The impact of technological innovations on work design in a cellular manufacturing environment

Eric Molleman and Jannes Slomp

The impact of developments in market and technology on grouping machinery and work design is analysed. Over time a cellular design changed into a functional system with fewer cells, fewer workers and fewer but more advanced machines. This encourages high utilisation, specialised workers and the pooling of similar resources, making operators more process-oriented.

Introduction

In this study, we highlight the impact of advanced new technical equipment on work design issues in a cellular manufacturing (CM) production environment. A large number of studies deal with the influence of technical systems on work design (e.g. Benders, 1993; McLoughin and Clark, 1994) or deal with work design issues in cellular manufacturing systems (e.g. Huber and Brown, 1991). However, as far as we are aware, the impact of advanced new technical machinery on jobs within cellular systems has been relatively under-investigated, which is somewhat odd in view of the fact that in CM literature, human factors are apparently a major issue. In this longitudinal case study, we wish to contribute to this field. A longitudinal approach has the advantage that it provides insight into the dynamics of the complex interrelationship between advanced technology, cellular manufacturing and work design. In the next section we will introduce a model that forms our paper’s rationale.
The model

Cellular manufacturing systems and work content

A CM system is defined here as the grouping of equipment into relatively independent cells which are able to complete a set of part types. The primary objective is to minimise the amount of goods that need processing in more than one cell. As a result, the need for time-consuming and costly coordination between units, which is a burden in a functional lay-out, will decrease (Thompson, 1967; Galbraith, 1973). The potential responsiveness of cells towards changes in demand will be high, because responses do not affect other cells. With respect to human resources, this potential can be effected through cross-training which leads to multi-functional workers (e.g. Park and Bobrowski, 1989). Multi-functionality creates a buffer of capacity so that a cell can deal more effectively with shifts in demand, thus increasing the team’s flexibility (e.g. Ebeling and Lee, 1994; Molleman and Slomp, 1999). Another important potential benefit of multi-functionality is the opportunity for a horizontal integration of tasks, which is likely to contribute to higher quality performance because workers will probably gain better insight into the way different processing steps influence each other. The workers will be able to observe and correct deviations at an earlier stage, and this will improve quality. The integration of tasks will also enhance the job’s specific identity. This, according to the Job Characteristics Model of Hackman and Oldham (1980), will affect the quality of working life in a positive way and enhance the motivation of workers, and thus is likely also to contribute to performance. Shafer, Tepper, Meredith and March (1995) also found that job characteristics in a CM environment motivate employees.

Because cells are independent, it is also easier to move control tasks such as planning, quality control and logistic tasks from supporting staff or management to the cells and add them to the jobs of the operators (vertical integration of tasks). If the operational tasks are where the ‘action’ takes place, the delegation of control tasks adds elements to the cycle of ‘analyses-diagnoses-plan-action-evaluation’ (Kolb, 1984). A cyclical process of planning, doing, evaluating, and improving is the basis for improvements in work methods, for learning, and for involving and motivating workers.

A lot of firms have adopted CM as a strategy for improving performance. Case studies (e.g. Stoner, Tice and Ashton, 1989; Feare, 1995; Fry, Wilson and Breen, 1987; Collett and Spicer, 1995; Laughin, 1995) and survey articles (e.g. Wemmerlov and Hyer, 1989; Wemmerlov and Johnson, 1997; Slomp, Molleman and Gaalman, 1993) show that CM has important advantages; these include shorter throughput times, better product quality, lower material handling costs, and an improved quality of working life.

Technical systems and work content

McLoughin and Clark (1994) describe three main types of change in work content caused by new technology. At the level of individual tasks, advanced manufacturing technology frequently reduces the amount of manual tasks that need to be done, while generating new and complex tasks which require mental problem-solving and an understanding of system interdependencies. At the level of grouping of tasks (i.e. job design at the level of the individual worker and at the team level), new technology offers managerial choices about whether to separate the easy and complex work into different jobs or to integrate them within a single job. With respect to control and supervisory tasks, McLoughin and Clark indicate that in some instances, management has used the introduction of new technology as an opportunity for centralising the control structure, while in other apparently similar situations, managers have used it to delegate control to points as close as possible to the production process itself (vertical integration). This has partly been due to the finding that some new technologies have eroded the role of first-line supervisors, creating opportunities...
for assigning their tasks to a higher level or to delegating them in order to foster local autonomy and decision-making on the shop floor.

In his study on the influence of advanced manufacturing systems on job content, Benders (1993) also makes a distinction between the impact of advanced manufacturing technology on the pool of tasks to be done and on the grouping of tasks into jobs (primarily at the individual worker level) and the division of labour among jobs. He argues that advanced technology generally has the effect of immediately reducing the pool of operational tasks, making workers redundant. The impact on the grouping of tasks and the division of labour is largely indirect and is predominantly driven by managerial choices. However, technology is often attended by the emergence of complex tasks (programming, testing, optimising) as well as simpler operational tasks (loading and unloading), making it less likely that these tasks can be integrated into one appealing and motivating job. He also argues that the more expensive the new equipment is, the more important a high utilisation level becomes. When the addition to the operator’s job of tasks such as maintenance, programming, planning and scheduling obstruct such high levels of utilisation, these tasks will be split off and assigned to another job.

Our purpose in this longitudinal case study is to relate production technology (conventional versus CNC) and the manufacturing system (CM versus functional) to work design (Figure 1). Although our main focus is on the impact of technology on work design, possibly mediated by changes in the manufacturing system (arrows 1, 2 and 3), our data indicates that the elements also affect each other the other way around (arrows 4, 5 and 6). In Figure 1, this dynamic aspect is shown at the hand of arrows coming from both directions.

In the next section we introduce the firm, and more specifically, the Cutting Department, which is the subject of our longitudinal study. In that section we also will briefly describe the design process and the resulting cellular system as it was in the beginning of our longitudinal study in 1987. Thereafter we depict the first period (1987–1993), in which the changes were primarily directed to improving the CM system. Next we focus on the second period (1994–2000) in which changes in the technical equipment are the major issue. There have been a few developments which do not fit exactly within our model, but which have had an impact on work design. These issues will also be briefly described in order to show the relative importance of our model’s context. In the last section, we will discuss our results by relating

Figure 1: The model
Data were collected by means of document analyses and interviews. The study’s second author has had ongoing contact with the firm since the mid-1980s. In the period 1989–2000, 10 Masters students have done their Masters project (seven months’ work) in the firm (mainly within the Cutting Department), supervised by one or both of the authors. The information presented in this paper is based upon document analysis and interviews with various employees. The documents we analysed were production planning reports, performance sheets, reports of important meetings, audits, and master theses. The interviews were conducted by the authors over the course of the last 12 years. Although we have to acknowledge that in 1987 we did not intend to conduct this study, data were collected at more than one point in time, justifying the longitudinal character of our work. The content of this paper was discussed with three key persons who have been employees of the firm for more than 15 years: the production manager, the technical support manager (responsible for investigations into investments and layout) and one of the unit managers. In the event of any doubt, other employees were consulted.

The start

The firm and the Cutting Department

Holec Algemene Toelevering (HAT; in English, Holec General Supplies) is an independent business unit of Holec Systems and Components (HSC). HSC produces systems for the distribution, protection and conversion of electricity. The founding of HAT was the result of a reorganisation that took place within HSC in 1987. General Supplies delivers parts, tools and services to other business units responsible for end products and direct dealings with the clients. These business units also have the right to purchase parts from other suppliers, while HAT is allowed to deliver parts to other firms. The manufacturing of parts is HAT’s main activity. The department can be described as a make-to-order firm. In 1993, HAT carried out about 12,000 production orders, concerning about 6,000 part types. The average repetitiveness was approximately two per year. The number of part types in the HAT database is around 9,000. Some part types are produced in large volumes with low variety.

The CM system was introduced in 1987, at the same time as the establishment of HAT. Previously, parts manufacturing took place in three separate factories, and the processing equipment (about 200 machines) was scattered among these locations. The former manufacturing departments now included in HAT were organised along functional lines. HAT’s CEO decided to introduce a CM system according to a socio-technical systems design (Van Eijnatten, 1993; Benders, Doorewaard and Poutsma, 2000; Molleman and Broekhuis, 2001) in order to improve delivery performance, product quality, costs, the social climate and quality of working life, all of which were far from optimal in the former functional departments. Management considered these performance indicators to be essential for the firm’s survival.

The two dominant design criteria that were applied pertain to the autonomy of cells and to the exchangeability of part types among cells. Autonomy means that a cell should be able to process part types as completely as possible. It was assumed that this would enhance job identity, facilitate the decentralisation of control, result in shorter lead times, improve feedback loops that reduce problems affecting quality, and simplify tracing problems in the event of customer complaints. The exchangeability of part types among cells demands a design with fractal cells (or partly fractal cells). In a pure fractal design, each cell is able to manufacture all part types...
(Montreuil, Venkatadri and Rardin, 1999). It is not based upon set-up and routing similarities, but primarily on the availability of all of the manufacturing resources. Such a design simplifies the balancing of the workload over the various cells without introducing inter-cell movements, and therefore maintains team autonomy. The design process led to a design with 18 cells. The 18 cells were divided into four groups: metal cutting, sheet metal processing and powder coating, sheet metal and strip processing, and punching and galvanic processes. The powder coating and galvanic processing units are actually functional ‘cells’.

Our investigation concerns the eight metal cutting cells that together form the Cutting Department. In these cells, part types of materials such as steel, copper, aluminum and plastics/synthetics, undergo manufacturing processes such as sawing, turning, milling, drilling, tapping and bench work. Most of the part types entering the cells have already been sawn. Ordinarily, most parts first undergo a turning or milling operation, sometimes preceded by some bench work. All kinds of drilling, tapping and/or bench operations may then follow. In general, all the cutting processes can be done within one cell, but it sometimes happens that part types need to undergo an operation in another cell within the Cutting Department. Most parts, however, go to the powder coating or galvanic unit for a final processing.

Table 1 gives an overview of the functions and characteristics of the cells responsible for cutting processes as they were designed in 1987. It is evident that the first four cells (cells 7, 8, 9, and 10) are designed in such a way that they are able to process certain part types needed in the electric supply industry. The last four cells (13, 14, 15, and 16) contain general machines and are not used for part types with particular characteristics. Table 1 shows that most cells contain a mix of a single daily shift system and a two-daily shift system; that is, part of the operators work only in a single daily shift (from 8.30am to 4.30pm), while the others work in a two-daily shift system (from 6am to 2pm or from 2pm to 10pm).

Table 1: Basic function of the various cells and characteristics of the cells in 1987 (top) and 2000 (bottom)

<table>
<thead>
<tr>
<th>Cell</th>
<th>Character of the cells</th>
<th>Number of employees</th>
<th>Number of employees</th>
<th>Number of machines</th>
<th>Number of different part types</th>
<th>Turnover in million guilders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>in a single daily shift</td>
<td>in two daily shifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Main contact processing</td>
<td>10</td>
<td>17</td>
<td>928</td>
<td>1.974</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>CNC manufacturing of polar plates, punch work</td>
<td>4</td>
<td>7</td>
<td>300</td>
<td>.960</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Main voltage conductors</td>
<td>5</td>
<td>11</td>
<td>108</td>
<td>1.032</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Automatic, long and revolver turning, milling</td>
<td>8</td>
<td>16</td>
<td>638</td>
<td>2.040</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>General machining I</td>
<td>6</td>
<td>11</td>
<td>567</td>
<td>1.266</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>General machining II</td>
<td>5</td>
<td>8</td>
<td>290</td>
<td>.972</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>General machining III</td>
<td>6</td>
<td>12</td>
<td>580</td>
<td>.900</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>General machining IV</td>
<td>4</td>
<td>12</td>
<td>470</td>
<td>1.284</td>
<td></td>
</tr>
</tbody>
</table>

Situation in 2000

| 13 General machining (turning + some milling) | 1       | 13      | 16     | 1466   | 3.691  |
| 15 General machining (milling)              | 2       | 15      | 23     | 1034   | 3.809  |
The short term consequences

In the period immediately after the establishment of the cell structure, all operators were required to enhance their multi-functionality. It was planned that half of the workers would learn all the machining tasks carried out within their cells. In addition to these machining tasks, some team members became responsible for control tasks in the area of technology (maintenance, safety, training, accountability for production times, improvements on the work floor), logistics (scheduling and transport), and quality (product quality, work preparation, and dealing with team members’ ideas). Each of these three task areas was assigned to one worker, with the intention that the responsibilities would be frequently rotated among the team members. However, it soon proved inefficient and ineffective to rotate them too frequently (within six months).

Documents in the possession of the firm claim that there was a significant performance improvement in the period immediately following the implementation of the initial CM structure, as do the case studies referred to in the introductory section. There was, for example, a significant reduction in the number of indirect employees. There was also a substantial reduction of the throughput time, customer complaints decreased from 7.9 per cent to 2.7 per cent and inefficiency in terms of deviation from the norm for processing times decreased from 20 per cent to three per cent. Since the manufacturing lead times decreased, the period between work and rework (if needed) has also decreased. This shorter feedback loop motivated the workers to do the job properly the first time. Moreover, the operators indicated that they had more comprehensive knowledge of the part types they produced.

PHASE 1: 1987–1993

In 1989, the Dutch Institute of Labor Affairs performed a study in the manufacturing department on matters that included work attitudes, satisfaction and multi-skilling (NIA, 1989). The study showed that the CM design demanded for cross-trained workers to do the integrated jobs and that according to the workers, both their multi-functionality and their work satisfaction had risen since the introduction of CM. Workers also appreciated the increased amount of information they received from management. Although there was an overall preference amongst the workers for the new situation rather than the old functional organisation, critical comments were made about the increased need for coordination and communication within cells and between cells and supporting departments. Moreover, workers complained about relations with these supporting departments. Drawings were frequently too late, the required cutting tools were often not present, workers frequently had to interrupt their work in order to reach delivery targets for urgent orders, and so on.

In 1989, there was an opportunity to merge the production planning department and the process planning department. The manager of one of these departments left the firm and management decided to integrate both departments and appoint the remaining manager to manage the newly formed department. Since these departments were already closely connected because of their related functions and were already located in the same area, it was expected that grouping workers from both departments and letting them work for the same manufacturing cells would improve the support given to the various cells, and therefore reduce the above-mentioned team frustration.

As was indicated above, there was a need to improve communication within the teams and between the shop floor and the planning department, sales and customers (amongst others). The CM structure had reduced inter-cell relationships, but increased intra-cell interdependencies in terms of production flows and the need for coordination. This increased the need for intra-cell communication. Moreover, the cell structure emphasised cell boundaries, which made some cells quite self-contained and less sensitive to external communication and demands. These problems became evident during the first period (e.g. in the study of 1989), but it took some time before
they were diagnosed as such. In the period 1990–1992, management took several initiatives to improve communication within the cells, between cells and supporting departments, and between cells and customers. In 1992, for example, all managers and workers were trained in communication skills and customer relations. These measures, however, were only moderately successful.

During this period a few design changes also took place. Manufacturing cells 13 and 14 were both equipped with relatively old machines. As a result, the Planning Department increasingly tended to assign new work to cells 15 and 16, which were equipped with more advanced machines. Furthermore, cell 14 was a small cell with few team members and a relatively low number of part types. At the end of 1990, the firm invested in a new CNC machining centre as a replacement for one machine each in cells 13 and 14. HAT’s management decided to allocate the new machine to cell 13 and to terminate cell 14. The machines and employees of cell 14 were added to cell 13. Manufacturing cells 7 and 9 both performed cutting operations. They were quite similar with respect to their operations, machines and products, and were located in physically close proximity to each other. At first, cell 7 operated only with a single daily shift system. Later, however, workers in both cells began working in a two-daily shift system and thus the number of workers per cell present per shift became quite low. Consequently, at the end of 1990, HAT’s management decided to add cell 9 to cell 7. Up to this point the primary intention behind all these measures was to maintain and to foster the CM structure.

**PHASE 2: 1994–2000**

A strengths/weaknesses analysis performed at the end of 1993 indicated that the firm’s financial performance was poor and that its activities covered too broad a spectrum. The analysis showed that the best opportunities for the firm lay in the area of complex products which require advanced manufacturing. During the first period, in which the main concern was to foster the CM structure, the emphasis was on the replacement of conventional equipment. The new focus on complex products made investments in sophisticated machines more attractive. Fixed automated machines for large-batch manufacturing of relatively simple part types were disposed of, as well as several conventional machines. In this second phase, five CNC machines and three machining centres were bought. A machining centre is an integrated CNC machine able to perform several operations. An important aspect of the new equipment was the increased cutting speed that could be achieved. Some examples of these machines are a Deckel Maho machining centre able to perform several operations and two new turning machines which allowed unmanned production. A comparison of the number of machines in 1987 and 2000 shows a big reduction: from 94 to 39 machines.

The changes in market focus and the new investment policy were the major reasons to redesign (in several steps throughout this second phase) the CM structure, eventually resulting in two cells (see bottom Table 1). One cell consists mainly of CNC lathes and the other cell mainly of CNC milling centres. This redesign clearly points in the direction of functional design. These changes also modified the work design substantially. We will specify these changes in the following paragraphs. The move towards more functional cells was accompanied by several non-technical measures. In 1998, for example, the firm purchased a new production control system (SAP) that enabled good flow control and was therefore able to reduce one of the most disadvantageous effects of functional design; that is, the difficulty of tracing production orders.

The change in investment strategy had a big impact on work design. The more advanced the new equipment, the more training time was needed for a worker to become qualified to operate the machine autonomously. In order to be able to operate CNC machinery, operators had to learn about the machine’s control system and the programming language used, besides maintaining skills in relation to cutting conditions and cutting tools (also needed for conventional machines). For a machining
centre, even more training time was needed, because the programming of the machines is more complicated and demands more knowledge about the various cutting tools required and the accompanying cutting conditions. The new advanced systems had an important impact on the operators: they became more like system engineers instead of machine operators. Because of the substantial increase in training time, management encouraged workers to specialise in either CNC turning operations (cell 13) or in CNC milling operations (cell 15). Training issues were an argument for a more functional design, since this utilises workers’ specialised skills better. It would also reduce the training needs in the department, and enable training to become more focused on learning sophisticated processes in depth, instead of learning different processes. Moreover, it would make new manufacturing technology easier to implement. Furthermore, the dedication to processes caused by the employment of advanced integrated machines would lead to a situation in which workers derive their identity more from processes than from products. Consequently, the operators began to favour the functional arrangement of machines because it met their need for specialisation (or further specialisation, at least). This may partly explain why a more functional design did not result in a lower perceived quality of working life.

The cross-training policy was also modified because of the new investment strategy and the redesign towards more functional units. When cellular manufacturing commenced, the formal policy was that all workers should be able to handle more than one machine, and 50 per cent should even be able to perform all the operations in a team. In the second phase, the costs of training grew substantially due to the investment in advanced and integrated manufacturing systems. All these matters drove management to alter its cross-training policy. Nowadays, the machines within each cell are grouped in sets of three or four machines, and these require more or less similar knowledge and skills to operate them. Operators are only cross-trained with respect to the equipment in the machine group they are assigned to. This policy has also created greater opportunities for achieving multi-machine operation. Furthermore, the efficiency per worker has increased, because when the machines are running, the operators have the opportunity to do work such as quality checks, deburring and preparing the next job. The policy illustrates the way in which the firm is dealing with the drive towards more specialisation, while keeping an appropriate level of multi-functionality. Up to now there has been no indication that it is having a negative impact on motivation and team cohesion.

For economic reasons, the sophisticated machines have to run for as many hours per day as possible, and therefore the relative number of workers in the two-daily shift system increased substantially. The majority of the workers in 1987 (60 per cent) worked in a single daily shift system, while almost all workers in 2000 work in a two-daily shift system. Machine utilisation has become more important than worker utilisation. The cutting speed of the new machines is much higher, and consequently, so is the hourly output of the system. Moreover, the hourly tariff for the advanced integrated systems is higher, even if it is utilised in more shifts. At the present time, workers are encouraged to keep their expensive machines running. In the beginning period of cellular manufacturing, the focus was more on the efficiency of operators; at the present time, optimal machine utilisation is the predominant concern, which means that workers ought not to be busy with non-machine related tasks if this diminishes the machine-based performance of the department. Management considered this to be an argument to take non-machining control tasks out of the cells and to assign them to supporting staff.

Discussion

In this section, we will start with a global overview of all the major changes that have taken place in the Cutting Department between 1987 and 2000. Next we will relate the developments to our model and more specifically to the six arrows depicted in Figure 1.
The most obvious change is the reduction in number of cells from 8 to 2 in the 13-year period. Another striking one is that the number of machines needed for cutting operations have been reduced significantly: from 94 to 39. The same is true for the number of operators: these have decreased from 78 to 31. Even more significant is the percentage of operators working in a two daily shift system: this has gone from 38 per cent in 1987 to over 90 per cent in 2000. The number of part types has decreased by 36 per cent (from 3881 to 2480), but these part types have become more complex, mainly caused by a change in market focus. In spite of all these ‘reductions’, the turnover per employee has increased from 133,692 to 241,935 guilders.

The figures presented above indicate that the work setting of the Cutting Department has changed substantially throughout the years. Most of these changes appear to have come about as a result of well-founded decisions, suggesting a rational and deterministic evolution. However, we have to realise that the choices made do not stem solely from market demands, technological issues or performance measurements. Idiosyncratic management styles, and the interests of various actors as well as accidental events or incidents have played an important role in most decisions and therefore in the development of the CM system and the work design. All the changes that we will discuss in the rest of this section should be looked at in the light of these comments.

The implementation of the CM design in 1987 had a large impact on work design. Workers were cross-trained, and operational as well as control tasks were integrated (arrow 3). In the first years after the CM design was initialised, most actions were primarily inwardly directed at the maintenance and improvement of the CM system. Interventions aiming at the improvement of communication, the enhancement of skills or the autonomy of cells, were all intended to enhance the CM structure. During the first years, the investments in technology were primarily guided by the manufacturing system (arrow 4). These investments pertain to some advanced, dedicated machines and were meant to strengthen the position of some cells. These findings show that in the first period, the CM system was the primary force in determining work design and technology (arrows 3 and 4) and changes in work design and technology were all directed at strengthening the CM system.

During the 1990s, the managerial focus became more outwards-oriented. Besides managerial opinions made at the executive level, technological and market developments have also played a role in the change of managerial focus. Markets became more demanding and dynamic, which encouraged management to adopt a more market-oriented attitude. The manufacturing of low volume and high variety complex parts became a central issue in the new strategy, and made it attractive to invest in advanced universal equipment, which implicates a switch in investment policy. As a consequence, the changes in the second phase have had a much greater effect on the original CM structure, leading to a more functional design, with major changes in work design towards specialised functions. The departure of the CEO (who was the initiator of CM) in 1994 can be seen as the catalyst for the emergence of new policies.

Over the years, and particularly after 1994, the Cutting Department has acquired several new machines. Some important characteristics of the new machinery are the high level of automation, integration of process capabilities, flexibility, and expensiveness. The major advantages of CM are the substantial reduction of set-up times and of inter-group movements, which makes the control structure of the work floor relatively transparent and simple. However, most of the new CNC machines are able to perform a greater number of manufacturing steps. This has reduced the number of processing steps, the number of inter-machine moves and the number of set-ups. The remaining transport can be easily controlled by modern production control systems, which are even able to deal with complex flows through various cells. Advances in information and production control systems reduce the advantages provided by the transparency of a CM design, because production orders can be easily traced. Moreover, the flexibility of the new machinery enables quick changeovers, especially important in small-batch manufacturing. These characteristics of the
advanced technology equipment reduce the advantages of cellular manufacturing, and it seems that the new technology has reduced the need for cellular manufacturing. Moreover, with the purchase of advanced and expensive new technology, the need for pooling identical resources has increased, pointing in the direction of a more functional structure (arrow 1).

Our study indicates that technological innovations have had quite a large impact on staffing. In general terms, automation has reduced the number of workers needed in the manufacturing department, initially leading to smaller cells. Small cells are more vulnerable to changes in work demands, absenteeism and turnover. This encourages the merging of cells. Moreover, the new technical equipment is very expensive, which makes it necessary to achieve high machine utilisation rates. This has led to a much larger number of workers working in a two-daily shift system and has also reduced the number of workers per cell per shift (i.e. present at the same time), which again has been an important reason for merging cells. This has contributed to the situation in 2000 where there are fewer workers, fewer cells, more workers per cell, but—because of the shift system—on average, about the same number of operators per cell per shift. These factors suggest that for a cell, the optimal number of operators present at the same time is somewhere in the range of six to 10.

With respect to the qualitative side of the staffing, the developments indicate that the complex new technical systems demand highly specialised employees (arrow 2). This has had a substantial influence on the policy with respect to operators’ multi-functionality. Initially, management opted for a high level of multi-functionality within cells. Later on, when the equipment became more complex, maintaining such a high level became too costly and time-consuming. This has eventually resulted in a grouping of more or less identical machines within cells (arrow 5), and operators trained only to cross-operate these particular machines. Advanced equipment—especially when it brings complex tasks and costs a great deal—makes the pooling of identical machines (arrow 1) and workers with similar skills (arrow 5) attractive. It facilitates the exchange of work between machines, it reduces the vulnerability to absenteeism and facilitates multi-machine operating. Furthermore, to achieve high utilisation levels for these advanced systems, it is beneficial that the operators be attached to ‘their’ machine rather than performing other tasks. It is undesirable for these specialised workers to do other tasks and leave the equipment idle. As a consequence, non-machine related control tasks are moved to a higher level. The multi-functionality of the new machines and the new production control system has reduced the interdependency between workers, which also makes it easier for individual operators to be bound solely to their own machines. In the first period during which the CM system was the driving force, integration was mainly a work design issue. Now, the integration of processing steps is primarily realised by technological solutions. The comment should be made that with cells equipped with advanced universal technical systems which can execute multiple processing steps of a specific set of part types, the differences between a functional and a CM design are less apparent. We also make the comment that production management priorities have changed throughout the years, partly because of the introduction of highly advanced technical systems on the shop floor. Initially, the production manager’s focus was optimal employment of workers, but as the equipment became faster and more expensive, his primary concern moved to high machine utilisation. The foregoing shows that technology has become the driving force behind changes within the manufacturing system and work design (arrows 1 and 2). In turn, the changes in these two parts of the model have provided motives for making modifications in other elements. A functional design, for example, facilitates specialisation (arrow 3) and specialisation makes the pooling of workers with similar qualifications attractive (arrow 5) and the implementation of advanced technology easier (arrow 6).

Our study raises an important question. How have all these changes influenced the quality of working life? In 1987, cellular manufacturing was seen as an ideal opportunity for job enlargement and job enrichment, which were seen as essential elements in improving the quality of working life. It would now appear that the
operators perceive specialisation and doing all the tasks around an advanced system as contributing to the quality of working life. This change is probably related to investments in advanced new technology. Operators gain advanced training to operate a limited number of highly complex machines, and this encourages them to identify themselves with the machines, which they now regard as ‘their’ machines. Operators find the complexity of new machines sufficiently challenging to be interesting, and tasks relating directly to the machine such as programming, maintenance, tool management and detail planning are now experienced by the operators as making the job a ‘whole’ and integrated one. The purchase of advanced machines has made the work (and thus the workers) more process-oriented: previous studies show that such investments will often lead to fewer but more satisfying jobs (e.g. Benders, 1993). It would seem that there has been a change in the perception of the quality of working life. Tasks such as internal transport or production planning at the cell level, which were previously seen as contributing to job satisfaction, are no longer experienced by the worker as doing so. These arguments suggest a strong and direct relationship between production technology and work design, leading to a specific level of quality of working life. However, the changes depicted in this study strongly indicate that our model is a dynamic model in which decisions and options with respect to organisational strategy, the manufacturing system, production technology and work design all affect each other. Nevertheless, this case study indicates that a production structure with functional units equipped with advanced machinery may also lead to as high a quality of working life standards as a CM design. To validate this conclusion, however, comparative research is needed.

The case study presented in this paper illustrates the dynamic relationships between the design of a manufacturing system, technology, and work design. It has shown that a CM structure demands appropriate measures with respect to technology investments and job design. These involve considerable organisational effort with respect to selecting suitable investments, training in communication and skills, and establishing a decentralised organisation. In this longitudinal case study, changes in market strategy and developments in technology have resulted in a more functional system with specialised workers. These developments can, in our opinion, be generalised to industries facing similar market and technological innovation. This statement, however, needs further empirical support.

Acknowledgements

The authors wish to thank Han Busscher, HAT’s production manager, for supporting us in our search for documents and other information sources.

References

Galbraith, J. (1973), Designing Complex Organizations (Reading: Addison-Wesley).
van Eijnatten, F. M. (1993), The Paradigm that Changed the Work Place (Assen: Van Gorcum).