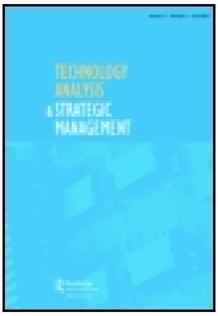

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Introducing programmable automation technologies: intended managerial strategies, choices and decisions

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Introducing Programmable Automation Technologies: Intended Managerial Strategies, Choices and Decisions

HARIDIMOS TSOUKAS

ABSTRACT *The Programmable Automation Technologies (PATs) constitute a solution to the problems organizations face as regards (i) their search for more efficient modes of handling environmental uncertainty, and (ii) improving the diminishing returns of the existing technical paradigm. PATs contribute to the further decrease of the product unit cost and allow for a substantial increase of flexibility in, and control over, the production process. In addition, it is argued here that the introduction of PATs constitutes a strategic decision which is part of a wider organizational innovation strategy, followed by management in their attempt to coalign effectively the organization with its environment. This strategy includes three interconnected but differentially treated areas: entrepreneurial, engineering, and administrative. Evidence from a case study shows that market competition and internal organizational resource imbalances determine the managerial focus of attention, and the means of rectifying a problematic situation.*

1. Introduction

The aim of this paper is to examine the strategies which management intends to pursue when Programmable Automation Technologies (PATs) are being considered for introduction in an organization, the stimuli for these decisions, and the objectives attached to them. Its purpose is twofold: to offer a descriptive account of the processes involved via a case study, and to link them to an explanatory framework able to illuminate some facets of the underlying causes which in a combined fashion generate the event under study.

Research in the past has been mainly concerned with either the introduction of large-scale computer systems in organizations and the way such decisions were made,[1–3] or with investment in new technology as one more strategic variable to be assessed and included in a meso- or long-term business plan. These two streams of research, in spite of the insights in the relevant themes they gave us, are faced with limitations.

First, computer systems have been the spearhead for new technology investment for about 25 years, in conditions (for most of the time) of economic growth.

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Nowadays, however, after the exponential growth of the microelectronics industry, whose most spectacular achievement has been the coupling of computer technology and communications, and the radical changes in product and labour markets, the industrial landscape is clearly different. The advent of *progammable* automation (as opposed to the dedicated automation of the previous two decades) permeates the core of the production system itself and places new demands and opportunities on business strategies, in contrast with the computer systems of the preceding decades which were usually deployed in peripheral spheres of company activities (e.g. accounting, production control, sales, etc.).

Second, there is a need to assess the specific weight of technology, and in particular of PATs, in the overall context of managerial strategies, not only in terms of the pecuniary commitment involved, but also of the forces which stimulate management teams to pursue the programmable automation avenue, and the objectives they have in mind.

In the light of the preceding remarks this paper sets out to discuss the following questions:

(a) Why do Programmable Automation Technologies (of any type) constitute the focus of managerial attention for their introduction into the production process?
(b) What is the role of PATs within the strategies management intends to pursue, and what objectives do managers attach to them?

Tackling these questions constitutes the core of the paper, while a limited number of issues (e.g. some aspects of the decision-making process) are touched in passing.

The organization of the material is as follows. In the next section, a 'spatial' conception and a temporal account of the development of organizational technologies are presented, and the main features and applications of PATs are reviewed. The main conclusion of this section emerges as the structurally imposed requirements for flexibility within, and control of, the contemporary production systems. These requirements are satisfied by the PATs since they constitute their essential features.

Next, in section 3, the PATs are placed within the wider strategic managerial framework and the reasons for their introduction are hypothesized. The main focus here is on the managerial attempts to coalign the organization with its environment and the role of PATs in such a process. Finally, in section 4, the findings of a case study are presented, and they are subsequently discussed in the light of the previously presented theoretical points.

2. In Search of Flexibility and Control: The Case of Programmable Automation Technologies

2.1 A 'Spatial' Conception of Organizational Technologies

According to Thompson,[4] all purposive organizations contain one or more technologies which are directly linked with the primary task of the organization and, therefore, they constitute the core technical system. The latter operates on a primarily instrumental logic which Thompson calls *technical rationality*. The inherent tendency of the technical rationality is to maximise its instrumentality, that is, its effectiveness. This can only be achieved by controlling all the relevant variables and excluding all the exogenous influences, that is by becoming a closed system of logic. An ideally closed system approximates the maximum of its performance because its action is dictated by the internal logic of the technology itself, excluding any external 'disturbances' (e.g. continuous process technologies). Consequently, the inherent tendency of the core technical system for technical perfection is attainable only when the organization has control over all the elements involved, that is, when the technical core is sealed off from environmental influences. However, core technologies do not exist in a vacuum. As Thompson[5] put it, 'technical rationality is a necessary component but never alone sufficient to provide organizational rationality, which involves acquiring the inputs which are taken for granted by the technology, and dispensing outputs which again are outside the scope of the core technology'.

In other words, the conversion component (i.e. core technical system) is linked forwards with the output and backwards with the input activities, forming a chain called *organizational rationality*. The input–output activities are obviously interdependent with environmental influences and since they are serially linked with the conversion component they are the conduits of these influences to the core technical system.

This remark has two interconnected implications. First, that the core technologies will always be influenced by environmental disturbances, and second that 'organizational rationality never conforms to closed-system logic but demands the logic of an open system'.[6] The conflict between organizational and technical rationality compels the organization to seek for modes of reducing the influence of environmental uncertainty on the core technical system. This can be achieved, as Thompson suggests, in at least three ways.

(1) 'Organizations seek to buffer environmental influences by surrounding their technical cores with input and output components'.[7] The buffering components develop characteristic technologies on their own (local or peripheral technologies) which are influenced by the core technical system and in turn 'influence the tasks, social structures, supervisory practices and management control systems of the organizational subsystems in addition to achieving the goals of the buffering systems'.[8,9] The degree of interdependence among the input–-conversion–output actitivies gives rise to different technological configurations.

(2) Buffering, however, is costly and the conflict between organizational and technical rationality may lead to the employment of other methods, such as levelling of input and output transactions. The emphasis here is on attempting to reduce rather than absorb environmental fluctuations.

(3) Alternatively, organizations seek to increase their adaptive and flexible capability in order to cope with environmental influences. Thus they strive to build up a 'requisite variety' of responses to predicted environmental changes, that is, to increase the flexibility of the core and/or peripheral subsystems.[10]

The above three alternatives can be combined in any proportion to give an organizational uncertainty-reduction policy. The criteria for determining any such combination are predominantly structural, such as labour, product and financial market conditions, the state of technological knowledge, etc. In the present environmental turbulence, exemplified by fierce competition, rapid technological changes, uncertain product life cycles, and a more demanding consumer public, organizational slackness is significantly reduced and, consequently, the emphasis is shifted towards as high as possible efficiency, cost-cutting measures and product/service quality.

A trend can be hypothesized towards the gradual reduction of the utilization of the buffering device as a means of uncertainty reduction, due to its high operating cost and its contribution to the 'inertia' of the total system at times when quick responsiveness to the market is highly valued. Attempts to reduce environmental fluctuations (i.e. levelling) are likely to increase but they have limited effects due to the multiplicity and complexity of the factors to be influenced, and/or their seasonal character. Thus, various forms of *flexibility*[10,11] and adaptiveness directed at the core and/or buffering subsystems are expected to be sought by organizations as a viable alternative of resolving the conflict between organizational and technical rationality.

2.2 A Temporal Account of the Evolution of Mechanization

The preceding analysis, based mainly on Thompson's work, is useful in offering a 'topographical–functional' framework for analysing organizational technologies and, in particular, for understanding the shift towards flexible technologies, such as the PATs; it lacks, however, a dynamic perspective able to give us insights into the uneven development of the production process and, consequently, into the advent of programmable automation. Coombs' analysis[12] is useful at this point. Extending Bell's work, he argues that in any production system 'manufacturing activities consist of combinations of three different but related functional activities which are susceptible to different levels of mechanization'.[13] These three activities are (i) the transformation of work-pieces or *primary mechanization*, (ii) the transfer of work-pieces between transformation sites or *secondary mechanization*, and (iii) the control of the first two activities or *tertiary mechanization*. If these phases of mechanization are placed into a historical frame, it can be argued that each one of them represents, successively, the dominant form of production technology from the middle of the 19th century to the present.

As Coombs argues, after exploring the pertinent historical data, the mechanization of transformation was the dominant technological regime (or technical paradigm) from the middle until the end of the 19th century, highlighting the ability of machinery to accomplish transformation tasks. The mechanization of transfer was the second regime spanning the beginning of the present century and World War II and it placed emphasis on using machinery to achieve transfer tasks. Finally, the third technological regime, we have been in, has started after World War II, and it has been focusing on using machines to achieve control functions. The pivotal force for the transition from one technical paradigm to another has been the emergence of a bottleneck and the effort it demanded for its transcendence. This process can be briefly described as follows: 'In the short term and medium term, particularly during the early period of each regime, performance tends to improve quite readily as a result of incremental improvements within the framework of the regime . . . In the long run, however, each regime encounters some intrinsic limit rather in the manner suggested by Wolff's law. As diminishing returns are encountered in the search to increase performance on the basis of the existing regime, attention gradually becomes focused on radical solutions'.[14]

Furthermore, there is a parallel evolution between the historical development of mechanization and the timing of 'long waves' in the development of the world economy. The post-1970 economic situation appears to be in the downswing of the long wave and brings into open the diminishing returns of the early phase (i.e. dedicated automation) of the post-war technical paradigm. The reduction of the direct labour cost which has been achieved during the early periods of tertiary mechanization is no longer adequate alone and is accompanied by managerial efforts to curtail overhead and material costs, in conjunction with the minimization of the value-adding time and the better gearing of the firm to the forces of the market. This calls for improvements within the existing technical paradigm which are being directed towards the further increase of the level of automation of the control functions, and consequently to the increase of various forms of *flexibility* of the production process. This requirement can be successfully matched by the utilization of programmable automation.

2.3 The Main Characteristics and Applications of PATs

During the early period of tertiary mechanization the main thrust of automation was towards what is called dedicated (or fixed) automation, namely, the usage of single-purpose, automated machines for the production of high throughputs of homogeneous products. High variability, complexity and responsiveness to the market could not be adequately handled.[15] The dramatic decline in the cost/performance ratios of microelectronics and their applications, in conjunction with rapidly changing market conditions, moving towards stiffer competition, and the increasingly important need for flexibility, gave a boost to the development of PATs.

This new generation of automation is the child of a successful marriage between computer science and manufacturing engineering. Its essential difference with conventional production technology is located in the utilization of information technology to provide machine control and communication. The use of computers to store, process and retrieve data on the one hand, and of communication systems to transmit these data to other machines in the plant on the other, allows the performance of a greater variety of tasks than dedicated automation, and also the automation of some previously human-regulated tasks.

The application of PATs occupies all the spectrum of business operations: PATs are used to help *design* products (e.g. Computer-Aided Design), *manufacture* products (e.g. Computer-Aided Manufacturing), and to assist in the *management* of many production operations (e.g. various tools and strategies for manufacturing management).

The benefits from the application of PATs are reported to be high, such as significant improvements in cost, delivery, quality, quick responsiveness to market changes, etc.[16–18] But what is equally important, is the opportunity for management to enhance their control of the production process, taking out many potential sources of interruption and building up a requisite capacity of different responses to external or internal anticipated incidents. Programmable automation, in its integrated form, provides the means for the potential realization of an old managerial ideal: how to bring the overall business under management's control, and ultimately 'wresting manufacture away from human interface in much the same way as happened in an oil refinery, sugar plant or cement factory'.[19] In its ideal form, a Japanese-inspired Just-In-Time (JIT) production system is envisaged so that 'the time required for parts to flow from goods-receiving through the shop and to despatch is only as long as the time it takes to complete all the value-adding steps in the manufacturing process'.[20] This value-adding time can be radically curtailed and, consequently, the efficiency increased, along with better quality, by effectively aligning the CAD, CAM and Manufacturing Management sub-systems so that they constitute a Computer-Integrated Manufacturing (CIM) unit.

To summarize, I have discussed in this section the increasingly important need for flexibility in the production systems by utilizing Thompson's 'spatial' and Coombs's temporal analysis of technology. It has been shown that the conflict between organizational and technical rationality in combination with the environmental changes which have occurred during the past 20 years, force organizations to seek more efficient modes of handling environmental uncertainty. The increase of flexibility and adaptability of the core and/or peripheral subsystems to respond directly to different anticipated environmental changes appears to be the most likely possibility. The same need for flexibility is projected as a means for improving the diminishing returns of the tertiary-mechanization paradigm. Programmable automation offers the much-wanted solution to the above problems via its application throughout an organization's activities, and creates the possibility for a substantially enhanced degree of management control over the production process.

3. The Role of Programmable Automation Technologies in Intended Managerial Strategies

As has been repeatedly argued, the environment, in the form of product, labour and resource markets, know-how, politics, law and public opinion, is the source of a great deal of uncertainty for the organization. Constant changes, competition in the product markers, lack of understanding of the relationship between causes and effects, lack of clarity of information, and the fact that the preceding factors are in one way or another out of direct organizational control, generate a great deal of uncertainty for the organization. For some scholars[4,21] the management of uncertainty is an essential task of any administrative process and lies primarily on the shoulders of what Parsons called the institutional level of management.[22] The latter, being in the vantage position of having a holistic organizational view, is responsible for 'maintaining an effective alignment with the environment while efficiently managing internal interdependencies'.[23] From this perspective, senior management serve as the primary link between the organization and its environment, and their perceptions of the latter determine the nature of the adjustments and strategic choices which are considered, as regards markets, technologies and administrative structures.

At this point it may be useful to say that the concept of strategy is used in this paper in Mintzberg's sense, namely, strategy is defined as a pattern in a stream of decisions, and is analytically decomposed into intended and realized strategy.[24,25] From this it follows that when we talk about managerial strategies or strategic choices we must specify which notion of strategy is employed. This need is not always recognized in the literature, with many scholars using implicity the 'intended' but arriving at conclusions as if they are using the 'realized' type of strategy.[17,26,27] As the title of this paper suggests, the 'intended' strategy is used here when mention is made to managerial strategies.

3.1 Organization, Environmental Influences and the Need for Innovation

As was noted earlier, senior management aims at achieving an effective coalignment of the organization with its environment. This is an, ideally, on-going process and is carried out through an organizational innovation strategy.[28]

Organizational innovations can be grouped into the following three interconnected areas: (i) entrepreneurial, where a new domain (i.e. activities the organization intends to pursue) is defined; (ii) engineering, where technical changes are envisaged; and (iii) administrative, where new organizational structures and control systems are advanced.[23,29] The quality of fit between three groups determines decidedly the degree of organizational success. The entrepreneurial, engineering and administrative phases represent strategic options available to management and they convey different implications. The innovation process frequently occurs in a sequential fashion, moving through the three stages, and the cycle can be triggered at any one of these points (see Figure 1). Each one of the three groups of decisions forms a 'design space'[30] which allows for further exercise of managerial discretion.

In the light of the preceding analytical schema, it can be argued that the introduction of PATs represents a strategic 'engineering' decision which is closely linked to the remaining entrepreneurial and administrative domains. It is a strategic decision in the sense that it is (i) unusual (i.e. non-routine), (ii) substantial (i.e. entails a significant commitment of resources, and (iii) all-pervading (i.e. sets off a host of other less important decisions).[31] Therefore, it can be hypothesized that PATs are more likely to be a part of a wider managerial strategy encompassing all the three phases of the innovation process, rather than an *ad hoc*, opportunistic decision. The emphasis, timing and quality of fit between the three innovation stages is a function of managerial perceptions of environmental pressures, internal imbalances (i.e. problems and accumulated inefficiencies) and management style.

Examining PATs in isolation, it could be argued that they are among other candidate types of technology to be used in the production process. However, as Moss argues, 'there is no exogeneous list of potential innovations which have equal chance of being chosen [but] there are some clear economic forces which will predispose businessmen to formulate one objective rather than another'.[32] A particular element of the organizational environment, namely, competition in the product markets ('inducement effect'[32]), forces management to formulate particular objectives and to utilize a certain type of knowledge. The latter is sought within the dominant technical paradigm.

Expanding his argument, Moss goes as far as to say that in any kind of investment project, whether it includes technical innovation or simply expansion of existing activities, imbalances among the firm's resources focus the attention of managers upon particular targets (e.g. elimination of bottlenecks, etc.). Consequently the knowledge that will be employed in acheving these targets will be determined by the knowledge, skills and experience of the human resources of the firm ('focusing effect'). The 'inducement effect', in common with the 'focusing effect', determines the final shape of an investment project in technology.

To summarize, I have discussed in this section the position of PATs within a wider organization innovation strategy. It has been suggested that senior management aim at coaligning the organization with its environment via entrepreneurial, engineering and administrative innovations. PATs are an 'engineering' decision with wider, it is hypothesized, implications in relation to the other two innovation

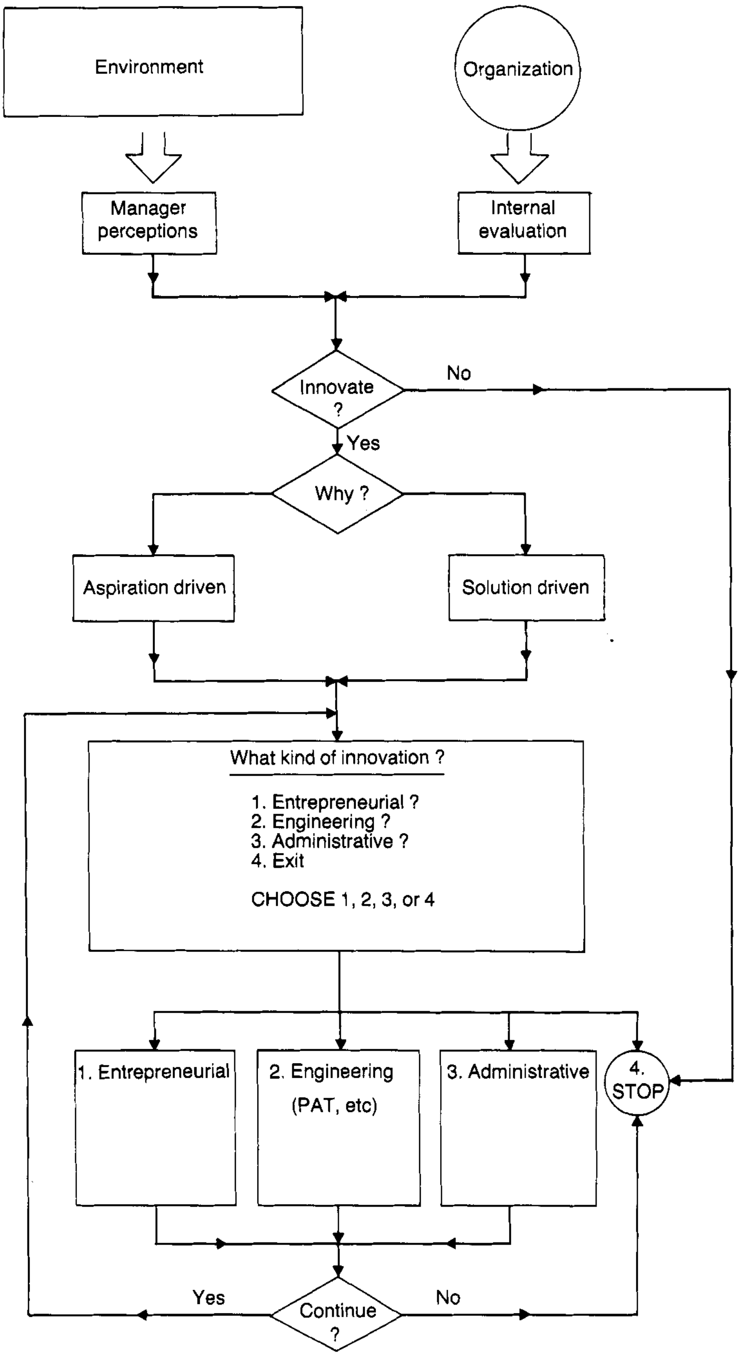

Figure 1. Organizational Innovation as a Strategic Choice Selection Process.

areas. Competitive forces induce, and internal resource imbalances focus, managerial attention on technical solutions within the existing technical paradigm by adopting specific types of PATs.

4. A Case Study

4.1 Methodological Remarks

Having analysed the main features of PATs in the wider context of organizational technologies and environmental influences, and sketched the skeleton of a theoretical framework for explaining why management goes about introducing a major technical change, I turn my attention to a case study to illustrate the mechanisms involved in the introduction of PATs in organizations. Some methodological remarks are useful here.

(1) The case study was undertaken at the British Rail Engineering Limited-Locomotive Works (BREL-LW) between January–April 1986 and it focused on a specific department. The methods used to collect the pertinent data were: (i) open-ended interviews with senior and middle management, engineers and worker's representatives; and (ii) documentary material provided by the company. My purpose was to investigate some aspects of the decision-making process regarding the introduction of PATs and not the wholeness of such a process. The latter would have a required variety of multiple methods based on a longitudinal basis, which was out of the scope of the present project.

(2) The case study does *not* aim at 'testing' or 'validating' the preceding theoretical framework. Such a view of the case study method would be simplistic and limited. Rather, within a realist epistemological perspective, a case study helps elucidate the manner in which certain postulated general tendencies, derived from abstract analysis and conceptualization, have acted in a specific organization. As such a case study neither 'confirms' nor 'refutes' a theoretical framework; it simply illustrates the contingent manner in which any theoretically derived generative mechanisms are realized in specific contexts. In addition, from a realist point of view, a case study by design does not deal with questions of empirical generalization regarding the phenomena that it studies; for a realist generality is a property of necessary relations resulting from abstraction and conceptualization, and is not expected to be found at the concrete level of a case study.[34-37]

(3) As has already been mentioned, the focus of the study has been kept on *intended* streams of managerial decisions. The distinction between 'intended' and 'realized' strategies is important, in the sense that the unproblematic, straighaway implementation of managerial plans and intentions cannot be automatically inferred from their mere existence. A more thorough view of managerial strategies will be obtained if the whole picture of the strategy formation process is taken into account and an explanation for the existence of its various components is provided.

4.2 Background Information

British Rail Engineering Limited (BREL) is a subsidiary of British Rail (BR) with plants throughout Britain specializing in different works. The Locomotive Works, where the study was conducted, includes two main operations: (i) the repair and maintenance of locomotives of BR; and (ii) the manufacturing of railways wagons. The former department accounts for approximately 75% of the total revenue and its almost exclusive customer is BR. The latter department occupies a small segment of the railway wagons market, in Britain and abroad, and accounts for the remaining 25% of the total revenue. Approximately 2000 people are employed in total, one-quarter in the railway wagons department, and they are organized in five unions. A 10-member works committee, elected by the shopfloor workers, represents them in any negotiations with management.

BREL-LW is a small-batch manufacturer of railway wagons, producing them according to customers' orders. The receipt of orders and the consequent design is done at headquarters in London. The processing of orders (i.e. bill of materials, production planning, setting-up of lead times and data preparation) takes place at Derby works, and subsequently all the relevant data are transmitted to Nottingham's mainframe computer, where the master plan and the stock-available list are produced, which in turn are transmitted later back to Derby. This lengthy process of ordering and planning results in delays in monitoring production progress and stock recording, thus contributing 5–8 weeks to the overall lead time. Having finished the preparation phase, manufacturing takes place in the sequence depicted in Figure 2.

details		fabrication		painting		machining		assembly
↓	⇒	↓	⇒	↓	⇒	↓	⇒	↓
functional		flow		automated		dedicated		stage build

Figure 2. The Manufacturing Route and the Type of Associated Technology at BREL-LW.

Each of the illustrated five manufacturing islands is technically organized in a different way and imbalances between them cause shortages and line-balancing problems. At the fabrication stage, the present layout is a major constraint and the plate can travel up to one mile within the fabrication process. At the painting stage the capacity is poorly utilized, space utilization is unnecessarily high and excessive overtime occurs. Presently, in the railway wagons facility, as a result of the poor layout, a railway wagon travels 1.5 miles, utilizing 50% of the external transport resources.

Briefly, all these internal imbalances and inefficiencies, namely the off-site mainframe, the separation of design from manufacturing, the inconvenient layout, and the inefficiencies embodied in each manufacturing island, created problems to the railway wagons department, which manifested themselves in high lead times, high work-in-progress, high inventory of components and sub-assemblies, poor manufacturing management and inadequate management control. The end result was a significant amount of non-value-adding costs, and consequently, high unit cost, poor customer service and reduced competitiveness.

4.3 The Decision to Create an Integrated Railway Wagon Facility

The above-illustrated imbalances in the utilization of the company's resources and its failing competitiveness forced management to take action. The attention was focused on the railway wagons department for three reasons: (i) it is the main area subjected to market forces; (ii) it is an autonomous unit and lends itself to individual treatment; and (iii) BR's policy is to reduce as far as possible the maintenance of vehicles and to increase product development. Furthermore, management felt that the reorganization of the railway wagon facility alone could serve as a model for subsequent changes at the rest of the works. The initial intention had been to create a separate railway wagon businesses unit with its own organizational structure, but this idea was considered too radical for a start, and was, at least temporarily, abandoned in favour of a middle-of-the-road creation of an integrated facility.

The senior management's aim was to increase the return on capital employed (ROCE) and expand sales by: (i) cutting costs; (ii) improving customer service; and (iii) increasing commercial awareness amongst the employees. The ways for these targets to be achieved were: (a) the creation of a fast throughput system which, ideally, should exclude all the non-value adding operations, geared to the market needs; and (b) the integration of systems, workplaces, departments, and people in a new manufacturing facility. Such a manufacturing facility would be designed according to a quasi Just-In-Time (JIT) production philosophy according to which all interruptions (e.g. set-up times, line-balancing, etc.) are sought to be minimized, each operation is guided by the demand of the succeeding operation (demand-pull system) and ultimately every activity in the plant and every demand on suppliers is driven by the final assembly operation.[20,38,39] According to the senior management of BREL-LW, the end result of such a system was hoped to be lower unit cost, faster responsiveness to the market, better management control and improved customer service (see Figure 3).

Fast throughput system	*Integration*
—Low inventory	—Better coordination
—Low w-i-p	—Better manpower utilization
—High flexibility	—Better management control
	—Increase of commercial awareness

—Quick responsiveness to the market
—Elimination of ineffective time
—Reduction of lead times
—Reduction of overheads

$\Downarrow$

—Low unit cost
—Quick responsiveness to the market
—Better customer service

$\Downarrow$

—Expansion of sales

$\Downarrow$

Final aim: increased market share and ROCE

Figure 3. The Chain of Aims of BREL-LW's Senior Management, Regarding the Creation of a Fast Throughput, Integrated Railway Wagon Manufacturing Facility.

Having a strong belief commitment to a JIT-inspired production system, management decided to use the knowledge of a renowned consultancy firm which shared the same approach toward the design of manufacturing systems. The consultants in their study considered initially three alternatives: (i) an unintegrated production system with potential for productivity improvements and technical investment; (ii) an integrated system with minimum investment; and (iii) an integrated system with maximum investment. Finally, after a period of deliberations, an intermediate solution of an integrated manufacturing facility with phased investment was chosen.

The decision to proceed with this solution involved:

(1) *A low inventory layout:* the existing layout would be reorganized with the grouping of similar activities in order to be consistent with the requirements of an integrated, fast throughput system. The actually needed space would be remarkably reduced.
(2) *A computer-aided scheduling system:* the Optimized Production Technology (OPT) would be selected. OPT would calculate the sequence of operations for all the work centres by taking into account priorities and capacities. It would minimize w-i-p manufacturing lead times, throughput times, and concentrate scheduling on bottlenecks.[40-42] Furthermore, the company intended to use the OPT across the whole works and not only in the railway wagon.
(3) *The purchase of two CNC machines*
(4) *The installation of initially one CAD workstation.*

As far as manufacturing control is concerned, the ultimate goal was to develop a Computer Integrated System, linking production control with CAE/CAD, Commercial, Finance and CAPP systems. The new integrated facility would involve in the short run (i.e. for the present volume of sales) a 24% reduction in the manning levels (direct, indirect and salaried employees) through voluntary redundancies. In the meso-term (i.e. for the projected level of sales in 1990 which is expected to be three times higher than the present) the same number of employees as currently was predicted.

The benefits to the company from an integrated railway wagon manufacturing facility was estimated by the consultants to be remarkably high (calculations based on the 1985–86 volume of sales): a decrease in lead times by 55%, in w-i-p by 60% and in space utilization by 57%; an increase in the ROCE by 50%. Even with 30% less sales than those achieved in 1985–86, an integrated facility was deemed justifiable.

The completion of the consultants' proposals was followed by the establishment of a project team composed of internal engineers, in order to draw the new layour in cooperation with the consultants. An attitude survey was carried out by the consultancy firm, aiming at finding out how people felt about the planned changes and what they required from management.

All levels of management seemed to believe that the new production system would entail some organizational changes and demand a different philosophy of management if its benefits were going to be fully reaped. Unlike the old production system, where the supervisor had to 'keep the lads busy', irrespective of what they were doing, thus providing w-i-p, the new one does not demand people working all the time even when there is not really work to do. Delegation of authority and better control were frequently mentioned by managers as being necessary corollaries to the technical changes. The need for a new incentive scheme, not individually based, as currently happens, was recognized by senior management, and a productivity agreement and a multiple training scheme were agreed between management and unions. The whole package of changes seemed to have had the trade-union acquiescence as the only long-term means of preserving jobs.

To summarize, in this section I have reported a case study undertaken at BREL-LW. It was seen that the management chose to create an integrated, fast throughput railway wagon manufacturing facility in order to confront the falling competitiveness and the internal problems of the company. Various types of PATs were thought to assist effectively in the achievement of such a target, accuring considerable financial benefits. It was felt by management that the technical changes would entail different administrative systems for their effective operation.

5. Discussion

(1) From what has been seen so far, it follows that the decision to create an integrated railway wagon manufacturing facility involved a mixture of conventional and novel technical changes subjected to a new managerial philosophy towards manufacturing. PATs, in the form of CNC machines, CAD and the OPT scheduling system, are of significant importance in this package of technical changes. The new low inventory layout and the CNC machines are located at the core technical system and they increase its flexibility to cope with a variety of situations. On the other hand, CAD and the OPT scheduling system are located at the peripheral technical sub-systems (i.e. design and production control department respectively) absorbing variations in design specifications and production scheduling contingencies, thus buffering the core and guaranteeing its smooth, quick and efficient operation.

Flexibility is a key word for the new manufacturing facility. In general, as Gerwin suggests, PATs allow management teams to pursue flexibility along a number of dimensions: mix flexibility, component flexibility, modification flexibility, rerouting flexibility, and volume flexibility.[11] All these dimensions of flexibility are not necessarily in harmony with one another and each one is associated with different costs. However, this flexibility mix equips the organization with a 'requisite variety' of potential responses to be used according to the prevailing mix of uncertainties. The evolution of a policy towards flexibility will reflect the 'balance of emphasis'[43] which management deems appropriate to its priorities, its assessment of contingencies and (existing or near-future) uncertainties. In our case, modification and rerouting flexibility (i.e. the ability of the production process to cope with new designs of a given product; and the ability to change the sequence of the production steps according to the problems encountered, respectively) were consciously sought by management, mirroring its objectives for quick responsiveness to the market and low unit cost.

The JIT production philosophy attempts to increase the links between the input–conversion–output activities, which means a higher dependence of the conversion component on the correct operation of the input–output ones, and thus the easier transfer of environmental influences to the core technical system. On the surface, the integrated, fast throughput system bears a similarity to what Thompson[4] calls 'long linked technology' which entails a serial interdependence of the tasks to be executed. However, the flexibility of the core and peripheral systems allows them to activate a network of responses to different contingencies. To put it differently, the changes which the management of BREL-LW pursued sought to maximize the total system's efficiency (i.e. organizational rationality) and minimize its response time to external contingencies, while at the same time preserving the 'undisturbed' operation of the core system (i.e. technical rationality). This was achieved by jointly increasing the integration of the organizational rationality components, and the injection of flexibility into, primarily, the core and, secondarily, some of the peripheral systems. In such a production system people would still play an important role for its effective operation, and their incorporation into a market-oriented organizational rationality was pursued. Managerial control would become diffused and channelled through technical and cultural elements.

(2) It seems that the model of organizational innovation, illustrated in Figure 1, corresponds to the actions taken by the management of BREL-LW. The latter followed indeed the three choice phases (i.e. entrepreneurial, engineering, administrative), though with differential emphasis and timing, in their attempt to coalign the organization with its environment. The latter, in the form of competition, as perceived by senior management, played an important role in the taking of the decision to create an integrated railway wagon manufacturing facility. The management of the company, though, strictly speaking, did not define a new domain, but decided to follow a more aggressive marketing policy, rationalize the product mix by reducing its variety, and offer better customer service at a lower cost. Management felt that the effective coalignment of the organization with its environment, namely, the restoration of competitiveness of the company, had to be done through the reorganization of the railway wagon facility. Technical changes and, in particular, some types of PATs were an appropriate instrument to carry out such a policy.

At the same time management were aware of the social and organizational implications of this major technical change, but at a general level, without trying to incorporate the search for alternative administrative structures into the decision-making process. Technico-economic objectives predominated and set the scene for the changes to follow; any organizational or job design changes were left for the implementation phase (for similar conclusions see Hildebrandt[26]). Management appeared to perceive the entire decision-making process, from conception to operation, in a sequential fashion according to which decision making about technico-economic factors takes precedence, and it is later followed by installation, debugging and implementation, where at each stage different problems are made, different people are involved and different problems are solved.[44] For instance, the decision making about the technical changes was, first and foremost, a job for the experts, while the subsequent implementation phase, accompanied by decisions of 'lesser' importance, about the deployment of machines and people, was intended to be more participative.

(3) Although in the strategic choice literature the notion of managerial discretion is emphasized, the constraints managers face, and the particular contextual factors which lay their weight on the decisions made, are not frequently pointed out. Moss's arguments, outlined in the third section, are appropriate in order to explain why particular objectives are formulated and a certain type of knowledge is utilized. Market competition (i.e. the 'inducement effect') affects significantly managerial perceptions so that 'competitive forces focus the attention of management teams upon new markets or new ways of producing commodities for existing markets and so pre-empt internal imbalances as objects of managerial

attention'.[45] However, the selection of the means by which management attempts to meet the problems or opportunities created by inducement effects (e.g. in this case by opting for an integrated, fast throughout system), depend on the internal imbalances within the firm (e.g. in the case of poor layout, long lead times, high w-i-p, etc.) and the knowledge and experience of its personnel.

To sum up, it has been shown that rerouting and modification flexibility were sought by management via the utilization of some types of PATs. The conflict between organizational (i.e. total efficiency) and technical (i.e. core system effectiveness) rationality was resolved by increasing the links between the input–conversion–output components, and thus curtailing the response time of the total system to external contingencies; and by injecting flexibility into the core and some of the peripheral technical systems. PATS were regarded by management as part of a wider organizational innovation package with the aim of coaligning effectively the organization with its environment (i.e. restoring the competitiveness of the company). Perceptions of an increasingly threatening competition led management to focus attention upon a particular activity (i.e. the manufacturing of railway wagons) and on new ways of producing the pertinent product (i.e. integrated fast throughput system). The selection of the means by which management responded (i.e. some types of PATs) was a function of the internal imbalances of the company.

6. Conclusions and Suggestions for Further Research

(1) In this paper, the technical system of organizations has been conceptualized using the 'topographical–functional' distinction between core versus peripheral technologies and technical versus organizational rationality. The conflict between the latter two, along with the environmental changes which have occurred during the last two decades, force management teams to seek more efficient modes of treating environmental uncertainty. That means the gradual reduction of the buffering policy as the dominant medium of protecting the core technical system from uncertainty, in favour of more flexible and adaptive production arrangements. In the same vein, a historical perspective of the development of mechanization points to the need to search for flexibility within the existing tertiary-mechanization technical paradigm, as a means for improving its now encountered diminishing returns.

Both analyses of organizational technologies converge on the increasing need for flexibility of the production process, which is a fundamental feature of programmable automation. PATs, in their various forms (i.e. CAD, CAM, and tools for manufacturing management) become the focus of managerial attention since they offer a 'golden opportunity' for further cost reductions, increased flexibility and enhanced managerial control over the production process. As evidence from the case study has shown, the specific types of PATs which captures managerial attention are a function, first, of the *competitive forces* which induce managers to take action towards a certain direction, and second, of the *internal resource imbalances* which create efficiency and effectiveness problems.

(2) As has been seen in the case study, the management of the company was faced with the task of restoring its falling competitiveness which had deteriorated during the previous five years. To achieve its purpose, management decided to follow an organizational innovation strategy in which PATs were a significant

part. The strategy consisted of three interconnected but differentially important and sequentially considered areas: entrepreneurial, engineering and administrative. PATs were an 'engineering' strategic decision taken up by management in order to achieve the 'entrepreneurial' targets of lower unit cost, quicker responsiveness to the market and better customer service.

There is a fertile ground for more research concerning the introduction of programmable automation in organizations, with the aim of obtaining a picture as broad as possible of the underlying structures and mechanisms which generate the event of technical change in contemporary organizations. It would be interesting, for instance, to investigate the patterns of strategy formation regarding the introduction of PATs, in connection with broader business and corporate strategies; the extent to which a particular management philosophy (e.g. Just-In-Time) accompanies the introduction, or emerges during the operation of PATs; the determinants of the shape of the decision-making process in a variety of situations; or the modes of management control put into practice where programmable automation is introduced, and how (if at all) they differ from earlier modes of control within the same organization.

Also, further case study research could give more attention to the role of particular individuals or coalitions in the promotion of programmable automation in organizations, in combination with the power resources which are mobilized by the parts involved in the defence and promotion of their views. All these and, of course, many other issues can be investigated taking into account specific temporal, industrial, cultural, institutional and politico-economic contexts so that similarities and differences 'over time and between countries and industries'[46] can be highlighted with the view of grasping the underlying mechanisms which account for these differences.

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