineering
Minimum List Heading 369 - Other Electrical Goods
Sub-division 3 - Secondary Batteries (Accumulators)

Over the main period of development and implementation with which this study is concerned (1964-68), the group exhibited an annual growth in total sales which averaged nearly 8%. The bulk of its sales (over 70% at that time) are in the UK, followed by the countries of the EEC and then the rest of the world.

The group's UK employees then numbered around 50 000, of which 2500 worked in the division concerned with battery case manufacture. Although this figure remained nearly constant over a period of 10 to 15 years, the installed capacity rose by 100% as a result of the following and other changes in production methods.

The industry in which the firm operates is dominated by a few large companies, and competitive forces played a significant part in the need for product improvement which was part of the innovation. The firm's competitors followed suit in this regard.

Battery Case Manufacture

Car battery cases hold an acid solution and immersed electrodes to generate an electromotive force, and are required to be both resistant to corrosion from their contents and robust enough to withstand external damage which might cause leakage. They have been manufactured on an industrial scale since the beginning of the century, in various materials.

The original method was very labour-intensive and involved firstly preparing granulated rubber from scrap sources, mainly old tyres. This rubber was mixed with coal dust, moulded in dies to the required shape, and cured under high temperatures for about ten minutes. 350 workers were required on battery production at that time. Some firms in the industry have used this procedure until comparatively recently. However, for the past sixty years the company in question has used different materials for battery case manufacture, and the following technique constitutes the method used before the introduction of the innovation to be described.

Old Method - Compression Moulding of Bitumen-Asbestos

Bitumen, asbestos fibre, and china clay are first mixed together at high temperature. This material is then manually cut up into uniform pieces which are checked by weighing on a scale. These measured quantities of compound are put into moulds in a compression mill, and are cured for six minutes prior to removal. Sixty of these mills are necessary to maintain the level of output required, and a gang of workers is involved in conveying materials and finished goods. Skilled tool-setters change the moulds between batches.

Motivation to Change

Battery cases manufactured in this way have a short lifetime and a failure rate, through a tendency to leak acid, upon which it would be desirable to improve. Thus a refinement of the product takes place in conjunction with the innovation in the production method. This is intended to improve the market competitiveness of the batteries.

Productivity is low on account of the many separate production points afforded by sixty machines, the complex materials and product transport network which this entails, and the length of time which each case must spend in the mould before the next operation can commence. Labour costs, therefore make a large contribution to total manufacturing costs.

Lastly, the blue asbestos used in the compound constitutes a health hazard, and a process which obviates the need for its use would be desirable.

New Method - Injection Moulding of Polypropylene

This technique involves the straightforward injection of a thermoplastic into a die, in six large injection moulding machines. Polypropylene granules arrive by road tanker direct from a chemical manufacturer and are blown by compressed air into a large silo. From there the granules are dispensed by automatic injection through pipes into the mould, in

a measured quantity. The battery cases are formed at high temperature, and are then automatically removed and deposited on a conveyor. The complete cycle takes only 45 seconds, and operates under solid-state electronic control. The finished cases are carried off for inspection at a carousel and storage in racks. There is no manual handling during manufacture, either of the raw materials or the moulded cases. Tools in the injection moulding machines can be altered to make different sizes of battery cases.

Comparison of Old and New Methods

Throughout this section refer to Table 7.1.

Capital Equipment. The most notable difference in this respect is the ten-fold reduction in the number of machines, and hence production locations, necessary to manufacture the desired quantity of battery cases. All presses in the old process, which were of varying age, were dispensed with, and replaced by new injection moulding machines purchased "off-the-shelf" from outside suppliers. The firm added an extra control system of its own, which took two years to develop and is undergoing refinement. Computer monitoring of product consistency and of the machines' performances is undertaken, and faults per shift are categorised (e.g. electric, pneumatic, mechanical) for comparison over time. The 60% reliability of the

old presses (i.e. the percentage of their target running time which is achieved in practice) compares very unfavourably with the 96% attained by the new moulders.

Lastly, the cycle time of the new machines (i.e. the duration from commencing the manufacture of one unit to commencing the next) is only one eighth that of the old.

Labour. A substantial reduction is apparent, from sixty workers per shift in the old method to six in the new. However, an extra shift is required, and the net result is that the new process requires 15% of the labour force of the old, to produce the same number of battery cases. More interesting, perhaps, is the fact that direct workers (i.e. those who actually work at the point of production) have been completely eliminated in the new process. The injection moulding machines normally function automatically, and the system requires labour only for inspection of the cases produced (one man), changing the dies when necessary (two tool setters), supervision (one foreman), and maintenance. There is the possibility of further labour reductions as a consequence of this innovation.

Skill requirements are upgraded, particularly in maintenance crews, who must now have expertise in electronics. Training periods varied from one week for direct workers on the old method, to five years for skilled maintenance craftsmen on the new.

Raw Materials. The various materials which make up the input for the old process (bitumen, blue asbestos fibre, and china clay) are replaced by a single ingredient, polypropylene granules dispensed from silos. There is a relative reduction of a factor of five in the cost of raw materials achieved by the new process.

Energy. A net saving of energy consumed in production results from the introduction of the new method, although no detailed figures are available. However, the new raw material probably contains a greater energy input than the old.

Space. This factor has been reduced to about one quarter of that previously required, and a new factory was built to accommodate the new production system.

Output. Although the products of the two methods are identical in their utility, they are composed of quite different materials as already pointed out. This yields a substantial increase in product quality; the impact resistance of the polypropylene cases is ten times greater than that of the bitumen-asbestos ones, and their power-to-weight ratio is also higher. The life of the battery has been doubled.

The total annual output of battery cases by each method remains the same, at 1.5 million.

Economics. Output per worker is very much improved, by a factor of 6.7, which relates directly to the reduction in the total workforce. Although the skilled workers of the new method are more highly paid than their earlier counterparts, there is a net reduction in labour costs on account of the lower manning levels. This, combined with the five-fold reduction in raw material costs and the reduction in energy costs, results in costs per unit of output falling by 30%.

A capital investment of about £4 million for the new factory and £600 000 per injection moulding machine, at the then prevailing prices, was required for the innovation.

Work Organisation. The extensive layout of the old method, which was the result of haphazard evolution over many years, was replaced by a much more compact one incorporating a considerable amount of mechanization and automation. As a result the operators' tasks are quite different, and are not directly involved in the production process as such. They include machine monitoring, inspection of output, and tool-setting. This eliminates monotonous physical labour and is claimed to increase worker satisfaction.

There is a change from two-shift day time working in the old factory to a three-shift rotation, six days per week, in the new. This is a disadvantage as night shifts are unpopular with the workforce.

TABLE 7.1: COMPARISON OF COMPRESSION MOULDING AND INJECTION MOULDING OF BATTERY CASES

	COMPRESSION MOULDING	INJECTION MOULDING
Capital Equipment	60 Moulding Presses	6 Injection Moulding Machines
Product	Bitumen-Asbestos Car Battery Cases	Polypropylene Car Battery Cases
Production Labour per Shift	30	0
Ancillary Labour per Shift	30	6
Total Labour per Shift	60	6
Shifts per Day	2	3
Total Daily Labour	120	18
Production Time (minutes/case)	6.0	0.75
Total Output (cases/year)	1 500 000	1 500 000
Output per Worker (cases/year)	12 500	83 300
Equipment Reliability (% of target running time achieved)	60	96

Management. Factory managers and supervisors are now required to work shifts, which was previously unnecessary.

Development and Implementation

Planning commenced in 1962, and it was clear from the outset that a major innovation in both the product and the technique of production should be attempted simultaneously. The choice of polypropylene to replace the old composition required totally new manufacturing facilities, and in the end a new factory was built to accommodate this.

In 1965 blue asbestos became recognised as a health hazard, as a result of experiences in the ship-building and other industries, and in 1969 it was officially proscribed. This confirmed the inevitability of a shift away from the old production method, and the factory management regarded their early planning for the innovation to be fortuitously timely. After two years of development, however, a better rubber became available which would have been an alternative to using polypropylene, but this was not followed up in practice.

A team of up to eighty engineers in research improved the battery efficiency and developed an original control system for the injection moulding machines. These were installed in 1967 and the factory opened in early 1968. This necessitated transferring labour and

retraining both direct and maintenance workers, especially the latter. No redundancies were required but some workers took the opportunity to retire early.

Smooth co-operation was received from almost all of the sixteen unions involved, and this is attributed to the safety advantages accruing from the elimination of the hazard posed by asbestos in the old method. The introduction of a three-shift system to replace the previous two shifts was not well received and required compensatory pay negotiations.

Conclusions on Battery Case Manufacture

This case study illustrates simultaneous and radical innovation in both the product and the technique or production. Although the function of the battery case is identical in each instance, its composition, impact resistance, lifetime, production time, unit cost, and many other factors have been substantially improved upon. The layout of the production system has been greatly altered, the majority of manual tasks eliminated, and a totally new manufacturing facility built.

The reduction in labour requirements yields a very great increase in output per worker, and this combined with economies in energy and raw material inputs results in a lowering of unit production costs.

The desire to eliminate the health hazard of asbestos, as a motivation for the change in the

ingredients of the product, was later confirmed as an unavoidable requirement when legislation was enacted to prohibit its use.

TABLE 7.2: ADVANTAGES AND DISADVANTAGE OF INJECTION MOULDING WITH RESPECT TO COMPRESSION MOULDING BATTERY CASE MANUFACTURE

ADVANTAGES

1. Labour force reduction
2. Output per worker increased
3. Unit cost reduction
4. Health aspect improved
5. Product improved
6. Process simplification
7. Increased reliability of equipment
8. Manual tasks reduced

DISADVANTAGE

1. Increased shift working

Total mechanization of production operations (die changing is excepted), and total automation of the normal production cycle within each batch run (there are no direct operators), is achieved.

In contrast with many other advances in production methods, this innovation exhibits a major increase in

the reliability of the machinery used. This is probably attributable to the fact that the change consists of the application of a well-established industrial technique, thermoplastic injection moulding, in a novel area, battery case manufacture, rather than being merely a more complex method of carrying out the original process. It thus benefits from improvements in the production technique gained from previous experience of injection moulding in other industries.

In conclusion, this complex innovation involved substantial change in almost all aspects of industrial manufacturing, including the basic design of the product, the production process itself, raw materials, labour requirements, and other factors. External competitive considerations played a motivating role, and internal acceptance was ensured by the advantages to the health of the work force which came with the change.

7.2 CONFECTIONERY INDUSTRY

The innovation described here represents the solution of a long-standing problem in the industry - how to achieve confectionery jelly centre moulding on a continuous rather than an erratic batch production basis. It required several years of research by the manufacturer and a supplier of production equipment.

The Industry

The confectionery industry in Britain has traditionally been dominated by four firms, all founded by Quaker families.

Batch production technology was used up until the end of the second world war, and low wage rates provided no incentive to change. In the 1950s and early 1960s, however, labour costs rose to become the principal cost of production for a period, and a transition to continuous process techniques was started. This has continued, although rises in the prices of commodities (such as cocoa beans) in the early 1970s have meant that ingredients are again the main production cost items.

The industry is very competitive and product innovation is comparatively rapid, so flexible production techniques are desirable. Profit margins are low, and sales tend to be adversely affected by rises in value added tax and other marginal effects.

The Firm

The company, which originated in the eighteenth century, is now part of a British-owned group which manufactures confectionery, foods, tea, soft drinks, and health products. Part of its production is abroad.

Under the Standard Industrial Classification (CSO 1968, p9) the factory in which the investigation took place has specifications as follows:

SIC Order III - Food, Drink and Tobacco
Minimum List Heading 217 - Cocoa, Chocolate and
Sugar Confectionery
Sub-Division 1 - Cocoa and Chocolate

Sales of the group to which the factory belongs exceeded £1,000 million in 1979, with over 50% of the total coming from the UK. First-half results for 1980 exhibited a 6% increase in sales, despite the general recession.

Current employment in the factory is 2800, having been reduced from 5000 in the early 1960s, and further reduction is anticipated.

The product with which this study is concerned was first made in the 1930s, and current sales are valued at about £9 million annually.

Moulding of Confectionery Centres

In the manufacture of various types of confection a process commonly used is that of creating a jelly centre around which chocolate and other coatings are applied. The jellies are prepared initially in liquid form and poured into moulds. They must cool and set solid before they can be removed, in order that they retain their shape. Subsequent coating by passage through a flowing curtain of viscous liquid chocolate is often performed. This process is used both for individual assortment chocolates sold in boxes, and for chocolate-coated bars. The version examined here produces the latter.

Old Method - Moulding in Starch Impressions

The first part of the operation involves combining glucose, sugar, pectin and other ingredients in two stages, and raising them to a temperature of 180°F. The mixture is then cooked in a 'votator' (heat exchanger) at 143°F and under a pressure of seven bars to retain water. The surface inside the votator is continually scraped to avoid burning by prolonged contact of the mix with the hot walls. Flavouring and colouring are added in minute quantities and stirred, while the temperature is raised to 200°F. Gel preparation is now complete, and the material passes into a 'Mogul' depositor which fills the moulds.

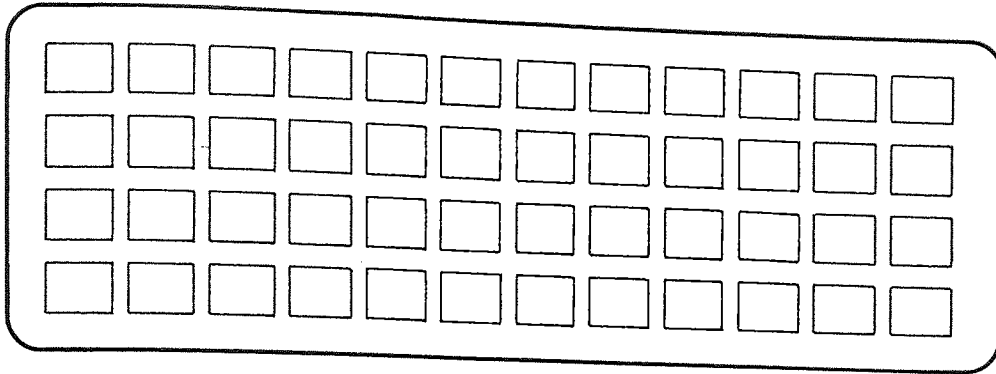


FIG.7.1: TRAY OF 48 STARCH MOULDS

The moulds consist of wooden trays which have been filled with starch (corn flour) of controlled moisture content, normally 11%. The starch is levelled and the negative impression of 48 jelly centres is made mechanically by pressing a metal die into the starch.

The trays of filled moulds are transferred to a cooling room and stacked to allow air to circulate, so that the jelly will set. This takes from 12 to 48 hours, and is dependent upon the mix of ingredients and ambient atmospheric conditions. A special recipe must be used at weekends to slow down the rate of settling so that jellies moulded on a Friday afternoon take until Monday morning to set and will then be ready for the next stage.

When the jelly centres have solidified, the starch mould is broken up and the 'units', as they

are now called, released. The starch is partially recovered, dried and cleaned for re-use in later moulds.

The jelly units must now be cleaned of starch powder by sieving and air blasts, and inspected for mis-shapes, before being manually placed on a conveyor leading to the chocolate coating machines.

The first of these, the chocolate bottomer, uses a mesh grid with chocolate-coated rollers underneath, to cover the base of each unit. After cooling they continue to the chocolate enrober, which consists of a roller discharging a continuous curtain of flowing liquid chocolate. The units pass through this, so becoming coated on the top and the four sides.

Further conveyance to a shaker and fan, to remove loose pieces and solidify the chocolate, followed by a patterned roller to decorate the top of the bar, complete the process.

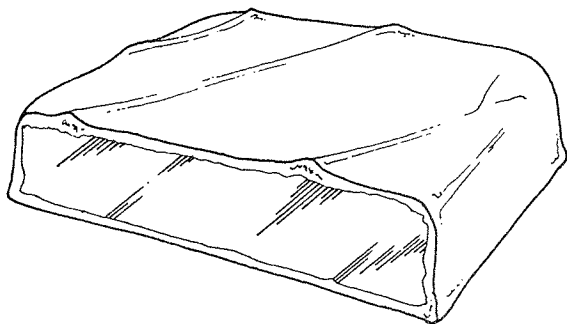


FIG.7.2: FINISHED CHOCOLATE-COATED BAR

After manufacture the units are transported directly to the packing station for quality control, weighing, wrapping of each unit individually, and batching into cardboard boxes ('outers') containing 48 units.

The minimum time for the whole process is 12 hours, but it can take up to four days.

Motivation to Change

The overriding preoccupation was to achieve a continuous process in manufacturing, rather than the time-consuming batch production techniques employed by the old method. This would yield a major advantage in the control of the operation, which was highly variable in setting times and quality between batches (Jeffrey, 1969).

The process of setting involves the removal of water from the jelly, and since the hygroscopic starch moulds play an active part in this, the time taken to set depends on the prevailing atmospheric humidity. This varies on a seasonal and even daily basis. Because of this uncertainty and the long process time, work is complicated by weekend and holiday closures, the latter requiring production to cease two days in advance.

Concern over the quality of the jelly centres focuses on three aspects:

- a. Gel consistency, which may vary widely with ambient conditions
- b. Mis-shapes due to the starch moulds collapsing
- c. Contamination by foreign matter, such as wood splinters from the starch trays and bristles from brushes required to dust the starch from conveyors.

The use of starch to make the moulds, and these being later broken down again into powder, makes the factory environment very dusty, and a fire hazard on account of the explosive properties of starch dust in air.

Lastly, the process is very labour intensive, using manual labour to place and sort every jelly on the conveyor belt.

It is apparent from the above that most of the problems would be solved by standardising the process for every batch of jellies, in particular by eliminating the variability in setting times, and by replacing the wooden starch tray moulds which contribute to the bulk of the quality problems and provide a potential source of danger to the operators.

Development

The physical and chemical processes taking place during the setting of the jelly, and their dependence upon small variations in the quantities of ingredients

and the ambient conditions of temperature and humidity, were previously incompletely understood.

Detailed study of this proved fruitful, and attempts to change the act of setting from being a cooling and drying process to a purely cooling one, were eventually successful through precise changes in the recipe. In the old method most of the moisture was transferred to the starch, which later had to be dried, and so the mould itself played a direct part in the setting. This therefore effectively eliminated the necessity for starch moulds.

At this point an external confectionery equipment manufacturer approached the company with a development of their own. This was a process which used magnesium stearate as an agent to release confectionery which had set in metal moulds, and which became the starting point for the design of the method eventually employed.

Because the process of drying by absorption, impossible in a metal mould, had now been dispensed with, this outside development could feasibly be applied to jelly centre manufacture - except for the fact that magnesium stearate was not then a permitted food additive.

Joint research teams from both companies commenced work. Great difficulty was experienced in achieving a smooth de-moulding of the jellies and many mould surfaces, including metal, rubber, polypropylene, and other plastics, were found to be unsuccessful. Eventually, the application of air

pressure through small holes in each mould, which had been coated with Teflon (tetrafluoroethylene), achieved the desired result. An acetylated monoglyceride, Myracet, was found to be the best releasing agent, with minimal effect on the qualities of the confection.

Although the first machine of this type was installed in 1966 to produce small chocolate-box centres, that used in the current innovation was commissioned in 1977 and makes much larger jelly centres for a chocolate-coated bar.

New Method - Moulding in Metal Dies

Much of the new production method has close similarities with the old. The process again starts with two mixes (a dry mix followed by an 'ultra' mix), but with a slightly different set of ingredients, which includes glucose, sugar, pectin, acids, calcium phosphate and starch.

Cooking takes place under pressure in a votator, and flavouring and colouring are added and mixed. When the gel slurry is prepared, it is pumped by a depositor into a tray of Teflon-lined metal moulds.

The moulds have been sprayed with an acetylated monoglyceride (Radional or Myracet) as release agent, to prevent the gel from adhering to the Teflon. The substance is a permitted food additive.

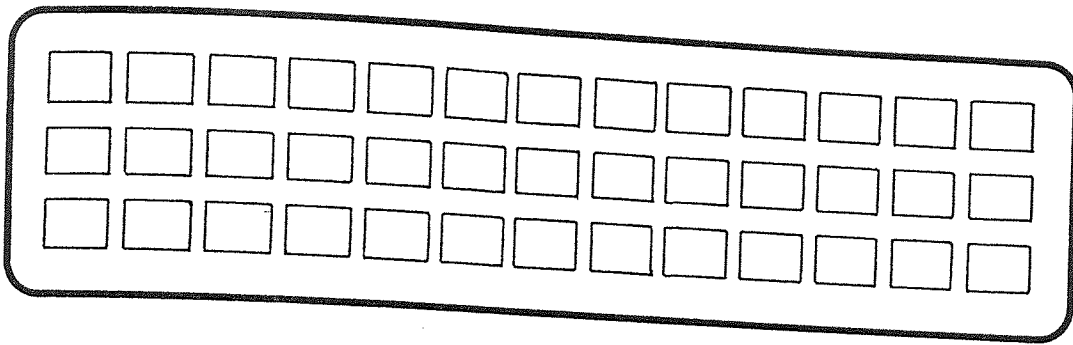


FIG.7.3 : TRAY OF 39 METAL MOULDS

The trays of filled moulds are fed into a three-zone cooler of controlled temperature and humidity, where they set solid in about 20 minutes. On emerging from the cooler, the trays are mechanically inverted and the 'units' of jelly ejected by compressed air introduced through nine small holes in the base of each mould. The release agent ensures complete separation, with no broken jellies, partial ejections, or 'tails' left.

The jelly centres are deposited in rows on a conveyor, and carried to the chocolate bottomer, enrober, shaker, and patterning device as in the old method. Packaging then follows at the last workstations, with newer packing machines.

The time taken from deposition through cooling to the final chocolate-coated unit is now 35 minutes, and the overall process time (including mixing and cooking of the gel mass) is $1\frac{1}{2}$ hours.

Comparison of Old and New Methods

Throughout this section refer to Table 7.3. Parts of both methods are virtually identical; the recipe preparation, mixing, and cooking stages, and in the later sequences of chocolate enrobing packaging. It is in the important and previously time-consuming process of allowing the gels to set that the main differences lie.

Capital Equipment. Mixers and votators are used to prepare the gel in both methods. The first major departure in the new method comes at deposition, where metal trays of moulds take the place of the older wooden ones with starch impressions. The two old 'Mogul' depositors are replaced by a single faster-operating one of more modern design.

Whereas in the older method the trays were stacked to cool and set in a store, this is now done while the metal trays are in continuous motion in an enclosed and carefully controlled environment.

The de-moulding equipment has also been improved upon. Automatic ejection by compressed air supersedes manual breaking-up of the starch trays. There are seven packing machines for each method.

Longer term flexibility in production has, however, been reduced because the solid metal moulds are not so readily altered in size than were the starch impressions.

The reliability of the new machinery is greater, reflected in its target utilisation rate of 85% compared with 60% for the old.

Labour. Per shift, the old method required three workers on the mixer and votator, two dealing with waste, four on each of the two depositors, one to recover the starch after use, and six on each of the two enrobing machines. One operator to transport chocolate brought the total in production to 27.

This compares with 10 by the new method; one on each mixer, one dealing with re-cycled material, one plant operator, one overseer, operators for the rotator and enrober, and three workers with more general duties.

Packaging in both methods requires an operator and a packer for each machine. Binding the wrapped bars into boxes required a further 16 on the old process (making 30 in total), whereas the ancillary workers on the new process number just 11, due to their using more mechanized equipment, giving 25 in total - a saving of 5 in packing.

Maintenance requirements are four workers per shift on the old process, and five per shift on the new.

The innovation has produced little effect on skills. Two workers on a slightly higher grade wage rate have replaced four who worked on the equivalent part of the old process.

Although difficult to judge, the elimination of certain repetitive manual tasks has probably increased worker satisfaction on average.

Raw Materials. A less fluid chocolate is required in the new process, which allows a saving on some expensive ingredients. However, those that are used require to be of higher and more consistent quality. Starch is no longer needed, but the releasing agent is an additional expense.

Energy. The energy input is increased, since manual removal and stacking of trays is replaced by a continual mechanized and partially automatic process. The manual de-moulding is also now replaced by machinery, which consumes electricity and compressed air.

Space. Since the old method required two plants from the point of gel deposition onwards, the space needed by the new process is just 60% of the old.

Output. The nature of the product is identical by each method; chocolate-coated jelly confection bars of dimensions approximately 7 cm by 5 cm.

The time taken to produce 1000 'outers' (cardboard boxes each containing 48 wrapped bars) is somewhat better in the new process - almost 0.71 hours, as against 0.84 in the old. In terms of outers

per hour, this exceeds 1400 by the new method compared with under 1200 previously achieved.

The quality of the product has been improved in three ways. The centre is more consistent in texture, whereas it was formerly variable according to atmospheric humidity and temperature. Deformities of the jelly's shape are a less common occurrence because a rigid metal mould is used in place of the starch impressions, which frequently collapsed. Lastly, contamination of the product is greatly reduced; no starch is present, no brush bristles or wood splinters from the old trays can get into the jellies, and there is no more manual handling of them in production.

Economics. The output rate of the new production method is 19% greater than the old, but this is achieved with just 66% of the labour. The net increase in output per worker is consequently 94%, due in the main to the reduction in direct labour employed.

Work Organisation. Several manual tasks have been completely eliminated in the change from the old to the new production method. These include the loading, transport and stacking of the wooden trays, which are replaced by a mechanized arrangement of metal trays.

Another labour-intensive operation, de-moulding, has also been mechanized. Previously each wooden

tray brought out from the cooling store was emptied manually; the starch was broken up, the set jellies shaken out, and the starch separated and sieved. This procedure left the jelly centres haphazardly distributed, and they had to be placed manually onto the conveyor leading to the chocolate enrober. The metal moulds use no starch, and the jellies are placed on the conveyor without manual intervention, by automatic ejection with compressed air.

Health and Safety. The new process is safer than the old, by virtue of its obviating the necessity for starch to be present. Airborne starch dust can be explosive, and it was produced in considerable quantities when the moulds were broken up to release the jellies.

Management. Managerial control over the production process is much improved by the innovation, which has facilitated the planning of output schedules. This is attributable to the predictability and shorter timescale of the setting process. The variability of setting in the old method meant that one batch which took longer to set than anticipated could hold up subsequent production.

TABLE 7.3: COMPARISON OF STARCH TRAY AND METAL DIE MOULDING OF CONFECTIONERY CENTRES

	STARCH TRAY	METAL DIE
Capital Equipment	Mixer Votator 2 Depositors Stacking Store Starch Recycler 2 Enrobing Conveyors 7 Packing Machines	Mixer Votator 1 Continuous Moulding Plant 1 Enrobing Conveyor 7 Packing Machines
Product	Chocolate-Coated Jelly Bar	Chocolate-Coated Jelly Bar
Production Labour per Shift	27	10
Packing Labour per Shift	30	25
Maintenance Labour per Shift	4	5
Production Time (hours)	12 to 96	1.5
Average Output (Outers*/hours)	1186	1414
Output per Direct Worker (Outers*/hour)	20.8	40.4

* Outer is a packed box containing 48 bars

Implementation

The labour force in the factory as a whole was reduced over the two years taken to implement the project, on the basis of seniority. Some redundant labour from the old process was redeployed elsewhere in the factory, but the issue of the new equipment's introduction was contentious. The firm is one which has traditionally had good labour relations, but its most serious recent industrial dispute took place in 1978 over this innovation, and the plant was temporarily 'blacked' by electricians.

The increased output of the new plant was taken up by rising demand for the product.

Conclusions on Moulding of Confectionery Centres

This innovation is, as noted earlier, the realisation of a production method which has been long sought in the confectionery industry, and was achieved by fundamental research into the ill-understood physical and chemical processes involved in gel setting.

It was the combination of a new jelly recipe with an improved moulding process, and ancillary rationalisation of the subsequent stages of production, which finally effected the solution.

The innovation permits the transformation of jelly centre moulding from a highly variable batch

production technique to a strictly controlled and virtually continuous process. This means that production need no longer be stopped two days prior to holiday closures, nor the recipe changed every weekend to lengthen the setting time.

Productivity has been substantially raised, partially by increased output from the single production line which replaces the two of the old method, but in the main from a one-third reduction in the labour employed.

The quality of the product is improved in several respects, among them hygiene and gel consistency, by dispensing with starch moulding. This also eliminates a potential fire hazard.

From the fact that the jelly units are dislodged automatically from regularly-spaced dies in a metal tray, rather than knocked out of starch and manually placed in haphazard fashion on the conveyor, there derives an additional potential benefit. It now becomes more feasible to automate feeding and wrapping at a later date, should that be desired. It would have been difficult to achieve with the random spacings and orientation resulting from manual de-moulding in the old method. If carried out, this is estimated to reduce the labour force by about one third.

A final benefit worth noting is the more economical utilisation of factory space with the new method.

TABLE 7.4: ADVANTAGES AND DISADVANTAGES OF METAL DIE WITH RESPECT TO STARCH TRAY MOULDING OF CONFECTIONERY CENTRES

ADVANTAGES

1. Labour force reduction
2. Output per worker increased
3. Increased process control
4. Greatly reduced process time
5. Quality improved
6. Safety aspect improved
7. Manual tasks reduced
8. Floor space economy
9. Creates conditions for future automation

DISADVANTAGES

1. Process more critical to variation in raw materials
2. Production flexibility decreased

The greater control over the process afforded by the innovation does have some disadvantages. The new technique is more critical with respect to temperatures, the specifications of ingredients (which means that supplies from outside must be carefully checked for impurities), and the ratios of ingredients - i.e. the recipe must be more strictly adhered to.

Flexibility is also lost in the longer term. Changes in the sizes of confection bars are occasionally required, e.g. for metrication, or because company policy dictates that a smaller-sized bar is a more desirable way to pass on increased costs than is a price rise. This is more expensive with the metal die trays, where a size change costs around £50,000.

As a final point, although the new plant is theoreticlaly more reliable than the old ones, the consequences of a breakdown are also greater, since with two plants there would normally be one to fall back on. The production risk is therefore greater. Furthermore, with a stoppage in the new technique, the entire cycle of jellies in the cooler tends to be lost.

To summarise, this innovation almost doubles labour productivity by eliminating several manual tasks. It greatly improves managerial control over the process and reduces its time, often to under one tenth of what was sometimes previously necessary. The quality of the product is improved, and the safety of the working environment enhanced.

As a penalty, the new process is more sensitive to changes in a number of external factors, and when breakdowns occur the loss involved is greater.

7.3 AUTOMOBILE INDUSTRY

The technical innovation examined in this case study was introduced in a subsidiary plant of one of the U.K.'s large motor manufacturers. The process was making parts which, after subsequent assembly on the main vehicle production line, constitute the car body shell. The particular system examined was, at the time, unique in Britain, and has since found more widespread application.

The Industry

High rates of import and export of cars between nations, the large scale international transfer of automobile production technology, and the multinational nature of many large manufacturers, means that the automobile industry is only properly seen in a world context.

Its importance is illustrated by the fact that it provides one of the major barometers of economic performance, since it is a large consumer of such basic commodities as steel and rubber, and is a determinant of other major industries, including road construction. So its general condition is the subject of much debate because of these wider economic consequences, and close attention is focussed on predictions of car ownership (Hirt 1979; Adams 1977; Moulins 1978).

Within the broader world picture, the industries of North America and Western Europe are currently facing severe problems, and among those the U.K.'s are particularly prominent.

The automobile industry is characterised by frequent non-fundamental changes in the product. Often on an annual basis, car models are marginally re-designed in appearance and accessories, then commercially re-launched, although the basic technical specifications may be unaltered. Less frequently, completely new models are introduced, but the industry's product has for many decades been, in essence, a four-wheeled passenger vehicle powered by an internal combustion engine.

The social value of these annual incremental alterations has been questioned by some writers, and estimates made of the costs incurred (Grilliches 1961; Fisher et al 1962).

The British automobile industry has firms of greatly differing size, ranging from huge mass-production plants to low-volume factories making high-value vehicles. The latter have generally been much more profitable than the larger concerns (Rhys 1977, p254), whose catalogue of economic difficulties has been well documented.

There are four major car companies, which produce between them virtually all, by volume, of the U.K.'s national output (99.5% in 1978, when this investigation took place).

The industry exhibited rapid growth from the early part of this century to the late 1960s, but since the early 1970s has been in decline relative to its main international competitors, both in the foreign and home markets (Turner 1964, 1971; Richardson 1977). The 1978 UK production level of 1.2 million cars stood at just two-thirds of its peak output, recorded in 1972.

The U.K. motor industry's recent problems have been variously attributed to a selection of economic and social factors, ranging from historically inadequate levels of investment (C.O.I. 1975, p16) to poor industrial relations. Whatever the reasons, imported vehicles have accounted for a steadily rising share of the British domestic car market; 37.9% in 1976, 49.3% in 1978, and 56.7% in 1980 (S.M.M.T. 1976, 1978, 1980).

The Firm

The company in which the investigation took place is a subsidiary of one of the U.K.'s major motor manufacturers. The larger holding company of which it is a part is a producer of a wide range of automotive products, including cars, trucks, buses, agricultural tractors and other specialist vehicles. Of these, car operations are the most extensive.

Under the Standard Industrial Classification (C.S.O. 1968, p21) the factory in which the

investigation took place has specifications as follows:

S.I.C. Order X1 - Vehicles

Minimum List Heading 381-Motor Vehicle Manufacture

Its output consists largely of pressed steel panels for car bodies, to be assembled at other locations which are also part of the overall holding company.

Cars contributed about 70% to the group's overall sales of around £3000 million in 1978. About 60% of the total revenue was generated in the U.K., with the largest share of the balance going to Europe.

The group's U.K. employees in 1978 numbered over 160 000, with a further 23 000 overseas. The factory in question employed 3700.

In the period leading up to the investigation, the company experienced a steady erosion of its share of the U.K. car market, while sales of its British and especially foreign competitors rose.

Automobile Production

The production of automobiles is a complex process which has been in continual evolution since the turn of the century.* It incorporates many different industrial techniques, including all forms

* For a rare and illustrated contemporary account of early automobile production, see Showalter, 1923.

of metal-working, plastic moulding, painting, glass manufacture, upholstery work and intricate assembly tasks.

In volume car production this has become a highly integrated process with a multitude of component flow lines converging at a final assembly line. Along this line a train of car bodies moves in regular progression through many work stations, at which the various components are added. At the end the vehicle is complete to the last detail, and can immediately be driven away. Productivity increases resulting from the introduction of assembly lines have been enormous, and are put at 23-fold for the first four decades in the U.K. (Cleator, 1955, pp113ff).

Assembly line techniques were first introduced by Henry Ford for magneto manufacture at Highland Park, a suburb of Detroit, Michigan, in 1913. They have since spread to become virtually ubiquitous in the automobile industry world-wide, and in a multitude of other manufacturing processes.

The moving production line, for both vehicle assembly and the making of components, remains the mainstay of the industry's stock of manufacturing techniques. Its pre-eminence has been reinforced by the very limited success (under restrictive conditions of low volume output) of the only major challenge to the continuous line - the team approach to car manufacture adopted at Volvo's Kalmar plant

in Sweden (Foy 1974; Taylor 1976; Roach 1977; Gyllenhammar 1974, 1977, 1978; Jenkins 1978).

The economic and social effects of assembly line production in the automobile industry have been studied in depth, particularly in the USA (Walker & Guest 1952; Chinoy 1955; Blauner 1964). This case study, however, is concerned with the production line manufacture of one of the major component items of the car body shell, pressed steel panels.

The Manufacture of Car Body Panels

The various panels which are assembled to form a car body are made from steel sheets. The sheets are conveyed through a line of linked presses each of which makes a partial contribution to the total pressing and cutting required to produce the panel, which emerges in a finished state at the end of the line.

The presses descend with great force on the steel sheet and permanently form it into a shape determined by two complex and accurately contoured dies, bearing the reverse imprint of each side of the desired shape.

The first pressing will result in a panel which conforms only approximately to that finally intended, which may be a car door, roof bonnet, boot, window-frame, or side-panel. A series of pressings are usually necessary to achieve the final shape, and some

of these stampings will also guillotine the metal - for instance, a trapezoidal hatch-back door from a square steel sheet, or to cut out window spaces and headlight apertures.

The panels may also require to be turned over between presses, if subsequent operations require deformation in opposite directions, such as for re-entrant shapes, rainwater gutters on roof panels, and similar features.

The operation is performed on a batch basis, so at the end of each batch run the dies must be changed prior to commencing the next. The dies are typically two metres wide, and being of great weight are awkward to handle. They are removed from both the upper and lower faces of the presses, and replaced with a different set, in a skilled operation which takes the duration of two or three shifts. Feeding rack configurations are also altered, and tolerances adjusted to the new sizes, before the next batch run is commenced.

Each press line will typically be put through a cycle of six or seven different panel batches, each of which will run for about two weeks.

Old Method - Manual Transfer

The original manufacturing technique examined in this investigation employed a line of six large presses able to produce any of the larger body panels

which go to make up a saloon car.

A pile of flat steel sheets is first deposited by fork-lift truck directly in front of the first press. These are each known as a "blank", and having been first brushed with a lubricant are manually installed in the open press by two unskilled operators, one on each side of the line. Accurate positioning is achieved by the loaders locating the panel against lugs over the lower die. The insertion of the blank is detected by sensors, and after a brief delay, the press descends with several tonnes force to stamp out the first form, and simultaneously trim excess metal. The waste material thus formed falls into the building basement through apertures in the floor, where it is collected for re-cycling.

The press then rises to expose the incipient panel, which is automatically removed onto a conveyor by a swing-arm unloader. This device is attached to the press itself above the aperture from which the panel is ejected; the arm rotates inside the open press, grips the panel by suction pads, and rotates outwards before dropping the panel onto the conveyor. From this short conveyor, the panel is manually inserted by two operators (again one on each side) into the next press.

Some of the subsequent presses may have their dies inverted or otherwise differently aligned in relation to those on the previous one. This is because the press can only form the impressions by

the application of a descending force, and certain shapes require the vector to be effected in different directions relative to the steel panel.

So for certain presses, the handlers may have to invert the panel or turn it through 90 degrees on the conveyor, prior to the next loading, where accurate location is again ensured by guides.

This process of loading, pressing and trimming, ejection, re-orientation (if required) and conveyance to the next press is continued down the line. At the end, after ejection from the last press, the finished panels are stacked in pallets by an operator. From storage, they are later transported in these pallets to other locations within the company for assembly into car body shells by spot-welding.

Motivation to Change

Technical advances in press operations have, over many decades, been minimal. The mechanical press was introduced as a metal-working tool around the turn of the century (Browne 1965; Bradley 1972), and the type of swing-arm unloader employed in the old method came into general use in the early 1950s. More recently, the only other major innovation has been the sheet feeder, used to load the blanks into the first press. This device was already in use on some presses within the company investigated. Thus for many years, the technology of press operations had

been largely static, and scope for a radical improvement was perceived by the firm.

Substantial increases in productivity were thought to be attainable because the old method was highly labour intensive, requiring two direct workers for each press. The press line was also highly inflexible, in that all presses were required to stamp, then eject the panels, virtually simultaneously. This necessity for co-ordinated operation meant that a single breakdown, however brief, induced a stoppage of the entire line.

Development

First to be established was the principle that the company would keep down development costs by doing as much of the work themselves. It was decided that an economical and perfectly feasible approach would be to retain the existing press facilities, and upgrade them by improved transfer, loading and unloading devices. This would obviously be much less costly than installing a totally new line, and was adopted because the limitations in the old method lay not in the presses themselves, which performed satisfactorily despite long service, but in the connections between each press in the line, where manual intervention had always been thought necessary.

So the firm's engineering department designed original transfer devices to move and re-orientate

the panels, and made an original improvement to the method of ejection from the presses. In addition, loaders for each press and feeders for the blanks at the beginning of each line, were bought from an outside supplier.

This modification and refurbishing of older plant permitted automation of a press line at around 8% of the cost of new capital equipment. When complete, the first of the planned new press lines was the most advanced in the U.K.

New Method - Automatic Transfer

In the new technique, a sheet feeder loads, in succession, a stack of blanks into the first press. This operation, and the line as a whole, is under the control of one operator, but there is no manual intervention by him.

After pressing, the panels are removed by a swing-arm unloader and smoothly ejected onto a moving conveyor by applying positive air pressure from inside the suction pads. This is an improvement over the old method, which merely allowed the panels to fall by the neutralisation of the vacuum in the pads, and which sometimes happened unevenly, causing the panels to fall askew and bounce off the conveyor.

The conveyor then carries the panel a short distance to the company's self-built panel handling device. This consists of a set of rotating frames

capable of holding several panels simultaneously. It captures panels arriving from the conveyor, turns them around for the next pressing (if re-orientation is required), and inserts them into a mechanical loader. The handler is able to store several panels between them leaving one press and entering the next.

When sensors detect a vacancy in the subsequent press, the loader places the panel on the lower die. This insertion, using guide rails and photovoltaic sensors, is performed more accurately than human operators could.

The sequence of stamping, ejection, and transfer to the next press continues down the line in similar fashion, until the panels are stacked in a pallet with manual assistance from the only other operator.

Comparison of Old and New Methods

At the time of the investigation, one automated line of presses was in regular operation and a further five were undergoing modification. In addition, another 13 of the older manual transfer lines were being used in the factory building in which the study was performed.

Throughout this section refer to Table 7.5.

Capital Equipment. The types of presses used in both the old and new techniques are identical, and of large bed-size (the dies are about two metres wide).

In fact, the individual presses of the new line had actually been previously used for production by the old technique. They were re-furbished and had more sophisticated control and sensing electronics installed. The main difference lies in the transfer mechanisms, in which a simple conveyor (plus manual labour) is replaced by a more complex integration of improved swing-arm unloader, conveyor, panel manipulating device, and automatic loader. A sheet feeder is also employed at the beginning of the line to load the blanks into the first press in the new method.

A major advantage of the new system is that the panel manipulating device can "stack" panels to a limited extent - if the rate of panel ejection from one press is temporarily greater than the rate of take-up of panels by the subsequent press, the excess can be stored in sequence until the backlog is cleared.

The old equipment required continual sequential operation of all passes in one line, and if one press had to stop working the entire line had to follow suit.

Labour. The old technique employs 12 unskilled manual workers who have the task, in pairs, of loading each of the six presses. An additional operator supervises the stacking of finished panels. In the new method, just two operators are required: one to control the line and oversee the loading of blanks at the start of the line, and a stacker at the end performing a

similar function to that of the old method. All the manual loaders are eliminated. Double-manning was a condition of union agreement to the innovation, so the total direct labour is four.

There is a small increase in the number of skilled maintenance workers, whose job is enhanced by the necessity of acquiring expertise in new fields. This claim of improved job satisfaction is substantiated by events during the implementation of the innovation (see below).

The job satisfaction of the remaining direct workers is likely to be little changed, as are skill content and wages rates, and other benefits.

Raw Material. This is unaltered, between the two methods, and takes the form of steel sheets of various sizes.

Energy. The new technique is clearly more energy-consuming. Over and above the power used for the presses, conveyors and unloaders in the old method, it requires electricity to work the panel manipulators and new loaders. No detailed figures were available. The main energy consumers by both methods, however, are clearly the presses themselves - several tonnes weight require to be raised and lowered in a controlled manner for each stroke.

Space. The innovation results in no appreciable difference in this factor. Existing press lines are merely modified and take up virtually the same floor space as before.

Output. The same items, pressed steel panels, are produced by both methods, but the new one yields an improvement in the quality of output. Less of the panels are rejected because of mis-stamping, on account of the more accurate automatic location in the dies.

The manually-loaded presses operate at a typical rate of 410 SPOH (Strokes per Operating Hour) and have a utilisation rate of 40%. Part of the redundant time is due to the necessity to change dies between batches, but reliability is also a problem. The net operating rate which this yields is 164 SPH (Strokes per Hour).*

For the automatically-loaded press the corresponding figures are 600 SPOH with 50% utilisation, giving a net operating rate of 300 SPH.

Economics. The chosen solution to the problem of increasing output (i.e. altering existing presses rather than buying new ones) required a capital investment of just £250,000 at then-current prices to refurbish each line, compared with £3 million for

* $0.4 \times 410 \text{ SPOH} = 164 \text{ SPH}$

TABLE 7.5: COMPARISON OF MANUAL LOADING AND AUTOMATIC LOADING METHODS OF PRESSED STEEL PANEL PRODUCTION

	MANUAL LOADING	AUTOMATIC LOADING
Capital Equipment	6 Presses (2m Bed Size) 6 Swing-Arm Unloaders Conveyors	6 Presses (2m Bed Size) 6 Modified Swing-Arm Unloaders Conveyors 5 Auto-Loaders 5 Panel Manipulators 1 Sheet Feeder
Product	Pressed Steel Panels in Various Sizes	Pressed Steel Panels in Various Sizes
Labour	13	4
Output when Running (SPOH*)	410	600
Utilisation Rate (% of Shift Time)	40	50
Average Output (SPH*)	164	300
Output per Worker (Panels/Hour)	12.6	75

* SPOH - Strokes per Operating Hour

SPH - Strokes per Hour

the equivalent in new machinery. The running costs of the new machines, however, are somewhat greater than the old.

Output per worker shows a great increase, with the new method exhibiting a six-fold rise in productivity, from 12.6 panels per direct worker per hour, to 75.

Work Organisation. Although the number of workers is greatly reduced by the innovation, the tasks of those remaining are not much altered. The job of stacking the pallets at the end of the line remains, and the supervision function involves only rare intervention, such as to clear blockages of panels.

Ancillary job functions which precede and follow the press operations, such as supplying panels, removal of pallets, and other servicing tasks, remain largely labour-intensive.

Implementation

The starting point for the innovation was, as noted earlier, a plan to increase the factory's output to cope with rising demand for pressed steel panels, generated by the company's introduction of a new model of saloon car.

This increase in production was therefore able to offset the labour loss implied by the high productivity gains realised in the new technique. Workers

thus displaced were readily found new jobs in other, more labour-intensive, operations within the factory. In fact, the corporate plan for the production of the new car model envisaged an increase in total employment at this particular factory from 3,700 to 4,400, partly at the expense of other plants within the group.

The process by which the implementation of the innovation was achieved is best illustrated by a chronology of events.

July 1976. Announcement of plan to increase capacity of presses at the factory in question, to meet requirement of group's new car model.

September. Plans outlined in detail to joint management council for the plant, which consists of senior shop stewards and management. This committee could not reach agreement to support the proposed innovation, and referred the matter to five negotiating committees of senior shop stewards of the five main trades unions.

November. Four of the unions agreed that the automated press lines were a desirable innovation, that increased production capacity was acceptable, and they would nominate two union members to a management committee supervising the automation. The union representing the direct workers dissented.

December. New automatic press loading devices purchased and delivered by outside supplier.

March 1977. After three months' negotiation, the direct workers' union agreed to the same points as the other unions, but on certain conditions. These included no redundancy, and double-manning on the new press lines.

April. Extensive negotiations on details of the implementation, involving national union officials the group's industrial relations directorate, extended the issue beyond local plant level.

May. Agreement reached on all points except gang size. Negotiations stalled. Group general manager wrote to all employees, to no avail.

June. Management decided to introduce the modified press lines without agreement of direct workers. Tradesmen and engineers, however, supported the plan and built the new lines.

September. Direct workers refused to man the finished lines and factory stoppages ensued. Disagreements continued over job specifications, and direct workers declined job expansion to include machine monitoring role.

November. Partial agreement reached to operate the line, but maintenance crew has to perform some routine operational tasks (e.g. re-filling of oil bottles) which have not yet been allocated to direct workers, as envisaged.

It took, therefore, 1½ years from the first announcement of the plan to reach regular operation of the new press line, albeit with certain matters unresolved, and twice the required level of manning. Experience over the subsequent two years showed up some technical flaws in the system, which resulted in the target utilisation rate not being consistently achieved. The innovation was, however, extended to other press lines in other plants within the company.

Conclusions on Car Body Panel Manufacture

This case study provides an example of incremental technical change. Existing and long-established equipment was modified and had ancillary devices added, to largely automate what was previously a mechanical but manually-assisted production process. It permits a substantial increase in labour productivity.

This productivity gain is achieved in two ways; by dispensing with over two-thirds of the labour employed in the old method, and by nearly doubling the average output per press line.

The quality of output is also improved, by better (automatic) control of panel location in the dies, reducing the number of mis-stamps.

Ten manual loading jobs are eliminated, and by this the remaining operators are kept at a safer distance from the descending press, which provides a potential hazard (although it had already been much improved by adding safety devices which inhibit the operation of the press if a part of the worker's body is interposed).

Production flexibility is increased by the stacking capability of the handling devices, which transfer the panels between the presses in the new method. This avoids the need to operate all the presses nearly simultaneously, which was a feature of the old method. It makes some allowance for different rates of stamping, and can accommodate short delays for adjustments to part of the line, without a complete shutdown.

Because the company has in total over 240 similar presses (of 2 metres bed size) at various factories, there is considerable scope for the diffusion of this innovation, even without putting it on to the wider commercial market for industrial machinery. Development costs would therefore be much more favourably amortised.

On the negative side, the ancillary devices which have been added to the press line make it more energy-consuming, as is usually the case with increased

technical sophistication. This also incurs higher maintenance requirements as another penalty.

TABLE 7.6: ADVANTAGES AND DISADVANTAGES OF AUTOMATIC LOADING WITH RESPECT TO MANUAL LOADING CAR BODY PANEL MANUFACTURE

ADVANTAGES

1. Labour force reduction
2. Output per worker increased
3. Quality improved
4. Manual tasks reduced
5. Production flexibility increased
6. Potential for wider diffusion within company

DISADVANTAGES

1. Difficult to implement
2. Energy consumption increased
3. Higher maintenance requirement

The importance of union acceptance of technical innovation is well illustrated by this example. Although the skilled maintenance workers readily accepted the innovation, and the four relevant unions quickly reached agreement with management, it took many months of negotiation with the unskilled

direct workers' union, whose jobs were numerically most affected. It proved impossible to achieve the desired manning level, and only half of the potential productivity of the press lines was achieved.

Seen in the context of the company's wider policy, this innovation was part of a concerted effort to improve productivity in its car manufacturing operations as a whole. The firm has had a consistent problem of low productivity, repeatedly emphasised in its annual reports, which compares unfavourably with its overseas competitors. A programme of heavy investment in new equipment, starting in the mid-1970s and including this press line automation, was closely associated with the introduction of the new car model.

7.4 CLOTHING INDUSTRY main producers within effective factory and design.

This industry provided an unusual case study; a production operation was transformed from a totally manual procedure to one in which an automatic machine played an important part, and the work was removed from workers' homes to the factory. Original equipment was designed, the first successful machinery of its type ever developed.

The Industry

Through the mid-1970s the textile and clothing industries suffered from declining markets and a rising share being taken by imported garments from overseas low-cost producers. The particular sector in which this study was carried out is the manufacture of lingerie.

The market for women's underwear is supplied from two distinct sources. The major manufacturers, which include both the trademarks of garment companies, and the main department store chains, selling their own brand products, provide most lingerie sold in the U.K. However, a significant share of the market is captured by a large number of small firms which produce un-branded garments at lower cost for limited local distribution through fashion boutiques and market-place stalls.

These latter firms, often operating from small premises and relying heavily on home-based workers,

Brassiere Manufacture

Brassieres are assembled from a variety of components which include bias-binding, straps, hook-and-eye fasteners, slides and stiffeners. These items are usually manufactured individually within the group by various techniques. Bias-binding is basic to many of the components and is produced by cutting nylon fabric at an angle across the warp and weft (similar to the process outlined earlier for rubberised fabric in case study 6.3), to give it greater strength.

The factory investigated was making several components from bias-binding, including that of particular concern for this case study, the brassiere shoulder strap. Rolls of bias-binding are sliced in cross-section by a blade. This cuts it into a large number of smaller rolls which, when unreeled, provide a strip of material for the straps.

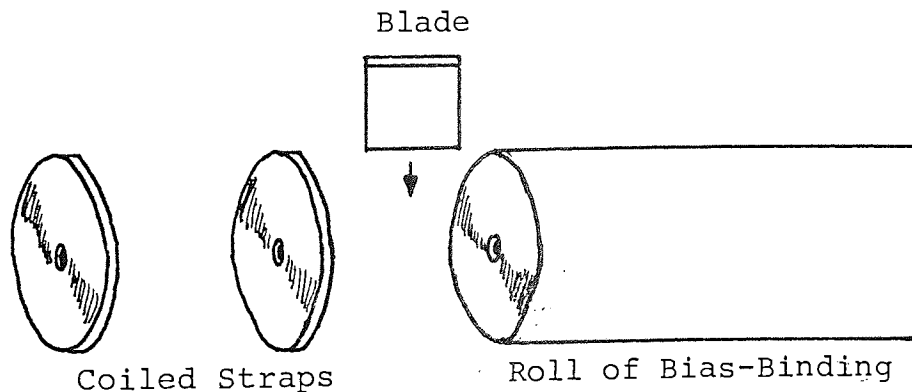


FIG.7.4 : CUTTING OF STRAP MATERIAL

The strap material is cut to the appropriate length, and the straps have a slide and a ring put on. The slide is securely fastened by doubling over the protruding end of the strap and sewing it down, thus holding the slide inside a loop.

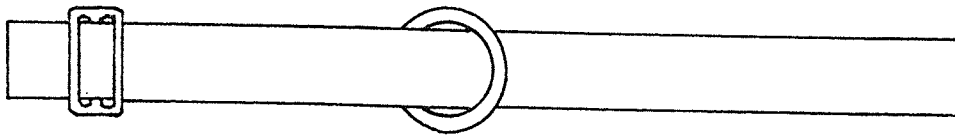


FIG. 7.5 : STRAP WITH RING AND SLIDE

Old Method - Manual Slide Attachment

After the straps are cut, batches of them are sent to out-workers, along with boxes of rings and slides. They must then thread the ring onto the strap, and accurately position the slide half an inch from one end. When each strap has been arranged in this way, they are returned in bundles of 60 to the factory.

There, a manually operated machine folds the half-inch ends over and stitches them down to hold the slide in position. With the slides thus attached, the straps are returned to the outworkers who then thread the slides through the spare end. This holds the ring inside a loop, and completes the brassiere shoulder strap. It then goes with the other components (cups, back-straps, etc) for assembly

into the finished garment. If their consumption rose

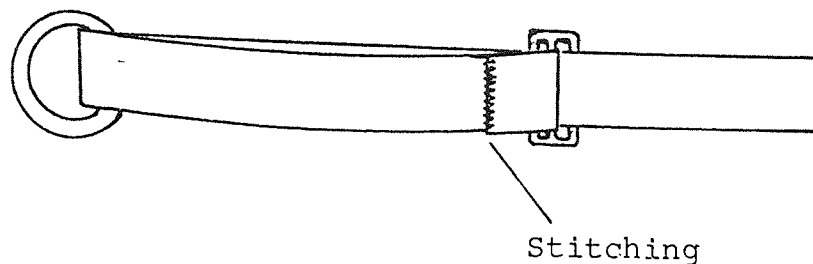


FIG. 7.6 : FINISHED STRAP

Motivation to Change

The main reason why mechanization of the operation was desired was that labour costs were seen by the firm's management to be rising faster than capital costs, and had reached the point where labour reduction became economically desirable.

A problem was also evident in the consistency of the work produced by the old method. Different out-workers varied in the accuracy of positioning, and the manually-controlled sewing of the tab also exhibited undesirable variation. The main buyer of the straps enforced strict standards on positioning, length of the end sewn down, and other parameters. A reduction in raw materials consumption was also thought possible through finer tolerances achievable by increased machine work.

Lastly, a rise in output would be desirable. Although there was no increase in the overall market for the product, the firm aimed to improve its market share. This might permit raw materials to

be purchased more cheaply, if their consumption rose significantly.

Development

The history of attempts to mechanize this operation commenced in a decision in 1960 by a company, which later became a member of the present group, that automatic brassiere strap production was feasible. Initial rotary machines were slow and relied on high-frequency radio welding of the material rather than sewing. Changing demand, however, made elastic shoulder straps the norm in the late 1960s, and since these are not amenable to high-frequency welding, no further progress was made.

Attempts to automate the threading of the ring and slide only, with the sewing done by conventional methods, were technically successful but not always economically appropriate. It was subsequently decided to try to integrate threading and sewing on one machine, and initial versions put into test production were not successful, due to unreliability.

Development work on the prototype which provided the eventual solution took two years, and was performed at the group's central engineering laboratory for the firm concerned. It was simpler in concept than some of the earlier attempts, and on its first batch run in the development workshop achieved 98% acceptance quality on a total of 3,000 straps.

The original machine was then installed in the factory for in situ testing, and the necessity for a number of modifications became apparent from this experience.

When the design was finalised, a further three machines were built at the development workshop and sold to the subsidiary firm for £7,300 each. Since the group effectively subsidises research and development for its member firms, the figure does not reflect these costs. Between 20 and 30 machines are expected to be bought eventually.

New Method - Mechanical Slide Attachment

Ancillary equipment has been built around a conventional industrial sewing machine. The slides are stacked in a special rack and descend to meet the incoming straps which move horizontally across a workbench towards the sewing machine's needle. One slide is matched to each strap, and a moving rod pushes the end of the strap through the two slots in the slide, so threading it. The end is then folded over and it passes under the needle where it is sewn down automatically.

The strap now has its slide sewn in place, and still requires to have the ring put on and the slide threaded, so that it conforms to the finished form illustrated earlier. For this last operation, it must go to out-workers.

Comparison of Old and New Methods in electricity

The basic difference between the two methods is that one of the two journeys which the straps made to out-workers in the old method is eliminated, because the threading of the slide is now done mechanically. Putting the ring on, and the final strap threading to secure it, is still performed by out workers.

Capital Equipment. A similar sewing machine is used in both cases, except that additional equipment, designed by the group's research department, is attached to it in the new method. This extra machinery threads the slides onto the tapes prior to sewing. Flexibility is reduced, because just a single strap width can now be accommodated.

Labour. No displacement of internal labour resulted from the innovation, but the requirement for out-workers is reduced by about a half. Maintenance labour requirements are increased to a small degree. One operator is on each sewing machine in both methods, but this may be reduced later in the new system.

Raw Materials. There is no change to the basic components of the strap; a tape of bias-binding, a plastic-coated metal ring, and a similar slide.

Energy. There is a small increase in electricity consumption on the new machines, but it is a small proportion of total costs.

Space. The new equipment takes up more space, and poses some problems in this small factory.

Output. The old method produces one strap per 17.3 seconds, whereas in the new, this is theoretically reduced to 5.3 seconds at best. The practical operating rate, however, is likely to be around 10 seconds.

The quality of the product is affected in two contrary ways. Firstly, a different pattern of sewing in the new technique (zig-zig rather than linear) produces a more secure fastening of the slide. However, because the new machine will accept sub-standard tape which is curved or twisted, this may be made up into straps automatically and have to be rejected later. This was less likely on the old method, where the out-worker could reject curved tape when performing the first threading operation.

Work Organisation. This is substantially altered, in that about one half of the out-worker's manual tasks are mechanized. Within the factory, the sewing machines require supervision in both techniques.

Management. The firm has a high ratio of management to direct workers (only about 50% of total staff work directly on production). This is because the most labour intensive operations are carried out in the homes of out-workers, and because a substantial administrative staff is required to co-ordinate their work, delivery and collection. This is likely to change as dependence on out-workers decreases.

Implementation

The working prototype machine was installed in the factory for production evaluation, but this did not proceed as anticipated. The development workshop handed it over to the firm for three months, with the expectation that 400 hours of working time would be logged. When it was returned after the trial period, with assurances that it had functioned well and been extensively used, an internal clock which had been surreptitiously installed, showed less than 70 hours elapsed. This was insufficient to evaluate properly the operation of the machine in factory conditions, and it transpired that the firm was short of maintenance resources and unable to rectify faults quickly.

The firm's management were confronted with the information and they agreed that the first trial was inadequate. Delayed testing resulted in the loss of a 25% Department of Industry grant under a product

and process development scheme. WORLD OF MECHANICAL
ENGINEERING

The altered sewing pattern of the new machine (in zig-zag form) meant that the main buyer had to accept and approve the change. Although the new design was stronger, the producing firm was somewhat reluctant to accept it because of the difficulty of persuading the buyer to modify the standards.

The change was also thought to endanger the secrecy surrounding the innovation. It was closely guarded because it was a technical breakthrough which had been unsuccessfully attempted by the group's competitors, and the new sewing pattern was the only clue that a new production process was being used.

Conclusions on Brassiere Strap Manufacture

This innovation represents, as noted, the solution of a long-standing mechanization problem in the industry, whose development and implementation was a closely kept secret.

Productivity has been raised and production time reduced by the elimination of part of the convoluted old process of sending straps in small batches to out-workers, having them returned to the factory for sewing, and then sent again to the out-workers for final threading.

TABLE 7.7 : ADVANTAGES AND DISADVANTAGES OF MECHANICAL WITH RESPECT TO MANUAL SLIDE THREADING OF BRASSIERE STRAPS

ADVANTAGES

1. Labour force reduction
2. Labour productivity increased
3. Quality improved

DISADVANTAGES

1. Production flexibility decreased
2. Product standards changed
3. Maintenance requirement increased

An improvement in the quality of the product is achieved, but it does have a concomitant disadvantageous effect, in that any alteration in the nature of the product requires clearance from the buyer, stimulates curiosity, and endangers the secrecy of the innovation.

The initial obstacles to implementing the new technique were found to come from the management of the innovating firm, which misled the development workshop, inadequately evaluated the machine in tests, provided insufficient maintenance, and thereby lost a production innovation subsidy for which they had applied.

Chapter Eight

ANALYSIS OF CASE STUDIES

The foregoing nine case studies, though of interest for the particular circumstances under which the innovations occurred, contribute little in isolation to the wider debate on technical change unless projections and generalisations can be made from them.

The section following, therefore, contains a comparison of the main points analysed for each of the case studies. The significance of the aspects covered in this presentation of results is discussed at more length in the subsequent chapter on the broader issues relating to technical innovation in industrial production.

Three main categories of factors are considered, and contrasted between the case studies; the inputs

to the production process, aspects of the output, and a selection of ancillary variables which changed with the innovations. Throughout these sections refer to Table 8.1.

8.1 CHANGES IN FACTOR INPUTS

The principal inputs to the production process, known as the factors of production, are capital, labour, raw materials, energy and space.

Capital Equipment. Alteration in the stock of capital equipment employed in the new production techniques was found in all of the innovations. Sometimes capital equipment was dispensed with, as in rubber extrusion, which lost the warming mills, and in the confectionery example, where the new technique resulted in a net reduction in the physical volume of capital because just one plant, though more technically advanced, replaced two slower old ones.

In others, there was a substantial increase in capital, particularly where much manual work was eliminated, as would be intuitively expected; in cover painting, tyre trimming, and panel pressing.

Without exception, however, all the examples exhibited increasing complexity in the capital equipment used.

TABLE 8.1 : COMPARISON OF INNOVATION CASE STUDIES

	6.2 Rubber Extrusion	6.3 Ply Batching	6.4 Cover Painting	6.5 Cover Moulding	6.6 Tyre Trimming	7.1 Battery Cases	7.2 Confectionery Centres	7.3 Panel Pressing	7.4 Garment Components
<u>Factor Inputs</u>									
Capital Saving	x						x		
Labour Saving	x		x	x	x	x	x	x	x
Material Saving				x		x			
Energy Saving	x			x		x			
Space Saving	x	x				x	x		
<u>Output</u>									
Product Change						x			
Size Limitation	x				x		x		x
Quality Improvement			x			x	x	x	x
Volume Increase		x		x	x		x	x	x
<u>Other Variables</u>									
Process Stages Reduction	x			x		x	x		x
Labour Productivity Increase	x	x	x	x	x	x	x	x	x
Manual Effort Reduction	x	x	x	x	x	x	x	x	x
Safety Improvement	x		x			x	x	x	
Maintenance Cost Increase	x	x	x	x	x	x	x	x	x
Managerial Control Increase			x		x	x	x		x

TABLE 8.2 : CHANGES IN NET STOCK OF CAPITAL WITH
TECHNICAL INNOVATION

Case Study	Change in Net Capital Stock
6.2 Rubber Extrusion	-
6.3 Ply Batching	+
6.4 Cover Painting	+
6.5 Cover Moulding	+
6.6 Tyre Trimming	+
7.1 Battery Cases	+
7.2 Confectionery Centres	-
7.3 Panel Pressing	+
7.4 Garment Components	+

Labour. The majority of new techniques (eight of the nine) resulted in a reduction in the total labour employed. There are difficulties in defining the exact numbers of workers which are to be allocated to a particular process in a factory, because some have rotating duties which take them to various production locations at different times (e.g. maintenance, some service and indirect workers), and the distinction between direct and indirect workers is also sometimes unclear. However, the following table gives an indication of the ratio of labour reduction (maintenance excluded) exhibited by each case study.

TABLE 8.3 : CHANGES IN LABOUR WITH TECHNICAL INNOVATION

Case Study	Production Labour Ratio L(new)/L(old)
6.2 Rubber Extrusion	0.3
6.3 Ply Batching	1
6.4 Cover Painting	0.6
6.5 Cover Moulding	0.8
6.6 Tyre Trimming	0.7
7.1 Battery Cases	0.1
7.2 Confectionery Centres	0.6
7.3 Panel Pressing	0.3
7.4 Garment Components	0.7*

* Estimated combination of factory employees and out-workers.

Just one innovation caused no labour loss; in the batching of rubberised fabric plies the single operator on the old machines was retained on the modified batchers of the new method.

Two showed labour reductions to 30% of the former level, but more than half of the case studies (five out of nine) were in the range 60% to 80%.

Raw Materials. A point of definition requiring to be clarified is that the 'raw material' of one process is sometimes the output from another. This is particularly well illustrated in the rubber case studies. Painted green covers, the products of the Ilmberger

painting machine, go directly to the tyre moulders, where they become in effect material input.

Only in two innovations were net savings in material input achieved. The new tyre moulding operations, although able to accept identical tyre sizes, do not consume curing bags like the old method. The equivalent cost in the new method was just 13% of the old so a substantial net saving resulted. Injection moulding of battery cases, using a totally different raw material than bitumen-asbestos moulding, reduced these costs to one fifth of the former.

In three cases (cover painting, ply batching, panel pressing, garment component assembly) there was no difference in the raw materials between the old and new production methods, except that in ply batching the new machine is able to accept longer rolls of fabric, which is an advantage.

The remaining changes in raw materials occasioned by the innovations were disadvantageous - some limitations in the type of raw rubber accepted by the cold feed extruder, a size limit on the auto-feed tyre trimmer, and much greater control of ingredients required in the confectionery jelly mix (although some costly items were also saved).

Energy. The consumption of energy shows a distinct trend to increase where mechanization of formerly manual tasks has taken place (ply batching, green cover painting, confectionery centres, panel pressing

and garment component assembly). . . . the above,

Energy was saved, however, in tyre moulding because the old machines were inefficient and lost much heat during curing, and to a slight degree in rubber extrusion where energy-intensive parts of the old process are eliminated. In the most radical innovation, the new injection moulding technique for battery cases saved energy over the old method.

Space. No clear correlation emerges of changing floor space with technical innovation, although space economy is more common than the converse. Four new techniques required less factory area, three were approximately similar to the old, and two needed an increase.

The greatest saving came in battery case manufacture, where the reduction to one quarter of the former area was probably assisted by a complete re-design on the new site. Other economies were yielded in rubber extrusion, where the warming mills are dispensed with; in ply batching, where the operator's work area is curtailed; and in chocolate bar manufacture, where one modern plant replaces two old.

Increases in the space required were evident in green cover moulding and in the clothing factory, where ancillary mechanization adds to the physical extent of the equipment.

It seems probable and is borne out by the above, that incremental technical change is more likely to add to space requirements than is the wholesale introduction of newly-designed equipment. The exceptions would be those cases where work layout is currently inefficient, and space can be saved simply by re-organisation, as in ply batching.

8.2 CHANGES IN OUTPUT

A number of aspects of the output from the production process can be identified. The most important of these are its nature (i.e. the type of product), the dimensions able to be produced (where these vary from batch to batch), quality, and the rate of production.

Nature of Output. This factor was virtually identical for eight of the nine innovations studied; that is, there was no product innovation associated with the innovation in production technique. In the single exception, battery case manufacture, the product was re-designed and composed of quite different materials, but its utility is essentially the same as the old.

Some of the other new processes did require minor changes in the product (different rubber for cold feed extrusion, changed confectionery recipe), but the difference is not significant.

Size of Output. A number of innovations exhibited some limitation in the dimensions of the product which they could cope with. The new rubber extrusion process imposed a tighter constraint on the dimensions of the extrudate; the auto-feed tyre trimmer could not handle larger tyres, which still required to be manually trimmed; the flexibility to alter the size of confectionery centre afforded by the old starch tray method was lost in the innovation; and the brassiere strap machine was unable to cope with larger widths.

Quality of Output. Five of the innovations yielded definite gains in the quality of the output, and in some cases this was a major motivation for the change (cover painting, battery cases and confectionery centres). In car body panel pressing, improved quality appeared as a desirable side-effect, but in the sole case of brassiere strap manufacture, the improvement in quality of stitching was felt to be disadvantageous in some respects, by endangering the secrecy of the new process and requiring agreement to be reached with the buyer over altering what was an already acceptable standard.

None of the innovations resulted in declining quality, and the general trend is quite definitely towards improvement.

Rate of Output. In six of the innovations an increase in the rate of output was achieved in practice. This was desired in a number of cases because a market already existed for a higher level of production. Thus other car assembly factories within the same group of companies took all of the press shop's almost doubled output of body panels; retail demand for the confection increased, as did wholesale demand for the brassiere straps; and the tyre trimming was required to handle the output of more tyre moulding departments than before, so its throughput rose. In the remaining case of increased output rate, tyre moulding, fewer machines replaced the old and total capacity therefore remained similar.

In two innovations, the potential output level of the old and new systems was the same - for battery case manufacture, intentionally so to meet a static market, and for green cover painting. This latter was down in practice, though, because of a slow rate of tyre production earlier in the process.

Only one of the new production techniques showed a decline in the rate of output, of 3% for rubber extrusion, caused by the fact that the cold feed rubber requires more working to come into a pliable condition for extrusion. The following table gives an indication of level of output increase in each case.

TABLE 8.4 : CHANGES IN OUTPUT RATE WITH TECHNICAL INNOVATION

Case Study	Output Ratio Q(new)/Q(old)
6.2 Rubber Extrusion	0.97
6.3 Ply Batching	1.14
6.4 Cover Painting	1 *
6.5 Cover Moulding	1.33
6.6 Tyre Trimming	1.53
7.1 Battery Cases	1
7.2 Confectionery Centres	1.19
7.3 Panel Pressing	1.83
7.4 Garment Components	1.72*

* Theoretical ratio: in 6.4 the ratio 0.8 was achieved in practice because of under-utilisation; in 7.4 the production system had not yet reached its designed output rate.

8.3 CHANGES IN OTHER VARIABLES

A number of ancillary variables were found to exhibit changes which occurred when the innovations were implemented.

Process Stages. Some of the innovations have reduced the number of stages through which the product goes in the course of manufacture.

In rubber extrusion, the warming mills of the old method are dispensed with because the new extruder can accept cold raw material. The new

technique for the moulding of green covers eliminates the vacuum box stage, which was necessary to implant the curing bag. For battery case manufacture, the mixing of compound ingredients becomes unnecessary, since the new method has just one raw material. The new continuous process for confectionery centre moulding dispenses with the lengthy storage stage in setting. Finally, in brassiere strap assembly, one journey to and from the out-workers is removed.

In all of these examples, the process has, in effect, been streamlined. Certain procedures in manufacture are totally eliminated, not merely transformed. The effect is illustrated by a substantial reduction in the processing time for some of the innovations - battery case moulding to one eighth of the old time, tyre moulding cure time down by more than 20%, and confectionery jelly setting to a tenth or less of the former period.

Labour Productivity. This parameter is obtained by dividing the rate of output by the number of production workers in a process, and yields a measure of the efficiency by which labour input is transformed into output. The units of measurement (output per worker per unit time) will obviously vary with the product, but a useful comparison of the productivity gains realised by the different innovations is afforded by deriving a ratio of new to old labour productivities for each case study.

TABLE 8.5 : CHANGES IN LABOUR PRODUCTIVITY WITH
TECHNICAL INNOVATION

Case Study	Labour Productivity Ratio LProd(new)/LProd(old)
6.2 Rubber Extrusion	2.9
6.3 Ply Batching	1.1
6.4 Cover Painting	1.6*
6.5 Cover Moulding	1.7
6.6 Tyre Trimming	2.3
7.1 Battery Cases	6.7
7.2 Confectionery Centres	1.9
7.3 Panel Pressing	6.0
7.4 Garment Components	n.a.†

* Theoretical ratio. 1.3 was achieved in practice because of under-utilisation.

† Not available because of difficulty of finding an equivalence of factory personnel and out-workers.

Manual Effort. This aspect is seen to be reduced in every innovation, through two main causes. Firstly, process streamlining has eliminated manual operations associated with the warming mills in the old rubber extrusion technique. Straightforward mechanization is the largest single reason, in five cases (6.3, 6.4, 6.6, 7.3, 7.4). A combination of the two is in addition exhibited by tyre moulding, confectionery centres and battery cases.

Health and Safety. It is significant that over half of the innovations (five) have resulted in ostensibly safer processes, and a further three have reduced potentially stressful manual labour. In one instance, battery case manufacture, safety was one of the prime motives for change, and was re-inforced as such when one of the former ingredients became legally proscribed as a health hazard.

Although it is often difficult to assess the potential dangers posed by new production systems, especially when working experience is limited, the evidence does suggest a trend towards safer and less stressful working environments.

Maintenance. An increase in the cost of maintenance was evident in every innovation studied. This is despite improved equipment reliability in some of the new processes over the old. For example, although the new tyre moulders are more reliable than the antiquated ones which they replaced, their greater complexity caused a small (4%) rise in maintenance costs over a three-month period. The new confectionery moulder has a target utilisation rate of 85%, compared with the older system's 60%, but the maintenance crew on each shift is raised from four to five. Similarly, in panel pressing, the utilisation rises by 10%, but more specialised and expensive maintenance is required.

There are two likely explanations. The maintenance on newer machinery is more costly by virtue of the more highly trained staff required, and more expensive components to replace; and fault diagnosis on old equipment with which engineers have had long familiarity is likely to be quicker.

Managerial Control. The extent to which supervisory staff are able to exert control over the production process is clearly increased in five of the innovations.

The number of production points is reduced in cover painting (from five booths to one automatic machine), in tyre trimming (from various tables distributed around the factory to two work stations), and in battery case manufacture (where 60 old moulding presses are replaced by six injection moulders). Production flow is thus more effectively focussed.

In two other instances, confectionery centre moulding and brassiere strap assembly, the elimination of a stage in production which was largely outwith the hands of management (gel setting and the out-worker's rate of production), also contributed to improved control.

8.4 CLASSIFICATION OF INNOVATIONS

The extent to which the new production technique departs from the old method provides a separation of the innovations into three categories.

At one extreme is the replacement of the old system with a new one which was radically different in the way it handled the product: the automatic green cover painting unit replaced a manually assisted method, the semi-manual manufacture of battery cases was displaced by injection moulding, the manual handling of tyres for trimming was mechanized, and the moulding of confectionery jellies in starch trays was superseded by a virtually continuous flow plant.

An intermediate category of innovation can be identified in rubber extrusion, where essentially the same technique is being used, but on new equipment, with a raw material which is similar but in different form (cold rather than warm). Green cover moulding is likewise of this type, using new machines but a slightly different procedure which eliminates the insertion of curing bags.

A final category of less comprehensive innovation can be identified in the three remaining case studies, which all involve piecemeal alterations to existing machinery; in the batching of bias-cut fabric plies, car panel pressing, and brassiere strap assembly, extant machines were modified rather than replaced. The nature of the change is essentially incremental.

In this classification, radical innovation implies a new method which departs substantially from the old, and employs capital equipment which is more than just a development of existing machinery.

TABLE 8.6 : CLASSIFICATION OF INNOVATIONS IN PRODUCTION TECHNIQUES

	Product	Old Technique	New Technique
RADICAL INNOVATION	Battery Cases Jelly Confection Bar Painted Green Covers Trimmed Tyres	Compression Moulding Starch Tray Moulding Semi-Manual Spraying Manual Trimming	Injection Moulding Metal Die Moulding Automatic Paint Sprayer Auto-Feed Trimmer
INTERMEDIATE INNOVATION	Strip Rubber Moulded Tyres	Warm Feed Extrusion Manual Load Press	Cold Feed Extrusion Auto-Load Press
INCREMENTAL INNOVATION	Brassiere Straps Car Body Panels Batched Fabric Plies	Manual Slide Threading Manual Press Loading Table Batching	Mechanical Slide Threading Automatic Press Loading Mechanical Batcher

In intermediate innovation, the same actions are performed on the product; the main difference between old and new is that the latter uses equipment which represents a re-design of the original operation on the same principles (pressure extrusion and steam moulding in the cases quoted).

Incremental innovation has taken place in the final three case studies, because any new equipment bought or designed is essentially ancillary to the main production machine (sewing machine, press, or bias-cutter) upon which the process is ultimately dependent.

At a higher level of generalisation, a distinct element of continuity exists between all of the innovations. In every case, the innovation has not resulted in a change to the basic nature of what is performed on the raw materials to manufacture the product. The rubber is extruded in both cases (it could have been calendered), the brassiere straps are still sewn (ultra-sonic welding is a possibility, depending upon the fabric), the tyres are still trimmed (pip-less manufacture, which does not require trimming, is now feasible), the green covers are still moulded by steam pressure into tyres, and so on. Even in the most radical innovation, the battery cases are moulded in both old and new techniques, despite totally changed materials. In this sense, they are all 'manufacturing innovations', which are defined to be 'new methods of producing an essentially

established product by an essentially established process' (Braun, 1981).

The commonly employed product and process innovation distinction does not properly apply in any of the innovations examined. Though it is most closely approached in the battery case example, where the product design and composition changed, it has exactly the same function and offers no extra facilities.

A final aspect of distinction between the innovations is the extent to which they represent genuine innovation at the 'frontiers' of industrial technology, or whether they are merely technology transfer to the firm from outside. The first four case studies in the rubber industry were of the latter type, where the equipment was simply bought off-the-shelf from a manufacturer and installed.

Two involved a combination of the purchase of outside equipment and its modification to suit individual conditions (panel pressing and battery case moulding). The final three were completely original developments (tyre trimming, confectionery centre moulding, and brassiere strap assembly). The new confectionery process was developed in conjunction with a manufacturer of factory equipment and had never before been achieved, like the new garment machine. The automated press line was the first of its technical sophistication in the U.K., although similar ones existed in Sweden and West Germany.

Chapter Nine

CONCLUSIONS

The foregoing comparisons of the results of nine case studies of technical change highlight a number of alterations which occurred in the various factors relevant to the process of innovation. Although the examples studied cannot claim to be representative of the current state of technical development in British industry, they do illustrate important trends in the general phenomenon, which will have a direct bearing on a wide range of current and future projects in mechanization and automation. By clarifying at the micro-level parts of the innovation process which would otherwise be inaccessible, case studies can explain the significance of results obtained in wider but less detailed analyses.

9.1 THE CONSEQUENCES OF TECHNICAL CHANGE

The main issues for which technical change has important implications are discussed here. They include productivity, employment, skills, effort at work, job satisfaction and the workers' response. Potential future trends in innovation are also considered.

Technical Change and Productivity

In relating the conclusions of the case studies to the economic theory expounded in Chapter 5, a number of corroborating points emerge.

In all but one case, the numerical input of labour to each production process is reduced by the innovation. In that sense, those eight are examples of labour-saving technical change. However, the labour-saving definition is not quite so straightforward; it also embraces situations where the ratio of capital to labour is increased, irrespective of whether the net change in the labour input is positive, negative, or unchanged. This implies that the sole exception to the general rule of labour reduction, ply batching, is also a labour-saving innovation; the single operator remains, the capital equipment stock is increased, and output rises. All nine innovations may therefore be safely categorised as being of the labour-saving type.

Changes in capital stock are also evident. The crude indication given in Table 8.2 shows a predominant increase in the physical volume of capital equipment, with two exceptions. However, in all cases the value of capital has risen, as would be expected with machinery of increasing complexity.

The essentially labour-saving nature of the innovations is further indicated by the changes in labour productivity outlined in Table 8.5. All innovations exhibit increases, of between 10% and 570%. The greatest are in those cases where a totally new process was introduced (battery case manufacture) and where the most extensive mechanization took place (panel pressing).

In more general terms, increased efficiency in the transformation of inputs into outputs is clearly apparent; the labour input has been reduced, output has risen, and labour productivity is increased. All the innovations illustrate advances in industrial production techniques which are biased towards the substitution of capital for labour.

Technical Change and Employment

This issue has long been central to the debate on the effects of mechanization and automation in industrial production methods, with both unemployment and job-creation argued to be among the consequences.

In the case studies, the largest reduction in labour, to just one tenth of the old figure occurred in battery case manufacture. It is significant that this was the only example which combined changes in product construction, a very significant technical advance in the production method, and more importantly, an alternative production location. A new factory was built and manning levels established from a position of neutrality, in that no precedent was available from which negotiations could proceed. The labour level is thus more likely to reflect accurately the requirements of the technique than in some of the other cases, where management continued to press for further reductions after the introduction (green cover painting, car panel pressing, garment component assembly).

The other two large reductions (to 30% of the former level) occurred in rubber extrusion, where a large part of the old process was totally eliminated, and in car panel pressing, where extensive mechanization was introduced.

Over half of the cases show labour reductions to between 60% and 80% of the former level. The constant theme among them is that they all involve the straightforward mechanization of formerly manual tasks - loading and unloading of green covers for painting and moulding, manual handling of tyres to the trimming tables and trays of confectionery centres to the setting rooms, and the threading of slides

onto the brassiere straps. *innovation in garment*

Any labour loss, however, is not always reflected in the firm's net staffing. In the rubber industry studies (6.2 to 6.6) the factory in question had its total work force decline by 25% in the eight years preceding the investigation, so it is likely that the displaced labour was genuinely lost to the company. The same is true of the confectionery firm, where a two-year redundancy programme for the innovation was part of a wider strategy which implemented a 50% cut in factory personnel since the early 1960s.

In the pressed steel factory, no redundancy was implemented despite a 70% labour loss to the new press line and those introduced subsequently. This is explained by the fact that the firm had to increase output to supply panels for an important new model of car. Total plant employment was actually envisaged to increase by 19% as part of a company re-organisation plan. The displaced workers were therefore re-distributed to other more labour-intensive functions within the factory.

A West German textile firm investigated found themselves in an expanding market. They were able to introduce a new type of shuttle-less loom which ran faster than the old, and so achieve an increase in output to 2.3 times the former level without redundancy. This was despite the high labour costs prevalent.

The labour effects of the innovation in garment component manufacture were unequivocal and immediate; half of the out-workers lost employment, for reasons discussed later in the section on workers' response.

Just one departure from the general trend of labour reduction (or in the case of ply batching, a static level) was found. Not examined in enough detail to form an individual case study, a small firm in the metal-working industry instituted a number of labour-increasing changes in its production techniques. Working with high-value materials, such as copper, all of this company's major economies in production over a 10-year period had come through attempts to save on the consumption of raw materials, to which labour costs were subservient. It is significant, though, that this exceptional case occurred in an area of traditionally low labour costs.

The allocation of maintenance labour to the production process was increased in every case but one (green cover moulding), where the new machinery was substantially more reliable than the old.

It is apparent that employment reductions associated with specific industrial innovations do not always result in unemployment. Various circumstances peculiar to the firm may cause an internal re-distribution of labour. Critical among those is an increase in the demand for output associated with the innovation; firms in a buoyant market can sometimes adopt the strategy of labour re-deployment as an

alternative to lay-offs. However, the majority of the case studies did exhibit labour loss from the specific manufacturing operations in which the innovations took place.

Technical Change and Skills

The case studies exhibit a varying pattern in the effect of technical change on the skills of the work force. In six of them (four from the rubber industry, painting excepted; confectionery centres; panel pressing) the skill content of tasks, as indicated by wage rate, was virtually unchanged. At most, a more complex control panel had to be operated. The only example to illustrate an increase in production workers' skills was battery case manufacture, where radically new production machinery with a complex control system was installed.

Two showed a decline; the garment component case, where a manual operation of low skill content was eliminated, and green cover painting, the innovation with the most complex effect on skills. The succession of techniques from hand mops, to hand spray guns, to booth spray nozzles, culminating in the Ilmberger painting machine (detailed in case study 6.4), has the effect of progressively downgrading the level of manual skill and judgement required in painting.

Of more significance is the fact that, as skills are progressively eroded from the direct act of

production, they accrue to the subsidiary function of maintenance. Increasing complexity of machinery requires increasing sophistication of maintenance, and therefore of the technical competence of repair and service crews. Greater maintenance skill requirement also emerges in battery case manufacture, where a knowledge of electronics had to be acquired, and in car panel pressing.

These developments have important implications for future trends in maintenance work, where staff with a wider range of skills will be increasingly required as old demarcation lines become irrelevant. This phenomenon is already well established in the more technically advanced industries, such as chemicals production (Bradbury 1970).

It is therefore apparent that technical change can have a selective impact on skills, enhancing those of already skilled personnel, and either downgrading or having little effect on those with minimal expertise. This conclusion is corroborated by a number of other studies, among them Bright (1958a), Braverman (1974) and Isherwood (1978).

The effect may be described as a 'polarisation' of the work force, in which the gap between the lowly skilled direct operatives and the increasingly skilled maintenance workers is slowly widening, and less able to be bridged by training aimed at upgrading staff ability.

Technical Change and Effort at Work

The number of workers employed in a production process does not in itself give a wholly accurate measure of the labour input. One must also make an attempt to assess the 'effort' expended at work, that is, the types, numbers of duties, and how frequently they must be performed in fulfilling the job function. This aspect is particularly significant in the increasingly widespread application of the measured day rate of task evaluation to replace piece-work, or payment by results.

Every single innovation (see Table 8.1) reduced the workers' manual effort, either through the total elimination of certain procedural stages which had a high manual input, or by direct mechanization. It is difficult to illustrate this effect in isolation, particularly where there is a simultaneous reduction in the numbers of workers. However, the best example emerges from ply batching; one worker is employed in both the old and new methods, there is mechanization of the main part of his former task, and output is increased by just 14%. The clear implication is that he is, in effect, simply doing less than before.

In the case of the auto-feed tyre trimmer, output per worker more than doubled, but on the other hand the operator's duties are reduced from lifting tyres on and off tables to trim them, to simply trimming and the operation of a pedal. The reduction in effort

appears greater than the corresponding increase in output. The other innovations exhibit similar effects to different degrees.

Not among the case studies previously documented, a firm in the metal-working industry, where the rate of technical innovation is low but great potential exists even for simple mechanization, the savings from such developments can be many times the initial investment. Company policy, in these instances, is rather than to reduce labour or increase wages as output per worker rises, to reassess the job at a lower rate than that dictated by the theoretically achievable output, so the worker ends up doing less in the same time.

Another similar factory making non-ferrous capillary plumbing fittings found it economical to reduce what is done by the worker, even though he is indispensable. For example, whereas previously a machine operator would load two pieces into a small press, and unload them when finished, now after altering the dies to take three pieces simultaneously, he loads three, but they are automatically ejected. The machine speed remains the same (governed by the cycle time of the press), output rises, but he has less to do - three operations instead of four.

Even where direct production labour is totally dispensed with (the one example being battery case manufacture), an important point is that the machine-minder is usually still required, to control the

operation, monitor and perhaps clear blockages.

The phenomenon of reduced effort inevitably raises the question as to why it occurs. A number of possible reasons can be identified.

Human capacity, both physical and mental, dictates that the speed, complexity, or physical force required for some industrial processes are beyond the abilities of some or all of the workforce. Where there is a human link in a production system there will be some operating rate with which a worker cannot keep pace. It is likely to be expedient to have a machine take over the task well before this limit is reached. In the chemical industry, for instance, workers are required to monitor the production of ethylene, but this involves so many variables and such rapid rates of testing that direct human supervision is not possible. A computer mediates between the process and the human controller.

Health and safety reasons may dictate a reduction in worker effort, although many of industry's heavy manual tasks have already been mechanised and this aspect is now less relevant than in the past.

Control over the work process is often improved by reducing worker intervention, because the greater the extent to which a system is dependent on human effort for its output, the more vulnerable it is to human variability (innate ability, tiredness, boredom, and strain). So there may be an economic motive to eliminate this variation, assuming technology

can supply a sufficiently reliable alternative.

Co-operation from the work force may be secured by diverting to them some of the benefits of technical improvements in production, in the form of reduced work effort. The cost savings realised by a new technique may enable management to afford such reductions in work rates, to ensure compliance with the new procedures. This phenomenon is also identified by others, as in Weinstein (1965, pxi).

The concept of effort at work is rarely touched upon in the literature, but Goldthorpe (1966) does recognise its importance for his special category of workers whose attitude to work is described as 'instrumental', that is, for purely personal gain. The factory investigated had few industrial disputes, but where they did exist, they tended to concern "matters immediately relevant to the 'effort bargain'." (p238).

Touraine (1965) describes the situation where effort at work is to a large extent in the hands of the labour force, and the phenomenon of restriction of output, or 'idling', manifests itself. The managerial motive for eliminating such a possibility is clear.

Technical Change and Satisfaction at Work

This aspect is difficult to evaluate from the case studies, being largely a subjective matter for the individuals concerned. However, insofar as the state of industrial relations is an indicator of employee satisfaction, contact with supervisors is variously said to contribute to improved relations (Woodward 1958) and to militate against it (Goldthorpe 1966). In the innovations studied, the almost universal reduction in staffing, with little or no change in the allocation of foremen, is likely to mean an increase in such contacts.

Any detailed analysis of job satisfaction, alienation and related topics is also inhibited by the fact that the bulk of the case studies concern batch production technology, and the most common correlations of experience of work are with changing production technique - unit, batch, mass and process, as in Blauner (1964) and the others cited in Chapter 3.

Work groups, seen by Woodward, Sayles (1958), and the socio-technical systems theorists as being important to job satisfaction, are reduced in membership by most of the innovations, but they rarely inhibit the ability of the workers to interact. Only in tyre trimming does the new technique result in the operator being more closely tied to a work station.

In the light of the difficulties, and the contrary indications of previous research, the question of changing job satisfaction with technical innovation must remain open, except perhaps where the skill of maintenance workers is increased and so enhances their job.

Workers' Response to Technical Change

Effective modification of management's plans for technical innovation are clearly indicated in two case studies.

Firstly, in the painting of green covers, the current manning level of four on the new Ilmberger machine is more than planned, and the firm was continuing negotiations to reduce this to three.

Secondly, the most concerted union influence on the pattern of innovation is seen in the car industry study. The introduction of the new press line was the subject of much controversy, as the 1½ year catalogue of negotiations illustrates. Direct workers initially found the change unacceptable, and factory stoppages followed a management decision to introduce the innovation despite having no firm agreement. Gang size was, as with the Ilmberger cover painter, a central issue, and the eventual solution included an insistence on double manning, which was ultimately adopted. The important point, however, is that management could afford to concede

this diseconomy because of the high overall gain from the innovation (output per worker rose six-fold). This corresponds with Woodward's (1965) findings, where a higher value of output implies more scope for flexibility in bargaining with unions, though in that instance it concerned a process production technique.

The importance of union acceptance is further illustrated by the case of another press factory within this group, where swing arm unloaders of the type described were installed on presses without agreement, and had never been used in production when the factory was closed down six years later. The unloading had continued to be done manually, and the labour-saving device was simply ignored.

Perhaps the most striking aspect of the innovation in the press shop was the response of the skilled workers. Their four unions agreed to the plan within four months, and thereafter provided steady co-operation, despite opposition from the direct workers. This even extended to performing some tasks which should properly have been allocated to the machine operators. It provides a clear instance of worker response differing between skill levels, similar to Wedderburn (1972).

Workforce resistance was again evident in the confectionery firm. It is one of a number of Quaker-founded companies which have a long history of progressive attitudes to their employees and some of the best industrial relations records in the U.K.

However, the new process resulted in one of its most serious industrial disputes, in which work was temporarily halted.

At a glass factory, not included here as a full case study, union response even extended to issues outwith the factory and their members' direct interest. They opposed natural wastage as a means of achieving labour reductions on the grounds that not to replace retired workers would have a detrimental effect on the local labour market, which was unacceptable to them. It would also, of course, decrease their membership.

The literature also cites examples of union opposition delaying technical innovation. Bhattacharyya (1976) has found shop-floor resistance postponing for up to two years the introduction of numerically controlled machine tools. However, it is the threat to full employment which is the central demand in trade union response to technical change (Mortimer 1971).

The union reaction to the greatest change in labour between old and new methods was co-operative. Although the new battery case manufacturing technique employs just 10% of the old, no redundancy took place, and the elimination of the hazard posed by blue asbestos in the old method was a major factor in securing full agreement.

A special group of workers was particularly badly hit in the garment industry case study, where

fully half of the out-workers lost their jobs as a direct result of the innovation. They were able to offer no effective opposition. This type of employment is not typical of the U.K. labour market, although other industries do use out-workers (for instance, in fireworks and chamois leather manufacture). They are mainly women working in their own homes, are not collectively organised, and were therefore in no position to resist the change. They were also in all probability reluctant to protest, since this would draw attention to their earnings, which were (it is strongly suspected) often not declared for income tax.

Workers' response to technical change is thus seen to exhibit variation with their collective strength, the skill levels of different groups within the workforce, and the acceptability or otherwise of the different methods of labour reduction; natural wastage, re-deployment, and redundancy.

Implications for Future Technical Change

Opportunities are readily apparent for the more widespread application of several of the innovations. The new confection moulding machine is the first of its type, and can be used not just for the chocolate-coated bars in the case described, but for other varieties of bars and small chocolate-box confections. Most of the rubber industry innovations are likely

to replace the older techniques, although both old and new will exist side-by-side for a period. The garment industry development has immediate application elsewhere in the company and the wider industry, but attempts to limit the new technique to the originating firm will continue at least in the short term, in order to maintain competitive advantage.

In panel pressing, the new mechanized press line can be seen as part of a broader strategy in which it will be introduced in other press plants of the group. In fact, its inception and internal diffusion within the company is linked in a co-ordinated way to the new car model's introduction.

It is apparent that even quite simple mechanization, as in the case of ply batching, can result in significant productivity yields (14% in that instance), and other obvious potential developments can be envisaged for many of the processes. In fact, a number of the innovations, the last included, were seen by management to prepare the way for future mechanization and automation. The new confectionery technique, for instance, by producing the jellies at a predictable rate and in a regular pattern of distribution on the conveyor, will enable packaging to be automated at a later date, and in brassiere strap assembly it should not be difficult to mechanize the tasks performed by the remaining out-workers, that of threading rings onto the straps.

In the tyre industry cases, possible extensions of the new techniques which present themselves include the full automation of tyre trimming with mechanically-operated blades, and the automatic conveyance of green covers from the painting machine (from which they are currently manually collected) to the moulding press.

In view of the large increases in productivity realised in the case studies, it seems likely that similarly large gains wait to be achieved by relatively 'conventional' technical improvements, falling far behind the frontiers of manufacturing technology epitomised by microelectronics and industrial robots.

However, some precedents point to the need for a careful examination of each case, and it cannot simply be assumed that these potential developments ought to be undertaken.

In tyre trimming, a fully automatic device was developed and put into production, but its technical complexity made it unacceptably prone to break-downs and so it was abandoned in favour of the less sophisticated machine ultimately employed. Similarly, some of the prototype brassiere strap machines were over-ambitious in the extent of automation attempted, and were unsuccessful.

Not included among the detailed case studies, the engineering development department of a metal-working firm wanted to employ a microprocessor controlled sensing device for the inspection of the

components it produced, but found it too expensive. The costs of this particular step towards automated production were seen to be rising quicker than labour costs, and the operation remained a manual one. However, that industry, made up of a large number of small companies, was seen by two of its firms to have very wide scope for simpler advances. The level of industrial techniques in the average small tool-room is perhaps 50 years old, and the type of technical change presently occurring (the elimination of redundant travel in moving parts and piecemeal mechanization) has often already been carried out in similar operations in industries where resources of finance and manpower are greater.

A variety of factors therefore inhibit the full-scale application of technically feasible and potentially beneficial developments.

8.2 CONSTELLATION THEORY

A fuller understanding of the overall context of the case study results is achieved if technical innovation can be seen as an integrated process, from the inception of the idea through to its various consequences.

One framework in which to set the multiplicity of phenomena associated with technical change is known as 'constellation theory' (Braun 1981), and it identifies four phases in the process. At each stage

a variety of possible conditions and options chart the course of a new technique's introduction.

The scenario commences with a zeroth phase, the environment providing the background against which the innovation takes place. It includes the industry, the firm and its market position. The following first phase (it is the first stage in which actions occur) is the identification of one or more weak links, or deficiencies in the existing process, which represent the motives for change. The second phase involves the selection of a possible solution to the problem posed by the weak links, and normally a variety of options will be available to the decision-makers. Lastly, the third phase concerns the implementation of the chosen solution, and the process by which this is achieved. A number of key 'actors' are present to mobilise events at each phase.

The environment in which the innovation was conceived (zeroth phase) had a clear influence in most of the case studies. Pressures external to the pressed steel factory (although from within the same group) associated with the new car model to be introduced, required a greatly increased output of body panels; rising demand for the garment components and the confection encouraged technical innovation to increase output; and the highly competitive and declining market for tyres prompted mechanization to reduce costs in the five rubber industry case studies.

Where a firm finds itself in conditions of rising demand, labour-saving technical change is a particularly attractive option to management. This is because the increase in labour productivity which it invariably entails can be used to raise output, rather than reduce labour, which is often difficult or expensive to accomplish.

It is significant that all the examples were either in large companies or in small ones which were part of a much larger group. This meant that considerable technical resources were available to facilitate mechanization and automation, rather than the alternative of a simple change in production capacity at a static level of technology.

Identifiable weak links in the old production techniques include poor quality (cover painting, confectionery manufacture), inadequate process control (confectionery, garment components), unsafe or unhealthy working conditions (tyre painting, battery cases, confectionery), energy wastage (green cover moulding), and an excessively high input of manual labour (trimming, ply batching, cover painting).

In the solution phase a variety of approaches were adopted, including the outright buying of commercially available plant (extrusion, cover painting), similar such purchases but with the company's own modifications (battery cases, panel pressing), and internal development of original equipment (garment components, panel pressing,

tyre trimming). Other strategies in this phase included a new factory for the battery case plant.

Lastly, implementation was both inhibited and facilitated by different factors in each case. Union opposition resulted in enlarged work crews (cover painting, panel pressing), and management resistance (or lethargy) meant that a government grant was lost to the garment component firm. Technical barriers forced the abandonment of attempted innovations in garment components and tyre trimming. On the other hand, union co-operation assisted the shift to the new battery case plant because of its health improvement, and the attitude of skilled workers helped overcome opposition to the new press line.

It is only with the right combination of identifying the weak links, finding an appropriate solution, and then steering it through a pattern of obstacles and facilitators, that any potential innovation in manufacturing techniques is able to be realised as a working production system; it requires a constellation of circumstances to be in the correct inter-relationship for the process, occurring within and influenced by the external environment, to take place.

The importance of the linkage between the phases is not always apparent in innovation studies. They may, for instance, concentrate simply on invention or diffusion as a means to solve technical problems in production, to the neglect of the social aspects

of implementation which are so often equally relevant. Yet other analyses have considered technical change (or 'automation' in its popular image) from the viewpoint of its labour-saving potential, excluding the many other aspects with which it has been demonstrated to have a close association - capital changes, skills, safety, product quality and so on. Only by attempting to consider all the facets of technical innovation is it possible to approach a proper understanding of this complex phenomenon.

APPENDICES

Assessment (TA) is

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Appendix One

TECHNOLOGY ASSESSMENT

Technology assessment affords an interdisciplinary framework for the analysis of problems relating to society's application of technology. A variety of such assessments have been performed, which attempt to evaluate the consequences and implications of specific technologies over a wide range of social, economic and other areas (for examples, see Bowers et al, and Turtle). The approach highlights a number of issues associated with the case study method, which are considered here. These include the problem of ideology as it relates to carrying out technology assessments, and a variety of possible assessment procedures which are advocated by different writers.

The Scope of Technology Assessment

The origin of the term technology assessment (TA) is attributed to a U.S. House of Representatives Committee on Science and Astronautics Report of 1966. Two distinct definitions of TA are identified by the U.S. National Academy of Engineering, (1) Problem-oriented, and (2) Technology-oriented. Thus:

- "(1) Assessments directed to the solution of identified problems of society which are usually amenable to systems analysis for their solution; and
- (2) Assessments to enable society to cope with the unfolding chain of cause-and-effect relationships stemming from a new technology" (N.A.E. 1975, p4)

The latter type is most prominent in the literature, and will be mainly considered here. A more explicit definition of this type of TA is given in a study done for the National Science Foundation:

"'Assessment' refers to the analysis of the potential or actual impact, both beneficial and deleterious, of a proposed, ongoing, or completed technological development, including the analysis of alternative technological possibilities, but not necessarily including the recommendation or taking of action decisions with regard to such analysis". (N.A.E. 1975, p5)

Furthermore, as Kirchmayer points out (1975, p2), TA is more concerned with "second and higher order impacts" (i.e. unintended effects) than with those impacts the technology is actually designed to achieve, and the above NSF contract study adds that these secondary effects include "both positive and negative, both short-term and long-term".

The Methodology of Technology Assessment

One of the most immediately apparent aspects of TA is its lack of a coherent methodological approach, and the interdisciplinary nature of the techniques employed. Thus one of TA's foremost advocates, Emilio Daddario, says, "The method may well vary from case to case" (Kirchmayer, p213) and Walter Hahn's view is that "TA is not just a new procedural algorithm or paradigm only involving an especially trained elite corps ... there is no single TA method or approach to be applied in all cases" (Kirchmayer, pix). Martin Jones, in a survey of thirteen TAs clearly illustrates the ad hoc nature of the techniques involved (1975).

This is perhaps an inevitable result of the enormous range of topics to which TA is intended to be applicable. Coates (1975) justifies this by claiming the TA approach to be holistic, i.e. involving the analysis of a set of effectively self-contained systems, and that since "holistic thinking" cannot be done routinely on a prescribed basis it is essentially, in his words, an "art form", involving inventive and creative elements. This TA art form "must be actively created and framed to fit the individual issue or problem being assessed". The systems approach to analysis in TA is also emphasised elsewhere, e.g. by Thiriet and Sugier - "We must first insist again on this essential point: the

technology assessment concept relies on the systems concept" (p225).

An attempt has been made by Martin Jones (for the M.I.T.R.E. Corporation and the former White House OST) to develop a standardized approach to TA. He proposes a seven-step mechanistic procedure which can accommodate the interdisciplinary nature of the techniques required (1971):

1. Define the assessment task
2. Describe relevant technologies
3. Develop state-of-society assumptions
4. Identify impact areas
5. Make preliminary impact analysis
6. Identify possible action options
7. Complete impact analysis"

Similarly, the American NAE has emphasised the importance of "certain minimum standards" in TAs if they are to be useful (1975, p41).

Some writers see advantages in an iterative procedure in TA, that is, refining the conclusions by repetition of the analysis. Coates (p.97) proposes that, "you do it once to understand the problem; you do it a second time to get it right; and you do it a third time to burnish the results", and a US Senate Committee sees TA as "a purposeful and iterative search for ... the 'total impact' of a technology" (Kirchmayer, p5). But whatever the gains from such a method, some doubt must inevitably be cast on an assessment which may produce different results on successive analyses.

As a last point on the methodology of TA, the NAE identifies an important role for intuition -

"subjective, unprovable comments should be solicited actively and incorporated in complete technology assessments" (Kirchmayer, p93). The place ascribed to intuition in TA is thus very different from that in natural science, in that in TA intuitive judgements are presented as a justifiable part of the results, rather than as solely a means of gaining insight into relationships which are substantiated by research. This again serves to emphasise the lack of a systematic TA approach and must lay it open to criticism on the grounds of method.

Ideology in Technology Assessment

This has emerged as a central problem in TA. For the purposes of clarification three distinct types of bias in TA can be identified: in increasing order of subtlety these are (a) overt clientalism (b) overt (or virtually overt) assumptions about the state of society (c) hidden bias inputed by the socially conditioned nature of knowledge.

(a) Many TAs have been of a type done specifically to the requirements of an interested group, a phenomenon known as "clientalism".

Thus Coates says "the depth scope and reliability of the analysis will be a function of the scope of responsibility of the client" (and also of the technology and the budget (p112)).

Similarly, Turoff and Mitroff write of problems "when the sponsor requesting the work has rigid preconceptions with respect to the fundamental nature of the problem" (p192). This type of TA leads Coates to write elsewhere (Kirchmayer p171) that "the most obvious weaknesses of TA arise from the inevitable biases of the individuals and organisations who either request or perform the assessments".

However, some argue that there is a role for client-performed TA where it relates in a direct way to the political arena, as will be elaborated later.

(b) This type of bias in TA is well illustrated by Jones' seven-step TA procedure mentioned earlier, which incorporates "step 3. Develop state-of-society assumptions". It is openly admitted that societal factors including values are being considered. Strasser (1975) writes about performing TA "without causing unacceptable disruptions in our economic, social and political systems", and in Daddario's words, "society benefits when technology is fashioned around some value or goal, consistent with democracy" (1972, p213). R.A. Carpenter is more blatant, and describes TA as a "tool for the renewal ... of the free enterprise system ... (and) to enrich the information for management decisions".

On a more subtle point, Skolimowski (1975, p191) notes the danger that we are all products of a technological society; "We are all *technicians*. Our

attitudes and our mentality are profoundly affected by the ideals of technology".

By way of conclusion on this aspect, perhaps Jones' "develop state-of-society assumptions" would be better confined to an evaluation of societal parameters as they impinge on or are impinged on by the technology. It should not concern any normative or value basis on which the TA is performed, as some writers propose.

(c) This relates to an essentially philosophical argument on the nature of knowledge, but its interpretation has implications for the role of TA in the policy process. It concerns the validity or otherwise of a separation between scientific and political issues, between Descartes' "measurable and incomensurable". Thus L. White maintains that we must abandon this view and recognise "that quantity is only one of the qualities and that all decisions, including the quantitative, are inherently qualitative" (p177).

Another exponent of this view is Peter Berger, who argues that all that passes for knowledge in society is socially determined (1966), and Karl Mannheim writes that "reality is discovered in the way in which it appears to the subject in the course of his self-extension" (1929). Wynne has applied this viewpoint specifically to technology assessment and concludes that TA "represents a political rhetoric

which implicitly serves to rationalize certain structural features of (modern) capitalist society", these institutions having an "arbitrary basis of legitimation" (p111).

But whatever the truth of this assertion (and some examples quoted earlier serve to substantiate it), the criticism that current examples of TA, or even the prevailing view of what TA should be, implicitly endorse a certain economic and political system, or certain institutions within that system, is in no way a denial of the possibility that TA can be conducted in a manner such as to highlight consequences of technology which may be unintended.

It is a denial of the probability that TA can expose some consequences of technology which may be undesirable on the basis of certain normative premises, if these norms do not coincide with those prevalent in the dominant politico-economic institutions in society. In this case the failure to take account of such effects, regarded as undesirable by certain groups, is a failure in a political system characterised by an inherent mobilization of bias.

Technology Assessment in Practice

One procedure proposed to circumvent Wynne's objections is that the technology assessment should take place at a level inside the political arena, i.e. that various involved groups should conduct

their own (admittedly value biased) TAs. Benn (p489) suggests that "some research council funds should be specifically allocated to trades unions and other recognised community groups to allow them to sponsor relevant research into the best means of safeguarding the interests of their members".

The debate on the place of TA in the political process has been the subject of recent controversy. But the view that separate TAs should be performed independently by opposing political groups, often based on the arguments of Wynne, Berger and others, neglects an important point they are making on the socially conditioned nature of knowledge, which is that all knowledge, scientific or otherwise, in a given society is biased by the dominant values of that society.

Thus TAs carried out by all opposing groups in an issue who are content to operate within the existing political framework will be biased in essentially the same direction. (Of course, this is not true at an overt level, because they are in opposition at an overt level, but the suggestion is that very basic norms, perhaps methods of analysis and some premises, will be the same - in fact, Wynne claims that these prevailing norms are indefinable (p116), but nevertheless permeate the socio-political environment).

The position of those groups who are profoundly alienated and therefore not content to operate within the existing political framework is different, in that their "indefinable prevailing norms" are not congruent with those of society, but such groups are few and the political dialogue on most issues will take place without their participation. Thus the suggestion of moving TA into the active part of the political process does not provide a complete solution to the essential problem posed by those who maintain that all knowledge is socially determined.

On the practical side, the major disadvantage of this approach must be that the quality of the TAs performed by each interest group (or indeed whether one is performed at all) will inevitably be a function of the groups financial and other resources, the degree of organisation of the affected parties (some will be completely disorganised and have no representation, e.g. future generations), their legitimacy, and so on.

However Benn's proposal is based on the essential and reasonable premise that, in Brooks' words, "there is no objective or scientific basis on which final choices can be made. The choices themselves are political". Where Benn's analysis is suspect is in the assumption that given what Brooks has said about the political nature of the decision, the logical solution is to perform the technical evaluation at a political level. Brooks goes on to point out the role of technical analysis

as being to clarify the consequences of various technological choices, and this is where TA may best fit into the political process. The belief that expert opinion alone can resolve difficult and complex technological decisions is mistaken, because in the final analysis the decision will inevitably be based on values. But the contrary view that all technical and scientific issues are so impregnated with the ideology of the researcher and the social context of his work as to be merely an expression of the dominant political and economic forces in society is equally fallacious.

TA must inevitably investigate areas where there is little concrete information, and the results will correspondingly carry less weight. Its value, therefore, lies in a role as an evaluative and predictive interdisciplinary approach capable of ranging over a wide area of technical issues and, on a more speculative basis, a wide area of possible social outcomes.

Appendix Two

FACTORS MONITORED FOR CHANGES CONSEQUENT UPON TECHNICAL INNOVATION

- Capital Equipment
 - nature of machines
 - numbers
 - complexity
 - flexibility
 - reliability

- Labour
 - numbers
 - skills
 - wages
 - task definition
 - job satisfaction
 - industrial relations

- Other Inputs
 - raw materials
 - energy
 - space

- Output
 - nature of product
 - volume
 - quality

- Economics
 - capital costs
 - running costs
 - maintenance costs
 - productivity

- Work Environment
 - factory organisation
 - health conditions
 - accident rate

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