The Role of HRM Policies in the Implementation of Advanced Manufacturing Technologies

ABSTRACT

This paper investigates how HRM policies can contribute to the creation of a production environment in which the proposed benefits of the implementation of advanced manufacturing technologies can be realized. For one, data from twelve Dutch and eight British companies in the chemical and food & drink industries indicate that the use of advanced manufacturing technologies significantly alters the production environment. The strength of the impact is, however, dependent on the type(s) of automation methods implemented. Subsequently, a framework is developed to relate these changes to the design of HRM policies, incorporating the moderating effect of current structural arrangements. Although the majority of companies in the sample employs consistent HRM - technology combinations, also cases of "over"-fit were detected in which firms invested more in HRM than would be required by their current manufacturing technology. The overall conclusion is, however, that the emergence of the new manufacturing technologies indeed opens up a whole array of new strategic opportunities in which elements of cost <u>and</u> differentiation strategies can be exploited simultaneously.

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THE ROLE OF HRM POLICIES IN THE IMPLEMENTATION OF ADVANCED MANUFACTURING TECHNOLOGIES

FINDINGS FROM CHEMICAL AND FOOD & DRINK COMPANIES IN THE NETHERLANDS AND GREAT BRITAIN

ABSTRACT

This paper investigates how HRM policies can contribute to the creation of a production environment in which the proposed benefits of the implementation of advanced manufacturing technologies can be realized. For one, data from twelve Dutch and eight British companies in the chemical and food & drink industries indicate that the use of advanced manufacturing technologies significantly alters the production environment. The strength of the impact is, however, dependent on the type(s) of automation methods implemented. Subsequently, a framework is developed to relate these changes to the design of HRM policies, incorporating the moderating effect of current structural arrangements. Although the majority of companies in the sample employs consistent HRM - technology combinations, also cases of “over”-fit were detected in which firms invested more in HRM than would be required by their current manufacturing technology. The overall conclusion is, however, that the emergence of the new manufacturing technologies indeed opens up a whole array of new strategic opportunities in which elements of cost and differentiation strategies can be exploited simultaneously.

INTRODUCTION

Recent publications on the contribution of manufacturing technologies to the overall competitive strategy of organizations indicate that the basis of competition is changing (Kotha, 1995; and Dean & Snell, 1996). Instead of the ability to either produce at lowest costs or differentiate products (Porter, 1980), the combination of manufacturing flexibility (Garud & Kotha, 1994), efficiency and quality (Nemetz & Fry, 1988; and Parthasarthy & Sethi, 1992) is heralded as the important source of competitive advantage in the decades to come. Advanced manufacturing technologies, such as Computer Aided Manufacturing (CAM), Computer Aided Process Planning (CAPP) or Material Requirement Planning (MRP), carry the potential to meet these new competitive challenges, in the sense that - through their implementation - the boundaries between unit and small batch production, large batch and mass production, and continuous process production (Woodward, 1965) are blurred. This implies that combinations of these three production types become feasible (Adler, 1988; and Nemetz and Fry, 1988).

Traditionally, it was assumed that when the technical complexity of the production process was increased, the flexibility of the organization to respond quickly and efficiently to changes in volume and design would decrease (Hayes & Wheelwright, 1984; Parthasarthy & Sethi, 1993; and Hayes & Pisano, 1994). It is exactly this trade-off issue of decreasing organizational flexibility with increasing technical complexity that the advanced manufacturing technologies can relax (Zammuto & O'Connor, 1992). In other words: the basis of competition in manufacturing is shifting from economies of scale to economies of scope (Jelinek & Goldhar, 1984). That is, it becomes feasible to produce a larger variety of products on the same equipment without extra costs. Large batch, mass production and even continuous process firms may adopt features of unit and small batch production. This opens up a whole array of new strategic opportunities in which elements of cost and differentiation strategies can be exploited simultaneously (Kotha, 1995; Lei, Michael & Goldhar, 1996; and Dean & Snell, 1996). With the arisal of new manufacturing technologies, the traditional or strategy choice may be changed into an and option. This would imply that Porter's (1980) famous stuck-in-the-middle argument is loosing relevance: the middle operates feasibly at both the left (cost reduction) and right (product differentiation) of Porter's generic strategy dilemma.

The utopian potential benefits of advanced manufacturing technologies, however, do not come automatically to those firms that implement them (Jaikumar, 1986; and Meredith & McTavish, 1992). Many studies have indicated that investments in advanced manufacturing technologies alone are insufficient to obtain the potential benefits if the organization does not possess adaptive capabilities in other functional areas (Jaikumar, 1986; Zammuto & O'Connor, 1992; and Garud & Kotha, 1994). Since the introduction of advanced manufacturing technologies changes the nature of the contributions expected from employees, the ability of these employees to create new knowledge and acquire new skills seems to be a critical success factor (Jelinek & Goldhar, 1984; Leonard-Barton, 1992; Snell & Dean, 1992; and Nonaka, 1994). Machines still have to be operated by people. This implies that in order to realize the potential of advanced manufacturing technologies, the management of human resources and the design of the human resource policy have to be geared towards the changes made in manufacturing technology (Ettlie, 1986; and Adler, 1988).

This paper therefore attempts to contribute to deepening our understanding of the relationship between advanced manufacturing technologies on the one hand and human resource management (HRM) policies on the other hand in a sample of twelve Dutch and eight British chemical and food & drink firms. Note in advance that the purpose of this study is not to rigorously test this relationship, but rather to explore the complex nature of the fit between these two elements. Additionally, given the exploratory nature of the study, manufacturing technologies and HRM policies are framed in typologies that are mostly derived empirically, albeit incorporating existing classifications (reference withheld). Note, however, that given the inevitably embryonic state of the art of empirical research into the human resource impact of the introduction of new manufacturing technologies, explorative studies are still warranted.

The first section discusses the sample and methodology, and describes the typologies in which advanced manufacturing technologies and the design of HRM policies can be framed. In the second section the relationship between advanced manufacturing technologies, the organization of work and the design of HRM policies is discussed. This section focuses on the question of how the increased complexity, interdependence and uncertainty in the production environment affect the organization of work and - as a result - the design of HRM policies. A framework is proposed in which the advanced manufacturing technologies in our sample are related to the design of HRM policies. Subsequently, in the third section the technology-HRM combinations in our sample are analyzed with reference to the proposed framework. Finally, the fourth section is a conclusion.

SAMPLE AND METHODOLOGY

The sample

The sample consists of twelve Dutch and eight British business units and divisions of large companies in the chemical and food & drink industries. The selection of these companies evolved through a number of steps. Only the process in the Netherlands will be explained in detail here. A similar procedure was used in Great Britain. In the first step four criteria pertaining to the selection of companies were formulated to ensure inter-country comparability of data. First, the companies should be among the largest 1,000 corporations in the respective country in terms of *turnover*. Second, the firms have to be *manufacturing* companies. Third, the choice of the *industrial sector* is limited to eight industries. Fourth, the *unit of analysis* is defined as that part of the organization where management has the greatest autonomy concerning production and marketing decisions regarding (a) specific product line(s). The rationale behind this definition is to incorporate strategic choice in the analysis so as to underline that the interaction and/or coordination between internal elements is not merely determined by contingency forces, but is also based on managerial choice (Venkatraman & Camillus, 1984).

In the second step annual reports were collected on 115 manufacturing organizations belonging to the largest - in terms of turnover - Dutch manufacturing companies. These reports were examined to identify potential units of analysis within the organizations. After references had been obtained from people known to the manager who was contacted, a request to cooperate was mailed to a total of 34 Dutch companies. These requests - and follow-up phone calls - produced a total of 14 Dutch companies which agreed to cooperate. To ensure relative homogeneity in the sample, the analysis in this paper is focused on twelve Dutch and eight British companies in the chemical and food & drink industries.

Key sample characteristics are presented in the Appendix. The resulting sample size is small, since data collection was very time-consuming, for both firms and researchers. In a way, the benefit of a large sample size design was sacrificed for the sake of collecting detailed, in-depth and multi-faceted information in many functional domains. In this respect, the data set may be considered to resemble a multi-case information base.

Data collection

The data were collected in 1991-1992 by means of a questionnaire (see the Appendix) that was administered in structured interviews with the managers responsible for the diverse functional areas within the business unit or division. So, in this case, the production manager and the HRM manager were interviewed. Because the questions were aimed at obtaining an overview of the operations within these two functional areas, the members of the management team served as experts. To obtain the information on the two functional areas, an average of two interviews, taking approximately two hours each, was conducted.

The choice to interview two different managers who each addressed a different part of the questionnaire, was made to reduce one of the risks associated with key informant research: the inability of any single individual to provide accurate information on the organization as a whole (Bryman, 1989). Although the multi-person source of the data reduces the risk of common method variance (Podsakoff & Organ, 1986), this risk could not be reduced to zero as only on HRM in the Dutch companies limited secondary data sources - in the form of annual and social reports - could be obtained. The choice for the within-firm unit of analysis - which implied conducting interviews at the business or division level - made the collection of objective and secondary data virtually impossible since this information is only publicly available for the corporate level.

Operationalization of constructs

The two key functional domains central in this paper are advanced manufacturing technologies and HRM policies. To capture the current conceptions of both core variables within the companies interviewed, we decided to mostly derive workable typologies empirically while taking notice of the dominant categories that currently circulate in the literature (reference withheld). This is explained below.

Manufacturing technology

To analyze the technological setting of the companies in our sample, data were gathered on two topics. First, broad production types were analyzed by applying a set of eleven categories similar to Woodward's (1965) typology. In order to be able to compare the data from the two countries, however, few modifications prior to analysis had to be made. Since the set of categories applied in Great Britain differed slightly from the Dutch classification, the companies in both countries were re-assigned to the three broad categories of (1) unit and small batch production (absent in our sample), (2) large batch and mass production and (3) continuous process production. In a way, this three-way typology is consistent with Woodward's (1965). The procedure is summarized in Table 1.

Insert Table 1

Second, the impact of advanced manufacturing technologies was examined by asking the companies' production managers which advanced manufacturing technologies were in use and how they perceive their production environment. The perceptions of the production environment permitted to investigate whether the firms which implemented advanced manufacturing technologies, perceived significantly different trends in the development of manufacturing technology than their non-adopting counterparts. Mann-Whitney tests on the set of statements describing developments in manufacturing technology indeed revealed significant differences (Table 2).

Insert Table 2

Subsequently, a refined classification of eight production systems was developed that incorporates the implications of the adoption of advanced manufacturing technologies in terms of the level of organizational flexibility and integration (reference withheld).

<u>Large batch and mass production</u>

1. *Modified large batch and mass production*. This group contains firms that only employ CNC machines in production and/or MRP in their planning function. This category captures the technically least integrated and least flexible firms of the sample.
2. *Automated large batch and mass production*. The companies in this group integrated automation of their production function - by CNC machines and/or robots and/or CPS - with automation of the design of the production process through CAPP and automation of the planning function via MRP. So, compared to the first cluster, more integration has been achieved, implying that increasing flexibility is within reach.
3. *Flexible large batch and mass production*. This category comprises firms that automated their production process in an integrated way through CAM - in addition to CNC machines

and CPS -, the design function with CAD, CAPP and/or CAE and the planning function with MRP.

4. *Innovative large batch and mass production*. These companies are most advanced by integrating the three components of computer integrated manufacturing and flexibility. They automated their production function through at least the use of FMS - in addition to CAM and/or CNC machines and/or Robotics and/or CPS -, and integrated their design function with at least CAD - in addition to CAPP - and their planning function with MRP.

The four different levels of integration and flexibility in large batch and mass production should be viewed as elements of a continuum, where a company could progress from category 1 to 4 by implementing more new manufacturing technologies that increasingly enhance the level of integration and flexibility.

Continuous process production

5. *Automated planning in continuous process production*. This category includes companies that only automated their planning process with MRP. Advanced automation of neither the production nor the design function was implemented.
6. *Automated design in continuous process production*. This group contains firms that only automated their design function with CAD, CAE and/or CAPP without automating the production or planning function.
7. *Automated continuous process production*. This cluster captures companies that restricted automation to their production function by implementing CPS. Automation of neither planning nor design was in use.
8. *Flexible continuous process production*. The companies in this category employ CAM in production in addition to CPS, automated their planning function with MRP and their design function with CAD and/or CAE.

The different levels of integration and flexibility in continuous process production cannot all reflect a continuum, since the first three categories represent the automation of just a single function of computer integrated manufacturing (Vonderembse & White, 1991). A company can progress from automation of just a single function to multi-function integration. The fact that in continuous process production a lower variety of automation profiles is found, is not surprising. Since advanced manufacturing technologies offer opportunities for process integration and parts variety, the impact on continuous process production - where process integration is to a large extent already achieved and parts variety is thus not really permitted - is limited.

Human resource management

As has been proposed in an earlier paper (reference withheld), the HRM policies can be classified along two dimensions: the extent of strategic integration (Schuler, 1990 & 1992) and the degree of decentralization (Brewster & Larsen, 1992; and Storey, 1992). From this, four different types of HRM strategies can be derived:

1. *a traditional personnel management strategy*, where the level of strategic integration is low and the HRM strategy is formulated in a relatively centralized manner;
2. *an evolving HRM strategy*, where the level of strategic integration is low but the HRM strategy is formulated in a decentralized manner;
3. *an imposed HRM strategy*, which is integrated with the competitive strategy but developed in a centralized manner; and
4. *a true HRM strategy*, which is integrated with the competitive strategy and formulated in a decentralized manner.

In our sample the companies are classified according to both dimensions of HRM policies. The level of strategic integration was examined qualitatively so as to reveal whether personnel is specifically considered when the general strategic objectives of the organization are discussed (Schuler, 1990 & 1992), whether the personnel department is involved from the outset in the development of an HRM or personnel strategy and whether this strategy is written down formally. The level of decentralization was analyzed by examining the position of the personnel department within the structure of the organization (Brewster & Larsen, 1992; and Storey, 1992). Additionally, in Great Britain questionnaire data regarding decision-making responsibility in each of the three categories of HRM choices were analyzed: i.e., (i) recruitment and selection, (ii) performance appraisal and compensation and (iii) training and development. Note that analyses regarding the specifics of the actual implementation of the HRM components in both countries cannot sensibly be undertaken, because the mitigating effect of country-specific features such as industrial relations and education systems imposes different constraints on managerial discretion (reference withheld).

THE IMPACT OF ADVANCED MANUFACTURING TECHNOLOGIES ON WORK ORGANIZATION AND HRM POLICY DESIGN

Advanced manufacturing technologies and the organization of work

The increasing complexity, interdependence and uncertainty in the production environment that result from the implementation of advanced manufacturing technologies, can mainly be attributed to a further integration of the different parts of the production process together with an increase in product variability. When product variability outpaces the volume growth of output, work flow continuity and rigidity of differentiation are likely to decrease (Sorge, 1989). The responsibilities of employees are thus extended: their tasks shift from routine and repetitive to responsive and craft like, and the associated behavior should change from standardized to adaptive (Nemetz & Fry, 1988). Furthermore, the enlarged integration of the production process parts not only increases the number of aspects of the physical production process that have to be understood, but also requires knowledge of the information flows that drive the production process. The identification and solution of problems therefore increase in complexity (Adler, 1988).

This increase in the diversity and complexity of tasks that comes with the introduction of advanced manufacturing technologies, has also emerged from case study research in continuous and discontinuous process industries in France (Cavestro, 1989) and an in-depth study of the National Bicycle Industrial Company (NBIC) in Japan (Kotha, 1995). In addition to the fact that the task content becomes more complex, behavioral skills deserve more attention, too. With a tighter integration of different parts of the production process, it is no longer feasible for individual specialists to be responsible for their area of expertise only, without an understanding of how these parts relate to the larger whole (Hayes & Jaikumar, 1988). In order to manage the integration of different parts of the production process, inter-functional cooperation and team work gain importance (Buitendam, 1987; and Duimering, Safayeni & Purdy, 1993) so as to enable a systems view of the production process (Leonard-Barton, 1992). Furthermore, inter-functional cooperation and team work could create an environment in which learning and knowledge creation is facilitated (Senge, 1990; Leonard-Barton, 1992; and Nonaka, 1994). In general, through the introduction of advanced manufacturing technologies, the breadth as well as the depth of jobs is 'upgraded' through requiring higher technical, conceptual, analytical and problem-solving skills (Hayes, Wheelwright & Clark 1988; and Snell & Dean,1992).

The moderating effect of structural arrangements

The fact that the implementation of advanced manufacturing technologies alters the contribution expected from employees, does not automatically imply that organizations change their structures accordingly. The relationship between advanced manufacturing technology and job design is moderated by manifestations of organizational inertia (Child, Ganter & Kieser, 1987; and Kelley, 1989). Dean and Snell (1991) report that size, performance and dependency on a parent corporation are three factors that influence the technology-job design relationship. These findings indicate that it is a combination of technical, organizational and environmental factors that influences how the organization of work is configured. This implies that next to discussing the presumed 'ideal' configuration of advanced manufacturing technology and job design, it is equally important to analyze the implications that advanced manufacturing technologies may have for the re-design of other structural arrangements. To provide an illustration, the two extreme forms of mechanistic and organic organizations are discussed subsequently.

Organizations with mechanistic structures, on the one hand, face more difficulties dealing with the implementation of advanced manufacturing technologies than organizations with organic structures (Zammuto & O'Connor, 1992). In a mechanistic structure, organizations emphasize a control-oriented approach aimed at efficiency so as to deal with increased uncertainty. A control-oriented approach implies centralization of decision making and problem solving, resulting in simplified and highly specialized production jobs that are limited to the physical execution of work. The manufacturing process is viewed as a set of well-defined tasks that can be designed in an optimal manner by higher level staff or management. So, labor is a variable cost that can be reduced by creating tasks that are as specific - and thus as efficient - as possible. When uncertainty increases, more control is exercised. Although this approach may result in increased productivity due to less direct labor and training cost, the 'de-skilling' of jobs and the centralized structure prohibit organizational learning - making the successful implementation of advanced manufacturing technologies, and thus flexibility, very difficult

(Hayes, Wheelwright & Clark, 1988; and Zammuto & O'Connor, 1992). The paradox of this approach, however, is that through the implementation of advanced manufacturing technologies employees get more access to information on the production process but are prohibited to act upon it. Not only will this undermine the morale at the work floor, but it will also constrain exploiting the full potential of advanced manufacturing technologies (Hayes, Wheelwright & Clark, 1988).

Organic structures, on the other hand, are flexibility oriented. The manufacturing process in these organizations is seen as complex and changing. The increased complexity, interdependence and uncertainty associated with the implementation of advanced manufacturing technologies are therefore dealt with by decentralization of expertise and decision making. Management seeks to enhance the skills of employees at a decentralized level, implying the availability of multi-skilled workers in semi-professional positions. Because employees need to use their skills innovatively, organizational learning is enhanced so that the flexibility benefits of advanced manufacturing technologies are easier to obtain (Hayes, Wheelwright & Clark, 1988; Dean, Yoon & Susman, 1992; and Zammuto & O'Connor, 1992). Disadvantages, however, are higher training costs and higher wages of the multi-skilled workers.

The phenomena that are associated with mechanistic and organic approaches to advanced manufacturing technologies, are similar to two effects discussed by Child (1987) and Sorge, Hartmann, Warner & Nicholas (1983). Child (1987) discusses a strategy of job degradation or even job elimination - which would fit a mechanistic perspective - as opposed to a strategy of polyvalence with the removal of job demarcation together with job enrichment programs - which fits with an organic approach. Sorge, Hartmann, Warner & Nicholas (1983) distinguish companies that employ advanced manufacturing technologies to reinforce the control of personnel through polarization and differentiation of functions (mechanistic) from those that utilize advanced manufacturing technologies to extend the responsibilities of the production workers through depolarization and integration (organic).

Propositions on advanced manufacturing technology and HRM policy design

The above implies that (i) the job of production workers becomes increasingly complex due to changes in the production environment and (ii) structural arrangements have a large impact on how the management of human resources is perceived. So, to investigate the role of HRM policies in the implementation of advanced manufacturing technologies, two issues need to be considered. The first issue refers to the impact of the type of automation method on the production environment. As becomes apparent from the typology developed in the first section, there are different intensities in which advanced manufacturing technologies are adopted. This implies that changes in the production environment depend on the extent of automation and the type of automation method implemented. For example, the implementation of a CAD/CAM system might have a very different impact compared to the influence of the implementation of a FMS. This generates our first proposition.

Proposition 1: *The type of changes in the production environment differ with the extent of automation and type of automation method implemented.*

The second issue deals with the role of structural arrangements. In terms of the HRM typology derived earlier, the mechanistic and control-oriented approach to the management of personnel resembles traditional personnel management and, in a sense due to its centralized nature, imposed HRM. Because labor is unskilled or semi-skilled, recruitment and selection practices will be relatively simple and informal, training is limited and performance appraisal is aimed at detecting deviations from the standard (Snell & Dean, 1992). Because of the high level of specialization, jobs are narrowly defined and rewarded by individual incentives, hourly wages and seniority pay (Snell & Dean, 1994). Management of personnel in organic structures will closely resemble a true HRM approach and, due to its decentralized nature, evolving HRM. Because employees perform 'knowledge work', recruitment procedures are more sophisticated, training is more comprehensive and performance appraisal is geared toward improvement of the functioning of employees (Snell & Dean, 1992). Because jobs are defined more broadly and team work is important, employees tend to be rewarded by group as well as individual incentives, salary and seniority-based pay (Snell & Dean, 1994).

There are however some problems with this line of reasoning. Firstly, these two approaches to the management of personnel represent extremes on a continuum. The relationship between advanced manufacturing technology and personnel management is too complex to simply predict that traditional manufacturing is associated with traditional personnel management, while advanced manufacturing technologies are associated with true HRM. As said earlier, there are different intensities in which advanced manufacturing technologies as well as in HRM practices are adopted. Secondly, the direction of the relationship between the management of personnel and the successful implementation of advanced manufacturing technologies is not clear. Because of the existence of organizational inertia, organizations may either have implemented advanced manufacturing technologies in a mechanistic structure, being unable to meet the changed HRM requirements, or may have invested already in a HRM approach to personnel, being thus more likely to adopt advanced manufacturing technologies in the (near) future (Snell & Dean, 1992).

Because of the different intensities in the level of adoption of advanced manufacturing technologies and HRM policies as well as the difficulty in determining the direction of the relationship, a proposed framework of possible HRM-technology combinations is presented in Table 3.

Insert Table 3

Proposition 2 in Table 3 is based on three underlying assumptions. First, the HRM policy of the company does not apply to the production function alone but to the entire organization. So, production is just one of the functional areas that relate to the effective HRM policy. This might explain why a true, evolving or imposed HRM approach is employed when just modest implementation of advanced manufacturing technologies has taken place. Second, the content of the four HRM policies - in terms of specific HRM practices - is not known. The four HRM policies are categorized on the basis of the level of centralization and decentralization on the one hand and the level of strategic integration on the other hand. This explains the lack of differentiation in HRM policies for the categories of intermediate and extended implementation of advanced manufacturing technologies. Finally, we assume that organizations only change current practices if and when they perceive a need for change. So, to obtain a match between the HRM policy pursued and the advanced production technology implemented the production manager as well as the HRM manager have to perceive similar changes in the production environment. In the 'ideal' situation this would imply that cooperation between both managers has taken place, either by means of integrating both production as well as HRM policies with strategy - as would be the case in true HRM or imposed HRM - or through decentralization of HRM policies - which is reflected in true HRM as well as evolving HRM.

Some risk, however, remains with the imposed or evolving HRM policies. If personnel management is centralized, as is the case in imposed HRM, the changes in the production environment could just be perceived differently at the higher management level, resulting in other changes than required at the lower production level. Because of the centralized nature of imposed HRM, the approach could become mechanistic, thereby blurring the boundaries between imposed HRM and traditional personnel management. In the case of evolving HRM, the necessary changes might be perceived and induced at a decentralized level, but not approved by centralized management when they deviate from the strategy pursued.

RESULTS

Two steps

The analysis of the technology-structure relationship in our sample comes in two steps. First, the impact of the introduction of advanced manufacturing technologies on the production environment is examined in the first subsection (Proposition 1). The next subsection then analyzes whether the HRM policy chosen is in conflict with or in support of the production system that is implemented (Proposition 2 in Table 3).

The impact of advanced manufacturing technology on the production environment

Before the prevailing technology-HRM combinations in our sample can be analyzed, first the question whether and how the automation methods alter the production environment needs to be answered. Whether the adoption of each of the advanced manufacturing technologies results in a significantly different perception of the production environment in continuous process production as well as in large batch and mass production, is tested with non-parametric Mann Whitney statistics. The results for large batch and mass production on the one hand and continuous process production on the other hand are presented in Tables 4 and 5, respectively.

Insert Table 4

Insert Table 5

From Tables 4 and 5, we may conclude that many of the individual automation methods can result in a different perception of the production environment. Furthermore, the difference between large batch and mass production on the one hand and continuous process production on the other hand becomes apparent. For three of the automation methods - CAD, CAE and CAM - no significant difference in the perception of the production environment occurred between those companies that did implement these technologies and those that did not. This could be due to either the fact that these methods were implemented some time ago so that no changes in the production environment are perceived anymore, or the fact that the importance of these technologies to the entire production process is limited. Unfortunately, no data are available to explore this issue. Each of these developments and their influence on the management of personnel are discussed in the course of the next subsection.

Advanced manufacturing technology and HRM: opposing or reinforcing policies?

To determine whether advanced manufacturing technologies and HRM policies oppose or reinforce each other, the extent of automation as well as the type of automation methods is considered. The relationship of the extent of automation to HRM is examined first by means of Mann Whitney tests. The HRM categories were combined into centralized HRM - consisting of traditional personnel management and imposed HRM - on the one hand and decentralized

HRM - pertaining to true HRM and evolving HRM - on the other hand. Although decentralized HRM obtains a slightly higher mean ranking on the number of advanced technologies implemented (9.82 as opposed to 9.00 for centralized HRM), no significant differences appear. Also, when the HRM categories are combined into strategically integrated HRM - consisting of true HRM and imposed HRM - and HRM not integrated with strategy - i.e., evolving HRM and traditional personnel management -, no significant differences appeared. The mean ranking on the number of advanced manufacturing technologies implemented is, however, again slightly higher for HRM integrated with strategy than for HRM not integrated with strategy (10.38 as opposed to 8.80).

So since no general relationship between the advanced manufacturing technologies and the HRM categories can be detected, the technology-HRM combinations that are employed in each of the companies interviewed are summarized in Tables 6 and 7.

Insert Table 6

Insert Table 7

Each of these combinations will be subsequently discussed with reference to the results in Tables 4 and 5. Although it is, of course, generally not appropriate to use Tables 4 and 5 - since these present significant differences at an aggregated production system level - for the analysis of the individual companies, we deliberately do so here. The reason for this is that Tables 4 and 5 describe how companies with large batch and mass production on the one hand and continuous process production on the other hand perceive, on average, changes in the production environment when advanced manufacturing technologies are implemented. So, for example, in large batch and mass production the implementation of CAM is in the majority of companies associated with an increasing specialization of skills (Table 4). At the company level of analysis, an individual organization which implemented CAM, may not perceive this increasing need for specialization of skills, and may therefore adapt - or refrain from changing - its HRM policy accordingly. In this case, the company perceives its technology-HRM combination as consistent, but compared to competition it is not. Therefore, the aggregated results serve as an average standard, or benchmark, against which HRM policies are examined in the individual companies.

It should be noted that due to lack of data on the content of the HRM categories the discussion, unfortunately, can merely provide tentative suggestions on a potential HRM-technology fit. Furthermore, country and/or industry differences are not specifically examined because the companies are studied at the individual level, making more general suggestions on country and industry differences not feasible. The nationality and industry of each company will, however, still be indicated. The numbers of the firms correspond to a short company description in Appendix A. The results on the technology-HRM fit for all cases are summarized in Table 8.

Insert Table 8

LARGE BATCH AND MASS PRODUCTION

1. Modified large batch and mass production

Company 16 - a Dutch food & drink firm - with traditional personnel management has automated parts of the production process through the use of CNC machines. The only development that is perceived significantly different is that the time between the initial idea for a new product and readiness to enter into production remains constant or possibly decreases (Table 4). Although in itself the impact of this development on the management of personnel is limited, it could imply that parts of the production process become more efficient in the sense that the time needed to change the production process to manufacture a different product is reduced. The responsibilities of the production worker are then extended, since more planning and programming takes place at the CNC machine directly (Sorge, 1989). The impact of CNC machines on the management of personnel in this case is thus limited to the production employees working with the new technology. Since, however, personnel is managed in a traditional fashion, fitting within a mechanistic approach, the production workers' job is not expected to be altered significantly. The authority to change the programming or planning on the machines will be located at a higher level in the organization. As, however, the main emphasis seems to be on efficiency rather than flexibility, the present traditional personnel management system is not expected to constrain the functioning of the production process (yet).

Company 4 - a Dutch chemical firm - practicing evolving HRM, implemented CNC machines in production in combination with MRP in the planning of materials. In addition to the development in the production environment associated with CNC machines, three other developments related to the use of MRP have to be taken into account. MRP is associated with decreasing inventories of work-in-process and final products, increasing integration of the stages of the production process and a reduction of subcontracted work. So, MRP is mainly concerned with process flexibility. The production environment becomes considerably more complex, though, than when just CNC machines are introduced, because the increased integration can only be achieved when the differentiation of functions becomes less rigid (Sorge, 1989). In other words: jobs that were previously separated are combined, and are possibly even taken over by CNC machines. This implies an upgrading of the required qualifications of the employees, in the sense that their insight into the production process needs to be expanded so as to obtain the necessary integration. In an evolving HRM approach, the possibility is created at a decentralized level to act upon the requirements of larger integration and to obtain the efficiency benefits of a CNC-MRP combination. MRP as a planning system alone cannot, of course, provide the integration.

2. Automated large batch and mass production

Company 17, a Dutch food & drink firm employing traditional personnel management, has implemented all the automation methods mentioned above. Table 4 indicates that this firm therefore faces a whole variety of developments in the production environment: the range of products does not increase (CAPP), but the batch size in which the existing products are produced has become larger (Robots and CPS). This can only be associated with more efficient production when inventories decrease (MRP) and the stages of the production process are integrated further (MRP). The production process becomes more continuous in the sense that economies of scale can be obtained as a result of the increased batch size and enhanced integration. Although it may seem that from its emphasis on efficiency traditional personnel management would fit well with this production system, it will fail to create the conditions in which integration between the stages of production is facilitated. When the potential for integration is not realized, efficiency benefits will be lost due to the building up of inventories. A true or evolving HRM approach, in which the skills of the employees are enhanced and their responsibilities extended, would provide a better fit.

Company 9 - a British food & drink firm - has automated its production through the use of CNC, its planning system by MRP and its design of the production process with CAPP. This firm operates within an evolving HRM approach. Considering, again, the necessity to realize the integration potential provided by MRP and CAPP, an evolving HRM approach seems to be appropriate.

3. Flexible large batch and mass production

Company 2 - a British chemical firm - employs traditional personnel management. Moreover, this firm automated production by using CAM, CNC and CPS, whereas planning is automated with MRP and design through CAD. This company faces almost the same changes in the production environment as company 17, though the complexity is even larger because CAD and CAM are installed as well. The use of CAD and CNC machines results in a conflicting change pattern: the time it takes to enter a new product idea into production increases (CAD) as well as decreases (CNC). Furthermore, a need for an increasing specialization of skills is perceived (CAD and CAM). So, in this firm the interesting combination occurs of a less rigid differentiation of functions due to increasing integration between the phases of production on the one hand and an increasing specialization of skills due to the creation of new work roles and occupations on the other hand (Sorge, 1989). Traditional personnel management will deal with this increased complexity by intensifying control and thus providing more detailed job descriptions, procedures and regulations. It is very unlikely that within this personnel management system employees can be motivated, trained and retained to deal with such a complex and differentiated environment.

Company 12 - a British food & drink firm - adopted a true HRM policy and automated the production function through the introduction of CAM, CNC and CPS, the design functions through applying CAD, CAE and CAPP and the planning function with MRP. The changes in the production environment closely resemble those facing company 2, though two other developments are added: the number of people involved in design and development does not increase compared to the number of production workers (CAE), and the management of materials is decentralized to work stations (CAE). Especially the latter change is important, since this implies a substantial increase in the discontinuity of the production process while at the same time increasing the batch size. Integration of the different phases of production now becomes crucial to decrease inventories (Sorge, 1989). So, although in this company, too, decreasing differentiation of functions is combined with increasing specialization of skills, the consequences of an inappropriate management of personnel will be far more serious. If integration is not achieved, efficiency benefits will be lost due to the increasing inventories that are build up between the discontinuous stages of production. A true HRM approach therefore is most likely to be able to prevent this from happening. Furthermore, although no significant increase in production or design variants appeared yet, it could create the atmosphere in which not only efficiency but also flexibility benefits could be obtained.

Finally, company 13 - again a British food & drink firm - pursues a true HRM policy and implemented CAM in production, CAD and CAPP in design and MRP in planning. The changes in the production environment for this company can, again, be summarized as generating an extension of the responsibilities of production workers due to a less rigid differentiation and an increasing specialization of skills. True HRM should be able to create the environment in which employees can successfully deal with these changes.

4. Innovative large batch and mass production

Company 10 - a British food & drink firm - with an evolving HRM approach automated production through FMS and CPS, design through CAD and CAPP and planning through MRP. Surprisingly, no significantly different developments in the production environment were perceived by those companies that did implement FMS compared to those that did not. One explanation could be that since this is one of the most flexible - and thus advanced - production systems than can be employed, the companies implemented FMS in stages and/or some time ago, causing them to perceive no changes in the production environment anymore. This implies that they are already operating in a more complex environment. If the implementation of FMS really does not cause any significant changes, the production environment is similar to the one that the firms in the category of flexible large batch and mass production are facing. In either situation, evolving HRM seems to be suitable. For company 11 - again a British food & drink firm that utilizes true HRM - a similar reasoning applies. True HRM also fits with either scenario discussed above.

Company 3 is an interesting case. This British chemical firm automated production by means of CAM, FMS, CNC machines and Robots as well as design with CAD and CAPP. What is lacking here, though, is MRP (the automation of the planning function), which was associated with a perceived increase in integration of the production stages. So, here batch size increases (Robots), while inventories of work-in-progress and final products are perceived to decrease (CAD) without an increase in integration. Although CAD can contribute to a more efficient planning and programming of the production process (Sorge, 1989), and thus potentially to a decrease of inventories, no significant increase in integration results from the use of CAD (p = 0.2207). The only possible explanation is that the employees themselves, instead of an automated method, provide a substantial part of the coordination between the production stages. Whether this would be feasible in the longer run is questionable, even with true HRM.

CONTINUOUS PROCESS PRODUCTION

5. Automated planning in continuous process production

A Dutch food & drink firm, company 14, automated its planning process through MRP. The only change in the production environment associated with MRP is that the number of people involved in design and development increases, compared to the number of production workers. The meaning of this statement is, unfortunately, not completely clear: does it refer to the design and development of new products or to the design and development of the production process? When it relates to the design and development of new products, this change at first sight seems to be unrelated to MRP. However, it appears that the companies that implemented MRP also perceive, although not significantly, an increase in the number of products (p = 0.1635) and the variety of production and design variants (p = 0.1190). Since in continuous process production it is very unlikely that many people were involved in design and development of new products, a small increase in this number can already lead to a significant result. When, however, the statement refers to the design and development of the production process, it makes more sense. Since in continuous process production the production process itself is highly regulated and automated, there are no or just relatively few people directly involved with the production process itself. People working in the production function are mainly concerned with the design and maintenance of the system (Mintzberg, 1983). So, when an automated system for material planning is introduced, this may generate a further increase in the number of people involved in designing the process. The impact on the management of personnel in both cases, however, is limited to the possible creation of new functions in design and development. True HRM will certainly fit with this environment, and can also create the mentality that makes further implementation of advanced manufacturing technologies possible.

6. Automated design in continuous process production

A Dutch food & drink firm - company 19 - combines true HRM with automation methods of the design function by means of CAD, CAE and CAPP. The implementation of CAD as well as CAE shows no significantly different perception of developments in the production environment. Two changes are, however, associated with CAPP: batch size and the amount of work subcontracted both increase. The rise in batch size is a logical consequence of the more efficient planning of the production process, while the increase in subcontracting points to decreasing complexity in the production environment within the firm (Sorge, 1989). Both developments are not expected to have a large impact on the management of personnel. Although the production function in this company could therefore probably also function with traditional personnel management, the use of true HRM will facilitate future implementation of advanced manufacturing technologies.

7. Automated continuous process production

Company 5 employs traditional personnel management, whereas company 6 pursues evolving HRM. Both firms are Dutch chemical companies that only automated their production function with CPS. The only significantly different perception of developments in the production environment is that there is no increase in integration between the different stages of production. This makes sense, since more integration between production stages than is achieved in automated continuous process production, is hardly physically possible. The impact on personnel is therefore expected to be limited, so company 5 with traditional personnel management as well as company 6 with evolving HRM employ a compatible HRM-technology combination.

8. Flexible continuous process production

Company 7 - a Dutch chemical firm - and company 18 - a Dutch food & drink firm - both employ traditional personnel management, and both automated their production by implementing CPS and CAM, their planning system through MRP and their design function with CAD and CAE. They therefore face a production environment in which the number of people involved in design and development increases without perceiving further integration of production stages. Both developments were discussed above. In combination, however, they are likely to induce more complexity in the production environment. Although the use of CAD and CAE was not associated with a significantly different perception of developments in the production environment, they may, in combination with MRP, point towards an attempt to make production of a larger number or variety of products feasible without, through CPS, losing efficiency. If this is the case, then traditional personnel management constrains this development. If this is not the case, and merely increasing efficiency is the objective, traditional personnel management will not hinder this. The question then, however, remains why implementation of so many automation methods was necessary and whether the efficiency benefits gained will offset the costs incurred.

Company 1 - a British chemical firm - manages its personnel through imposed HRM and has automated its production function by means of CAM plus CPS and its design function with CAD. The only significantly different perception of developments in the production environment is associated with CPS: there is no increase in integration between the stages of production. Since the impact on the management of personnel is therefore limited, imposed HRM is appropriate. Finally, company 15, a Dutch food & drink firm with a true HRM approach, uses CAM, CPS and MRP. It therefore faces developments similar to those for companies 7 and 18. With a true HRM approach, however, it is expected to be able to cope with any possible future changes.

CONCLUSION

In this paper the HRM-production technology combinations that the companies employ, are analyzed in two steps. First, it is examined how the implementation of advanced manufacturing technologies is perceived to alter the production environment in large batch and mass production on the one hand and in continuous process production on the other hand. Second, the influence of these changes on the management of personnel is explored. Our sample reveals that the impact of advanced manufacturing technologies differs by the extent of automation and the type of automation method implemented. Furthermore, the impact is largest in large batch and mass production, mainly due to a perceived increase in integration between the stages of production and a decrease in inventories of work-in-progress and final products. The demands posed upon the management of personnel are therefore higher in large batch and mass production than in continuous process production. The only incompatible HRM-technology combinations were therefore located in large batch and mass production firms, since in continuous process production traditional personnel management provides a sufficient match in most cases. Both companies where inconsistent combinations are detected, employ traditional personnel management in conjunction with a manufacturing technology that requires a more flexible management of employees. Because the impact of advanced manufacturing technologies is less severe in continuous process production, five companies with continuous process production pursue HRM policies that are too advanced for the production technology implemented. All the other companies, strictly speaking, pursue a consistent combination of HRM and technology policy. The findings are summarized in Figure 1.

Insert Figure 1

What, unfortunately, could not be determined, is the direction of the relationships summarized in Figure 1.

Furthermore, the discussion on the HRM-technology combinations can only be tentative for four reasons. Firstly, the benchmark used to evaluate the impact of the implementation of advanced manufacturing technologies is the average perception of the chemical and food & drink companies in the sample. Since this sample is by no means intended to be representative of the entire chemical and food & drink population, further research in a broader context is necessary to examine whether the perceived changes in the production environment after the implementation of advanced manufacturing technologies indeed hold. Secondly, the content of the HRM categories remained uncovered, making it impossible to determine the extent to which HRM programs are implemented when a HRM policy is pursued. Thirdly, also no information is available on the date of implementation of the advanced manufacturing technologies. The date of implementation is important to gain an understanding of how well accustomed the companies already are to the new production environment. If the implementation took place a considerable time ago, the changes in the production environment may be underestimated due to the fact that the companies grew accustomed to a higher level of complexity and thus not perceive differences anymore. When this is indeed the case, it is possible that in the firms where traditional personnel management is, as yet, not in conflict with the manufacturing technology employed, still a misfit prevails. Finally, the competitive environment and the generic strategy pursued influence the way in which a firm manages its employees when advanced manufacturing technologies are implemented. For example, HRM policies that emphasize training and development of employees might be necessary in a competitive environment in which quality is of utmost importance to survive, while in an environment in which lowest cost are crucial traditional personnel policies prevail (Child, 1987). The same reasoning applies to whether flexibility or efficiency considerations guide the generic strategy pursued.

Nevertheless, from the number of consistent combinations, we may conclude that the interaction between the manufacturing technology, work organization and HRM policy does indeed operate. Additionally, the number of "over"-fits suggests that limited investment in advanced manufacturing technologies can be compensated by a larger investment in HRM. The larger investment in HRM would then influence the work organization in such a way that the same net effect results as when the work organization would be changed through use of advanced manufacturing technologies: i.e., increased efficiency and flexibility. This finding hints at the feasibility of combining Porter's (1980) generic strategies of cost leadership and product differentiation. New manufacturing technologies relax the stuck-in-the-middle dilemma. More research on this proposition, however, is necessary to draw definite conclusions.

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APPENDIX

SAMPLE STATISTICS

The characteristic sample statistics of British and Dutch companies in the chemical and food & drink sample are listed in Table A1.

Number	*Nationality*	*Industry*	*Size in number of employees*	*Type of product*	*Main target market*
1	British	Chemicals	25,800	Bulk & specialty chemicals	Industrial
2	British	Chemicals	3,061	Bulk chemicals	Consumer
3	British	Chemicals	1,100	Bulk & specialty chemicals	Consumer
4	Dutch	Chemicals	308	Specialty chemicals	Industrial
5	Dutch	Chemicals	Missing for company: 25,000 for entire group	Bulk chemicals	Industrial
6	Dutch	Chemicals	161	Bulk & specialty chemicals	Industrial
7	Dutch	Chemicals	270	Bulk chemicals	Industrial
8	Dutch	Chemicals	1,950	Bulk chemicals	Consumer
9	British	Food & drinks	744	Specialty teas	Consumer
10	British	Food & drinks	1,723	Alcoholic & non-alcoholic beverages	Consumer
11	British	Food & drinks	12,000	Confectionery	Consumer
12	British	Food & drinks	6,001	Frozen foods	Consumer
13	British	Food & drinks	2,524	Confectionery	Consumer
14	Dutch	Food & drinks	434	Alcoholic & non-alcoholic beverages	Consumer
15	Dutch	Food & drinks	1,270	Basic food product in bulk	Consumer
16	Dutch	Food & drinks	162	Frozen potato products	Consumer
17	Dutch	Food & drinks	360	Dairy products	Consumer
18	Dutch	Food & drinks	Missing for company: 7,077 for entire group	Dairy products	Consumer
19	Dutch	Food & drinks	100	Dairy products	Consumer
20	Dutch	Food & drinks	1,100	Confectionery	Consumer

Table A1: *Sample characteristics of the British and Dutch companies in the chemical and food & drink industry*

QUESTIONNAIRE

The data in this paper are collected by means of a structured questionnaire which was developed by the International Organizational Observatory (IOO). The IOO is a group of organizational researchers based in six European business schools. The group was inaugurated by CRORA, Bocconi University, Milan, Italy. Apart from the items addressed in this paper, the IOO questionnaire covers issues of the competitive environment, strategy, structure, R&D, control and information systems (reference withheld). Data collection in the British companies was performed by the British team at the Open University. Although the questionnaire used in Great Britain and the Netherlands is the same on most topics, also slight differences were introduced during the process. In this case, the questions for both countries are presented. The original language of the Dutch questionnaire is Dutch. It has been translated for this paper.

Manufacturing technology: Great Britain and the Netherlands

Production system

I. How would you characterize your organization's primary manufacturing technology?
In Great Britain companies chose one description that best characterized their production system; in the Netherlands companies indicated on a scale from 1 (correct description) to 4 (incorrect description) how much truth the indicated descriptions contained.

1. Output is individually produced to the specification of an individual client or small groups of customers.
2. Output is produced in batches of 500 or less.
3. Output is produced in larger batches, but they tend to be modular, consisting of both standardized components and components produced for customers' specification.
4. Output is produced in very large batches or on a mass production basis, and the products change very little over time.
5. Output is produced in very large batches or on a mass production basis, but new products are often brought to the market.
6. Output is for gaseous, viscous or solids, and is produced using continuous process technology.

II. To what extent do you use design and development tools and systems such as the following.
Use the following scale: 0=not in use, 1=used as experiment only, and 2=used.

1. Computer Aided Design (CAD): an information system to facilitate the design and modeling of products.
2. Computer Aided Manufacturing (CAM): an information system that controls manufacturing machinery in an integrated manner.
3. Computer Aided Engineering (CAE): an information system to assist in the examining and testing of design from a structural or engineering point of view.
4. Material Requirement Planning (MRP): an information system to support the planning of materials.
5. Computer Aided Process Planning (CAPP): an information system to support the design of the production process.
6. Robotics: automation of a specific part of the production process.
7. Flexible Manufacturing Systems (FMS): a collection of robots or CNC machines that can be employed in a flexible manner.
8. Computer Numerical Control (CNC): a machine tool that is directly linked to a controlling computer.
9. Continuous Process Software (CPS): software that controls the production process in continuous process production.

Developments in the production environment
Given the current state of production technologies, how do the following statements apply to your organization? Great Britain: 1=incorrect description to 5=correct description; the Netherlands: 1=correct description to 4=incorrect description.

1. The number of products is increasing.
2. The number of variants from standard is increasing.
3. Products are becoming more standardized.
4. The time between the initial idea for new products and their entry into production is becoming longer.
5. Work in progress and stocks of materials are being reduced.
6. Inventories of finished goods are being reduced.
7. Batch size is increasing.
8. The stages of the production process are becoming more closely integrated (from either the organizational or technical point of view).
9. There is a steady increase in the number of people involved in design and development, compared with the number involved in production.
10. There is steady increase in the number of people involved in planning and scheduling the production process, compared with the number involved in production.
11. The management of materials, components and work in progress is becoming decentralized to work stations/groups.
12. Plant and equipment are being used more intensively.
13. The variety and diversity of skills needed to produce output are increasing.
14. The previous statement has been largely resolved by subcontracting specific tasks.

Personnel management/HRM

The Netherlands
The level of strategic integration and decentralization was examined qualitatively by (i) interviewing personnel/HRM managers and (ii) analyzing annual reports, internal company documents and recruitment brochures. The level of strategic integration was determined by (i) whether personnel is specifically considered when general strategic objectives of the organization are discussed, (ii) the personnel department is involved from the outset in the development of an HRM or personnel strategy and (iii) whether this strategy is formally written down. The level of decentralization was determined by assessing the position of the personnel department within the structure of the organization.

Great Britain
Only questionnaire data could be used.

Strategic integration

1. Was the personnel department involved in the development of an HRM or personnel strategy from the outset?
2. Was this strategy formally written down?

Decentralization
Indicate the responsibilities of each of the following categories of personnel:

a. Senior management.
b. Personnel department.
c. Line management.
d. First line supervisors.
e. Other.

1. Who is primarily responsible for the recruitment of different grades of employees?
2. Who is primarily responsible for regulating employee departures of different grades of employees?
3. Who has overall responsibility for career development policies?
4. Who has overall responsibility for training?

Production system		*Woodward's (1965) categories*
1.	Unit production	Unit and small batch production
2.	Small batch production	
3.	Production in large batches of standardized components subsequently assembled diversely	Large batch and mass production
4.	Mass production with no frequent product changes	
5.	Mass production with frequent product changes	
6.	Production in large batches of standardized components subsequently assembled diversely with features of small batch and continuous process production	
7.	Production in large batches of standardized components subsequently assembled diversely with features of mass production but without frequent product changes	
8.	Mass production without frequent product changes in parts of the process and with frequent product changes in other process parts	
9.	Mass production with features of production in large batches of standardized components as well as continuous process production	Continuous process production
10.	Continuous process production	
11.	Continuous process production combined with mass production without frequent product changes, though aspects of the process have features of mass production with frequent product changes	
12.	Continuous process production with features of mass production without frequent product changes	

Table 1: *Assignment of production categories to Woodward's (1965) classification*

Advanced manufacturing technology	*Developments perceived in the manufacturing environment*
1. CAD	- The number of different production and design variants from standard is increasing ($p < 0.09$) - Management of materials, components and work-in-process is being decentralized to work stations ($p < 0.04$) - Increasing specialization of skills is needed ($p < 0.02$)
2. CAE	- Time between the initial idea for new products and entry into production is becoming shorter ($p < 0.08$) - Products are becoming increasingly standardized ($p < 0.04$) - Inventory of work-in-process and final products is being reduced ($p < 0.09$) - Management of materials, components and work-in-process is being decentralized to work stations ($p < 0.004$)
3. CAM	- Number of people involved in design and development compared with those in production increases ($p < 0.05$) - Increasing specialization of skills is needed ($p < 0.04$)
4. CAPP	- Production process stages are more closely integrated ($p < 0.01$) - Management of materials, components and work-in-process is being decentralized to work stations ($p < 0.09$)
5. CNC	- Time between the initial idea of new products and entry into production is becoming shorter ($p < 0.02$) - Inventory of work-in-process and final products is being reduced ($p < 0.03$) - Production process stages are more closely integrated ($p < 0.05$) - Number of people involved in planning and scheduling decreases compared to those involved in production ($p < 0.04$) - Management of materials, components and work-in-process is being decentralized to work stations ($p < 0.05$) - Due to the increasing complexity of the tasks, the amount of work that is subcontracted increases ($p < 0.08$)
6. CPS	- The number of different production and design variants from standard is decreasing ($p < 0.07$) - Inventory of work-in-process and final products increases ($p < 0.07$) - Due to the increasing complexity of the tasks, the amount of work that is subcontracted decreases ($p < 0.04$)
7. FMS	- Inventory of work-in-process and final products is being reduced ($p < 0.05$) - Management of materials, components and work-in-process is being decentralized to work stations ($p < 0.09$)
8. MRP	- Products are becoming increasingly standardized ($p < 0.04$) - Inventory of work-in-process and final products is being reduced ($p < 0.007$) - Production process stages are more closely integrated ($p < 0.04$)
9. Robotics	- Inventory of work-in-process and final products is being reduced ($p < 0.04$) - Production process stages are more closely integrated ($p < 0.03$)

Table 2: *Significantly different developments in production technology when advanced manufacturing technologies are implemented*

	Modest implementation of new manufacturing technologies: - *modified large batch and mass production* - *automated planning in continuous process production* - *automated continuous process production* - *automated design in continuous process production*	*Intermediate implementation of new manufacturing technologies:* - *automated large batch and mass production* - *flexible continuous process production*	*Extended implementation of new manufacturing technologies:* - *flexible large batch and mass production* - *innovative large batch and mass production*
True HRM	*P2a*: HRM can create a context for more technological change	*P2e*: 'Ideal' situation where the management of personnel and the production environment reinforce each other to gain flexibility benefits	*P2i*: 'Ideal' situation where the management of personnel and the production environment reinforce each other to gain flexibility benefits
Evolving HRM	*P2b*: Although HRM can create a context for more technological change, a risk exists that top management interferes when HRM deviates from strategy	*P2f*: Although management of personnel and the production environment reinforce each other, a risk exists that top management interferes when HRM deviates from strategy	*P2j*: Although management of personnel and the production environment reinforce each other, a risk exists that top management interferes when HRM deviates from strategy
Imposed HRM	*P2c*: Although HRM can create a context for more technological change, a risk exists that (i) demands from lower units are not taken into account and (ii) the approach takes on mechanistic features	*P2g*: Although management of personnel and the production environment could reinforce each other, a risk exists that (i) demands from lower units are not taken into account and (ii) the approach takes on mechanistic features	*P2k*: Although management of personnel and the production environment could reinforce each other, a risk exists that (i) demands from lower units are not taken into account and (ii) the approach takes on mechanistic features
Traditional personnel management	*P2d*: Personnel management reinforces emphasis on efficiency and productivity	*P2h*: Personnel management inhibits obtaining flexibility benefits	*P2l*: Personnel management inhibits obtaining flexibility benefits

Table 3: *Proposition 2 (P2a to P2k) on the relationship between technology and HRM*

Advanced manufacturing technology in large batch and mass production	*Developments perceived in the production environment*
1. CAD	- The time between the initial idea for and the production of a new product is increasing ($p < 0.03$) - The inventories of work-in-process and final products are decreasing ($p < 0.08$) - An increasing specialization of skills is needed ($p < 0.06$)
2. CAE	- Batch size is increasing ($p < 0.04$) - There is no increase in the number of people involved in design and development, compared to the number of production workers ($p < 0.09$) - The management of materials, components and work-process is being decentralized to work stations ($p < 0.09$)
3. CAM	- An increasing specialization of skills is needed ($p < 0.06$)
4. CAPP	- The number of different products produced does not increase ($p < 0.07$)
5. CNC	- There is no increase in the time between the idea for a new product and entry into production ($p < 0.09$)
6. CPS	- Batch size is increasing ($p < 0.06$) - There is no increase in the amount of work that is subcontracted ($p < 0.05$)
7. FMS	- There are no significant differences in the perception of the production environment between those companies that did and those that did not adopt FMS
8. MRP	- The inventories of work-in-process and final products are decreasing ($p < 0.08$) - The stages of the production process are more closely integrated ($p < 0.05$) - There is no increase in the amount of work that is subcontracted ($p < 0.03$)
9. Robotics	- Batch size is increasing ($p < 0.07$)

Table 4: *Significantly different developments in the production environment of large batch and mass production when advanced manufacturing technologies are implemented*

Advanced manufacturing technology in continuous process production	*Developments perceived in the production environment*
1. CAD	- There are no significant differences in the perception of the production environment between those companies that did and those that did not adopt CAD
2. CAE	- There are no significant differences in the perception of the production environment between those companies that did and those that did not adopt CAE
3. CAM	- There are no significant differences in the perception of the production environment between those companies that did and those that did not adopt CAM
4. CAPP	- Batch size is increasing ($p < 0.1$) - The amount of work subcontracted increases ($p < 0.09$)
5. CNC	- There are no companies in continuous process production that utilize CNC machines
6. CPS	- There is no increase in integration between the different phases of production ($p < 0.05$)
7. FMS	- There are no companies in continuous process production that utilize FMS
8. MRP	- The number of people involved in the design and development function is increasing, compared to the number of production workers ($p < 0.04$)
9. Robotics	- There are no robots used in continuous process production

Table 5: *Significantly different developments in the production environment of continuous process production when advanced manufacturing technologies are implemented*

	Modified large batch and mass production	*Automated large batch and mass production*	*Flexible large batch and mass production*	*Innovative large batch and mass production*
True HRM			Company#12 Company#13	Company#3 Company#11
Evolving HRM	Company#4	Company#9		Company#10
Imposed HRM				
Traditional personnel management	Company#16	Company#17	Company#2	

Table 6: *Human resource management systems employed in different advanced large batch and mass manufacturing types*

	Automated planning in continuous process production	*Automated design in continuous process production*	*Automated continuous process production*	*Flexible continuous process production*
True HRM	Company#14	Company#19		Company#15
Evolving HRM			Company#6	
Imposed HRM				Company#1
Traditional personnel management			Company#5	Company#7 Company#18

Table 7: *Human resource management systems employed in different advanced continuous process manufacturing types*

	NO FIT: inconsistent HRM technology combinations	*FIT: consistent HRM-technology combinations*	*"OVER"FIT: too much HRM for technology employed*
Large batch and mass production	Company #17 Company #2	Company #16 Company #4 Company #9 Company #12 Company #13 Company #10 Company #11 Company #3	
Continuous process production		Company #5 Company #7? Company #18?	Company #14 Company #19 Company #6 Company #1? Company #15?

Table 8: *Technology-HRM fit in the chemical and food & drink companies*

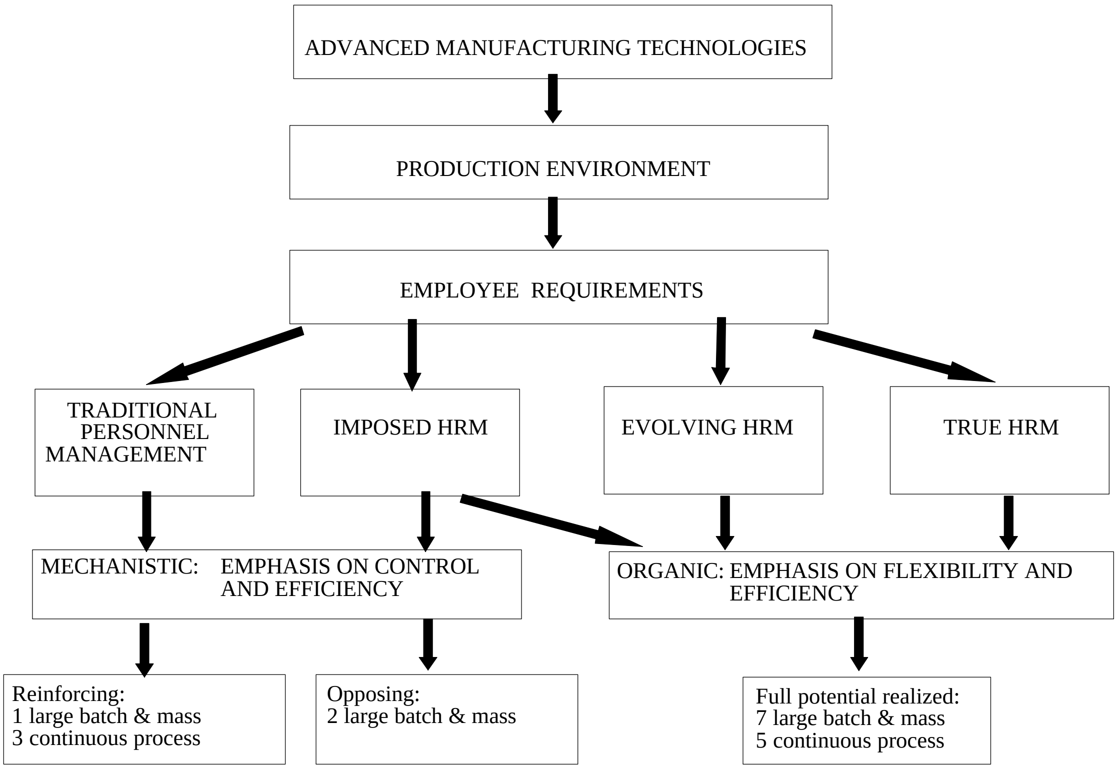

Figure 1: *The relationship between advanced manufacturing technologies and the management of personnel/human resources*