Improving the implementation effectiveness of cellular manufacturing: A comprehensive framework for practitioners

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Abstract

In today’s competitive environment cellular manufacturing (CM) is a well-known strategy to improving manufacturing performance. To obtain the full benefits that CM has to offer successful implementation is a critical factor. Evidence indicates that firms converting to CM often struggle with implementation and achieve results that are less than anticipated. A comprehensive review of implementation literature was undertaken and a multi-phase model developed and tested through a case study. The framework recognises the importance of both technical and human aspects of CM and provides practitioners with a better understanding of the various phases in the implementation process, including the many decisions which need to be considered for each step. In the case study company, implementation of CM not only provided many of the benefits associated with this form of manufacturing but also allowed operators to become a value-adding link in respect to process and product improvement and new product development.

Keywords: Cellular manufacturing, implementation, literature review, competitive manufacturing, case study

1. Introduction

In today’s competitive environment companies are endeavouring to establish and maintain a competitive advantage. Competitive advantage can be attained through superior product performance (design quality or consistent quality), new product introduction (product flexibility, development speed), or manufacturing performance (product and volume flexibility, low cost, dependability, speedy delivery) (Gunasekaran et al, 2001). In regards to manufacturing performance it is now widely accepted that the implementation of cellular manufacturing can help manufacturers meet their strategic commitments.

Cellular manufacturing (CM) is a well-known strategy in removing many of the inefficiencies experienced in functional batch-type manufacturing environments. It is widely accepted that the successful implementation of CM will bring improved benefits such as reducing delivery lead times and work-in-process inventory, while improving product quality and worker productivity. While there is no doubt about the increasing popularity of CM, companies at large fall short of achieving benefits that were perceived as being important to CM adoption. Udo & Ebie (1996) state that only half of those companies adopting CM ever attain successful implementation. They add that a considerable gap exists between the firms’ expectations and their actual achievements of CM benefits.

It is argued that a contributing reason why the full benefits of CM have not been achieved is due to the fact that the research literature on cellular manufacturing over the last 15 years has to an overwhelming degree focused on the development of procedures to solve the cell formation problem (machine order/layout, family part
grouping, work flow sequence) (Wemmerlov & Johnson, 2000). To a large degree this is also true in practice. It is now accepted that a number of fundamental social changes do occur when companies convert from functional manufacturing layouts to manufacturing cells. These social changes along with the required technical modifications will require careful attention by practitioners because of their potential impact on employee attitudes, motivation, and retention, and therefore the overall success of CM implementation.

It is now accepted that both technical and human factors have a major role to play in the success of CM. The existing body of CM research, with its strong emphasis on technical aspects, does not provide practitioners with a holistic view of the many implementation issues involved. This paper will build on the work of various studies to develop a comprehensive implementation framework and include the experience of a case study undertaken to test the proposed framework. The proposed implementation roadmap is designed for practitioners from all levels of the organisation including senior management, project engineers, manufacturing managers, through to team leaders. This comprehensive framework of the implementation process will allow practitioners to better understand the various phases involved in the implementation of cellular manufacturing.

2. Review of CM implementation
While there is no doubt about the increasing popularity of CM (studies show that cells are now adopted by between 43 and 53% of firms in the USA and the UK (Johnson & Wemmerlov, 2004, p.272)) there is also evidence that CM has not been successful in some organisations. Companies converting to CM often struggle with implementation and achieve results that are less than anticipated (Wemmerlov & Johnson, 1997; Yauch, 2000).

Over the past 15 years there have been various attempts by researchers to develop models for the implementation of cellular manufacturing. Some of these models have built on previous work while others have focused on individual areas of the implementation process. What is missing from the perspective of practitioners is a comprehensive step-by-step guide of the various phases to implement cellular manufacturing (CM). The earlier work had a strong focus on the design phase of manufacturing cells with the major consideration being given to the technical factors (machine order/layout, family part grouping, work flow sequence). The more recent research has identified the importance of the human factors in CM along with strategic and operational considerations, without providing a comprehensive model combining all the various facets.

For practitioners who are looking to implement CM, an understanding is needed between the various issues which may impact on the development, implementation and on-going success of cellular manufacturing. The early empirical work to develop social system factors that supported CM success was conducted by Huber & Hyer (1985) and Brown & Mitchell (1991). Huber & Brown (1991) used socio-technical systems (STS) theories and human resource management practices to provide implementation guidelines. Based on STS theories, they suggest that a complementary match between technical and social systems is needed to ensure optimization of CM implementations.
Kumar & Hadjinicola (1993) split the process into two phases; the design phase and the implementation phase. They conclude that the success of implementation lies in the fact that management must not only embrace the idea of CM but also view it as the first step in an ongoing effort continuously to improve the manufacturing function.

On a point that has been supported in later papers, Afzulpurkar, Huq & Kurpad (1993) suggested that ‘the transition from conventional manufacturing to cellular manufacturing is not usually made overnight but in small incremental steps’. The authors recommended the use of simulation modelling to help enhance the implementation of a CM project. While the paper focused on technical issues such as the reduction of set-up times, two factors were suggested which could critically influence the successful implementation of CM; the quality of teamwork between cell personnel and scheduling strategies.

To broaden the search for implementation models, a fruitful source of literature has been in the area of implementation of advanced manufacturing technologies (AMT) (Sambasivarao & Deshmukh 1995; Udo & Ehie 1996). AMT encompass a broad range of computer-based technological innovations which include numerical control (NC) machine tools, machining centres, industrial robots, computer-aided design and manufacturing (CAD/CAM) systems, and cellular manufacturing. The AMT literature is closely linked to the various factors which are aligned to the implementation of CM. After undertaking an extensive review of advanced manufacturing technologies, Udo & Ehie (1996) put forward an implementation predictive model which comprised of 26 variables classified into six broad categories; triple “C” factors, self-interest factors, housekeeping factors, literacy factors, tangible benefits, and intangible benefits.

In one of the first studies to investigate the implementation experiences of a large number of CM users, Wemmerlov & Johnson (1997) found that while manufacturing cells can provide substantial benefits, they also found that implementing CM is not merely an issue of rearranging the factory layout, but more importantly an issue that involves and affects the organisational and human aspects of the manufacturing firm. Surrounding cell conversions, the authors found that the number of comments about ‘soft’ (people) issues exceeded the number about ‘hard’ (technical) ones. As is the case with other studies, the authors found that successful change is more dependent on organisational than technological factors. They also found that ‘planning cannot be emphasized enough (and) small, incremental successes should be the basis for larger, integrated cell systems’.

It is true to say that cells in many cases may represent a highly effective structure in comparison with the traditional, functional workplace organisation. The most common problem faced by firms in connection with establishment of manufacturing cells were related to cell design, the implementation process, and human issues (Wemmerlov & Johnson, 1997). The importance of user involvement in effective change is also a frequent theme in the implementation literature. Restructuring the factory to adopt CM should not be viewed merely as a technical, engineering-dominated problem but as a change process where the people element dominates.

Based on a review of both existing cell design approaches and socio-technical systems (STS) theory literature, Hyer, Brown & Zimmerman (1999) propose a model
of cell system design that considers both technical and social dimensions. In concluding, the authors found that there are several key factors associated with the successful introduction of manufacturing cells. These include ‘selling’ the need for change, general decisions about structure and operation, analysis of social and technical subsystems, cell assignments, detailed design, and implementation. They go on to add that in contrast to existing CM literature, these elements paint a far more comprehensive picture of the change process and suggest areas where future research may be targeted.

**Table 1** Implementation of cellular manufacturing – Reviewed literature

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
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<th>Human factors</th>
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CM – cellular manufacturing  
AMT – advanced manufacturing technologies  
Technical factors – machine order, cell layout, family part grouping, work flow sequence etc.  
Human factors – training, communication, teamwork, worker assignment etc.  
Other factors – strategic, operational, social, environment etc.

The literature presents a broad range of techniques for the formation and design of manufacturing cells. These techniques focus on problems, e.g. the formation of
machine-part families, the assessment of grouping efficiency, the balancing of the workflow and the definition of the workflow, i.e. the sequence of the machines within the cell. However, while the knowledge about such techniques seems extensive, there seems to be an increasing need for the development of methodologies that may integrate these different activities into a process of implementation of CM in practice (Da Silveira, 1999). The importance for practitioners to understand the implementation process is captured in the following statement. ‘This is the kind of knowledge that may be more necessary in the present, when ideas, e.g. organisational learning and responsiveness, suggest that the ability to innovate may be as important as the innovation itself’ (Da Silveira, 1999, p.467).

Park & Han (2002, p.28) commented that ‘cellular manufacturing implementation is a rich and wide research area where interdisciplinary participation seems fruitful’. In a study of performance obstacles in CM implementation, they found that the major factors were: training and education, information, teamwork skill, supervision, and scheduling.

The picture that emerges from the literature is that many techniques have been developed to aid in cell design and implementation, but most of the techniques lack clear applicability and uniformity. This view is supported by Gunasekaran et al (2001) who argued that the various techniques discussed in the literature ‘offer no clear framework for the design and implementation of manufacturing cells’ (p.215). A summary of the literature reviewed in this study is presented in Table 1.

3. Development of new framework

The design and implementation of CM is not a straightforward mechanistic process but rather a multi-step process involving a host of decisions. Gunasekaran et al, (2001) note that this is an intellectually challenging process requiring a diversity of talent and knowledge. This section describes the methodology of implementation of CM proposed in this paper. A comprehensive review of the literature was undertaken and a sequential model for CM implementation was developed (see Figure 1). Each phase of the model is discussed in detail and a list of activities and decisions needed to be considered is presented for the various phases. This implementation process has six phases; Feasibility, Project team, Cell design, Human factors, Implementation, Continuous improvement. At the end of each phase section is a list of decisions which practitioners need to consider to improve the likelihood of success when implementing TBCM. The methodology of implementation of CM suggested in this study combines the ideas, methods and prescriptions of many studies into one logical, structured process.

3.1. Phase I - Feasibility

This initial stage involves the how and why firms decide to abandon a functionally organized production process in favour of a cellular one, rather than to seek improvements of the former. It involves gathering and analysing a broad range of data on the company’s strategy, structure and performance. Discussions need to include machine and part variety, people’s qualification and commitment, levels of interference with other areas, production volumes, management priorities, existing programmes of improvement, and the cost and time for the implementation of CM in the chosen area.
Hyer et al (1999) identified seven steps underlying their model for cell design. The first three of these steps were 1: Establish the strategic context, 2: Perform analysis of the existing system and 3: Make high-level structural and operational decisions. The authors go on to say that decisions here determine cell candidate activities and establish the fundamental cell operating philosophy (e.g., what role operators will play in cell management and operation, how the cell will interface with the rest of the organisation).

It is therefore necessary to determine clear objectives for the project to help in justifying the change and measuring the success of any such change in the future. Objectives may include the reduction of work-in-process, lead-times, scrap & rework, material handling, production area, batch sizes, and the improvement of product quality, machine utilization, and employee flexibility etc. To capture all the relevant production information in determining the feasibility of CM is a complex task. To overcome this barrier, Luong et al (2002) have developed a decision support system for the feasibility of cellular manufacturing systems using an expert system shell (VP-Expert).

Another important issue to be addressed at this early stage is the alignment with the strategic direction of organisation through senior management approval. As has been shown in many studies (Da Silveira, 1999; Udo & Ebiefung, 1999; Olorunniwo & Udo, 2002), the level of support from senior management is critical to the likely
success of the project. It is not uncommon in industry to find departmental managers spending time, money and other resources on the development of CM only to find at a later date that senior management have not been convinced of the need for change.

The following is a list of decisions which need to be considered at the ‘feasibility’ phase of CM implementation.

**Strategic decisions**
- Identify the need for change
- Definition of project objectives – establish major benefits that should be achieved by CM
- Commitment by top management
  - Clear understanding of CM capabilities
  - Clear understanding of business principles
  - Appropriate level of expectations of the CM
- Identify specific objectives for the long term, medium term and short term
- Match with corporate objectives and goals
- Specify the data information required
  - Preproduction cost factors
  - Direct production cost factors
  - Indirect production cost factors
- Justify new machines if necessary
- Detailed cost/benefits report
- CM cost justification

3.2. **Phase II – Project team**

Once the feasibility of the project has been decided along with senior management acceptance, the second stage involves the forming of a dedicated, competent project team. Planning, implementation, and operation of CM should be a team endeavour with at least some team members having a broad and solid understanding of human resources issues, project planning and change management (Wemmerlov & Johnson, 1997; Gunasekaran et al, 2001). These teams typically involve many different categories of personnel, although management, manufacturing engineers, supervisors, and operators are the most common groups involved.

While not all firms involve operators in the cell design and implementation process, Chung (1996) stated that ‘significant worker participation early in the technology implementation life cycle’ was critical to effecting change of AMT on the shop floor. It has been found that for successful implementation of cells, people who will eventually operate, manage, support and maintain the manufacturing cells should actively participate in their design and development (Wemmerlov & Johnson, 2000; Bidanda, 2005).

To add support for the above phases, Da Silveira (1999) discusses the need to develop and engage three groups of people relating to a CM project: (1) management, that should give support to the project; (2) shop-floor workers, that should understand and support its objectives and be trained for missing skills; and (3) the group that will execute the project, that should learn the methods and techniques of design and planning of manufacturing cells.

The following is a list of decisions which need to be considered at the ‘project team’ phase of CM implementation.

**Team formation – engage each group involved in project**
- Management
- Shop-floor workers
- Personnel to execute the project

**Project team role**
- Involve key employees in the implementation effort
- Formulate the major programmes and sets of procedures
Allocate responsibilities and tasks to divisions, functions and individuals
Assess the resources required and ensure their availability
Specify standards or targets of performance for corrective actions
Set the time-frame for the implementation
Specify the essential relationships among divisions and departments vis-à-vis employees
Allow flexibility and adaptability in the implementation process
Prepare the organisation – justification and selling
Determine who and by what process the cells will be designed

Top management role
- Initiate cell implementation
- Provide support throughout project
- Select cell implementation team
- Meet regularly with implementation team
- Communicate project vision
- Establish new reward system
- Maintain accountability and progress
- Respond to workers concerns

3.3. Phase III – Cell design
This is the most technically focused stage of CM implementation. The main aim of cell design is to identify part or product families, to create machine cells, and to allocate families to machine cells so that the intercellular movement of parts or products is minimized. The focus has centred on the structural and operational aspect of cell design. Structural decisions consist of; types of parts processed, part routing, machine needed, material handling equipment to be included, cell layout, tools and fixtures, as well as the number and types of operators. Operational decisions involve job design, roles of support personnel, inspection policies, maintenance policies, cell performance measurement, production and control procedures, and cell scheduling policies (Hyer, Brown & Zimmerman, 1999).

Cell design is the most researched area of cellular manufacturing (Wemmerlov & Johnson, 2000; Norman et al, 2002). The literature has predominantly focused on technical issues (machine order/layout, family part grouping, work flow sequence) using mathematical or simulation methodologies (Singh, 1993; Kazerooni, 1997; Shambu & Suresh, 2000; Albadawi et al, 2005). Much of this work has had a single technical objective therefore leaving us with a series of unanswered questions regarding the implementation process (Chakravorty & Hales, 2004).

Interestingly, it appears that firms design and implement cells using rather unsophisticated approaches. Wemmerlov & Johnson (2000, p.502) stated that ‘industry’s knowledge of mathematical cell formation procedures developed by academic researchers is non-existent, as is the actual usage of such procedures’. It is therefore hoped that an understandable, logical, step-by-step guide of the various phases needed to implement CM will help improve the success of implementation.

The following is a list of decisions which need to be considered at the ‘cell design’ phase of CM implementation.

Technical design
- Select family part/product types to be made in the cell
- Equipment selection/placement
- Determine material handling system
- Capacity balancing and product flow

- Create tooling and fixtures
- Identify bottleneck machines
- Set-up times reduction
- Part standardization
- Determine cell layout
- Choice of cell formation methods
• Plan cell operator assignments
• Programmed maintenance

Operational design
• Establish job design and job rotation policies
  ○ Capacity planned in cells
  ○ Jobs scheduled in cells
  ○ Jobs tracked in cells
• Determine inspection and quality procedures
• Determine maintenance procedures
• Determine production planning activities (link with master scheduling and materials planning)
• Determine production activity control (order documentation and release)
• Design cost control and reporting procedures
• Determine reward and compensation policies
• Establish on-going training activities
• Determine metrics and procedures for cell performance measurement
• Establish safety procedures
• Computer system compatibility
• Determine roles and responsibilities of supervisory personnel
• Change process plans

3.4. Phase IV – Human factors

It is clear from the literature that CM should not be viewed merely as a technical, engineering-dominated problem but as a change process where the people elements play a very important role in the success of CM (Wemmerlov & Johnson, 1997; Park & Han, 2002; Chakravorty & Hales, 2004).

In a major study of implementation experiences in CM, Wemmerlov & Johnson (1997) found that ‘people’ issues outnumbered ‘technical’ issues. The authors found that the most common factors affecting implementation were employee involvement in the process, employee education and training, and a lack of planning for the conversion. More training was seen as needed in a variety of areas, including overall training in cell concepts provided to operators, supervisors, managers, and support services personnel. In summary, they suggested that successful change is more dependent on organisational than technological factors.

In an attempt to determine performance obstacles in CM implementation, Park & Han (2002) found that four factors played an important role: information requirements, training and education of workers, supervision, and teamwork skill. These findings were recently supported by another study of human related issues in CM. In a survey of both operators and managers, Bidanda et al (2005) found that the most important human factors were identified as 1) communication, 2) teamwork, and 3) training.

In many cases the human factors of CM can be integrated or considered concurrently with the design phase. As part of the detailed design process, Hyer, Brown & Zimmerman (1999) suggested that cell teams participated in team start-up training, had extensive discussions of roles and responsibilities, and developed ‘codes of conduct’ specifying group norms and how to handle deviations from them.

To successfully complete implementation of CM into an organisation will require a major modification of the production system, which will result in significant changes in worker roles or at least that part of it which switches to cells. An important requirement for CM is an increased level of technical skills and flexibility for workers, along with the ability to work in teams (Norman et al 2002).

The following is a list of decisions which need to be considered at the ‘human factors’ phase of CM implementation.
Selection
- Realistic job preview
- Complex work sampling tests
- Generalists
- Ability to work in a team
- Flexibility
- Trainability
- Tolerance of ambiguity
- Cultural match
- Team selection decisions
  - Management selected teams
  - Operators volunteered
  - Team members chosen from work area
  - Operators bid to be on team
  - Union chose team

Training and Development
- Skill expansion
- Teamwork strategies
- Problem solving
- Self management
- Cell communication strategies
- Conceptual/integrative
- On-job training
  - Trained in running machine
  - Trained in quality functions
  - Trained to read blue prints

Reward/compensation system
- Group piecework
- Gain sharing
- Skill-based pay
- Profit sharing

HRM Planning
- Employee involvement
- Union and industrial relations
- Conflict management
- Focused on flexibility
- Input based
- Team coordination
- Minimize unnecessary output
- HRIS (MRP)

Employee Relations
- Cooperative
- Integrative bargaining
- Expanding-Pie perspective
- General employees’ morale
- Satisfaction levels
- Belief that CM can lead to personal reward or benefit
- Equitable reward structures

Job Analysis and Design
- Few job categories
- Work place layout
- Product oriented
- Analysis by work teams
- Worker assignment strategies
- Multi-activity charts
- Task inventories
- Job elements inventory

3.5. Phase V – Implementation
This phase concerns the physical implementation of the new layout. It involves the set-up of the new cells and the redefinition of production planning, management and control activities according to the characteristics of the layout.

Hyer et al (1999) break this phase into three parts; (1) communicate the change, (2) plan the change, and (3) make the physical move. Communicating the change would involve a series of meetings with employees to discuss the proposed layout and corresponding working methods. The meetings aimed to improve people’s commitment to the new layout, to clarify aspects still unclear and to improve its design (Da Silveira, 1999). Planning the change, the project team or project manager will coordinate all preparations – training, establishing councils, working with managers to delegate responsibilities, consolidating individual cell layouts into a master, preparing for the physical move, and so forth. Finally, the physical rearrangement of machines and personnel.

It must be noted that implementation follows detailed design, however, many key elements of implementation were happening concurrent with the design process itself. Providing information to those who will be affected by an organisational change is essential to successful implementation. The communication task is made significantly easier by virtue of the structure of the project/design team itself, which
includes representatives of key support areas. This reduces pressure on the implementation phase and ensures that cell support and interface issues are addressed early on in the process, not as an afterthought (Hyer, Brown & Zimmerman, 1999).

The following is a list of decisions which need to be considered at the ‘implementation’ phase of CM implementation.

Physical implementation of the new layout
• Communicate the change
  o Ensure the co-operation of employees in the implementation process
• Plan the change
  o Reorganisation to be performed at period of low demand
  o Increase finished goods inventory
  o Proceed in small steps in an effort to master CM’s challenges
  o Make the change – the physical move or reconfiguration
    o Reassignment of machines and people
    o Cells’ management and project feedback

3.6. Phase VI - Continuous improvement
One compelling reason why operators should be involved in the total implementation process is the very real likelihood that they will continue to contribute to the ongoing improvement of the cell. To demonstrate this important point, Wemmerlov & Johnson (1997, p.40) used the following quote from a participant in their survey: ‘I didn’t realize that you will get continuous improvement with the same operators in the same cell day after day’. The authors go to say that this quote conveys a pervasive sentiment emerging from the survey responses, namely the discovery of the great potential for operator involvement in the workplace suddenly unleashed through the reorganisation to cellular manufacturing.

An issue causing concern amongst manufacturers considering the implementation of manufacturing cells has been the possibility of short life cycles of a family product being produced in a dedicated cell. Wemmerlov & Johnson (2000) expelled this fear by stating that it appears, rather, that cells are in constant evolution and are improved by new equipment, processes, and methods to produce higher volumes, and more parts variants, at faster speeds.

Continuous improvement requires the individual cell teams, as well as the business and process groups, to take responsibility for evaluating cell performance and making improvements. Line meetings are a key mechanism for problem solving and continuous improvement. An example of the on-going gains made by an surveyed company, Hyer et al, (1999) noted that the cell team had (a) made decisions about how to reassign products and personnel in response to changes in product demand; (b) assimilated a significant number of new products; and (c) assimilated over 20 new direct labor personnel into the cells.

The following is a list of decisions which need to be considered at the ‘continuous improvement’ phase of CM implementation.

• Train & develop operators on CI techniques
  o Process improvement
  o Product development
• Seek and encourage operator opinions
• Evaluate and improve
4. Case study
The objective of this case study was to test the usefulness of the framework developed in section 3. The framework was used to implement cellular manufacturing at a major Australian manufacturer. To overcome the uncompetitive nature of its functional batch-type manufacturing environment, one department of the company proposed to establish a single manufacturing cell for a particular family of products. This department was under continued pressure to reduce manufacturing costs and improve product quality. The new cell involved five machines (2 presses, 1 indenter, 1 trimmer, and 1 piercer) and 3 packaging stations. An earlier attempt had been made to implement CM at the case study organisation but had been delayed due to the lack of a roadmap or comprehensive framework for management to follow. This shortcoming provided the motivation to research the topic and hence the beginnings of this paper. The case study thus provided an opportunity to observe the newly developed framework in a real world application.

The department head, anxious to avoid the problem which emerged with the earlier attempted implementation, was willing to use the framework as a guide to the proposed new cell. He also agreed that the implementation process be observed. The first author observed the implementation of the new cell over a period of several months, from the time of the first announcement by the department head till well after the physical establishment of the cell. The following seeks to describe the activity in each individual phase, noting how well (or not) the framework was followed, and drawing evidence from observation and user comments on the frameworks effectiveness/usefulness.

4.1. Phase I - Feasibility
It was evident from the beginning of the project, even with the new implementation framework, that the department head was eager to advance the project and therefore pay less attention to the early phases of the model. The early discussions seem to focus on phases III (machine set-up) & V (physical location), thereby effectively bypassing phases I & II. As the likelihood of a new manufacturing cell became known around the plant, senior management requested a feasibility report on the proposed project. While the departmental head was very enthusiastic and pressing for some physical evidence of the new project it was delayed by a number of weeks while a feasibility report was prepared. The firm needed to assess its long-term goals for manufacturing in Australia in the face of continued pressure from low-cost countries such as China. After some considerable time the project was given the green light to proceed, but the delay indicates the need to ensure that individual departmental plans are aligned or linked to overall strategic direction of the organisation. This lengthy delay also had an effect on those involved in the project with all the early momentum and enthusiasms for the new cell being lost.

The importance of securing ‘top management support’ very early in the life of such a project was not lost on the departmental manager. While at the time, the manager did not recognise the importance of gaining a commitment from senior management for the development of a single manufacturing cell, he commented later that phase I of the model provided him with a number of decisions which needed much greater attention than he would have done otherwise. In having to justify the feasibility of the project he was able to gain a much deeper understanding of issues associated
with the project such as the corporate objectives and goals, the projects objectives, justify why CM is best method, list likely benefits, and show direct/indirect costs etc. The report found the cell would provide major reductions in product scrap (improved quality), lead-times, WIP, and manufacturing overheads (reduced store transactions, material handling and transport).

In justifying the feasibility of the CM project to senior management another major opportunity to reduce costs was identified, even if the CM project did not go ahead. With a change in the supply size of raw material for this family of products, total manufacturing costs (TMC) could be reduced by over 20% or $130 000.

4.2. Phase II – Project team
Once phase I has been given the green light to proceed it is very important that a team of dedicated people are formed to oversee the project. As with phase I, this phase was not given the needed attention of the department head until the ‘lack of time’ became an issue. Initially the manager had appointed the production supervisor to coordinate the early development of the project. It was quite clear from the outset that the production supervisor was very busy with the day-to-day operations of the department and could not devote the necessary time to the cell project, therefore creating even more delays. While the size of this project was not considered large by the case study organisation a small team of specialized people was still needed. The eventual project team included the department manager, production supervisor, manufacturing engineer, a senior operator, and a dedicated technician to manage the project.

The importance of the project team and selection of its members cannot be understated. In the early part of the case study there were too few people involved in the project and those involved acted on an individual level. In individual discussions about the technical issues of the cell the views of the production supervisor were very often different from the views of the manufacturing support engineer. These types of issues can only be addressed and rectified by the forming of a project team who collectively oversee the management of the project. After a period of time the manager accepted the need for a team approach to the project and a series of team meetings began. In a show of growing appreciation for the new framework, the departmental manager commented that ‘maybe he should pay closer attention to the model’.

4.3. Phase III – Cell design
In regards to the design of the new cell the manufacturing engineer, in conjunction with the project team, decided to develop the new layout by drawing on the manufacturing experience of the group. This decision was in some way made easier by the fact that there was no sophisticated new technology or new machines being introduced to the new cell, therefore the company felt comfortable to draw on its own manufacturing experiences and to experiment to develop the technical side of the cell design, such as the cell layout, machine order, work flow balancing etc. The five machines which made up the new cell were already in operation around the plant and therefore each machine’s performance was well known. The family of products chosen for this cell had been a constant source of on-going quality problems and was ideally suited for a cell operation. The manufacturing engineer produced plans for the new layout which included the machine placement and materials handling system. A
flexible capacity balancing configuration was designed to allow either one, two or three operators to operate the cell at any given time. This gave the organisation much greater flexibility in regards to reducing lead-times for the product. After the cell was set-up, a fine-turning period in conjunction with operators took place to optimize cell layout.

Interestingly, after doing its own calculations on machine operating times and flow rates the company made inquiries about the possibility of having some computer modeling done to check the efficiency of the cell. The consideration of outside assistance may have been due to the fact that the cell design phase of the implementation framework discusses such modeling for cell formation and, if done, would have allowed the company to evaluate the benefits of such modeling. However, due to time constraints, no modeling was carried out.

4.4. **Phase IV – Human factors**

Using the framework as a guide the department manager requested that a senior operator be part of the project team and secondly, that operators could volunteer to work in the new cell. The manager indicated that normally such human issues would not be given consideration but was being guided by the framework. The senior operator on the project team was allowed time to communicate changes and seek feedback from the volunteer operators. The involvement of shop floor operators in the process delivered many benefits as the project progressed. A number of operators got involved and provided valuable feedback on the remaining four phases of the implementation process in the form of machine/cell layout (Phase III), training requirements (Phase IV), physical relocation of new cell (Phase V) and continuous improvement (Phase VI). It could be observed that a team focus between the volunteer operators was being formed before the cell was even physically implemented. When the cell was operational the team theme amongst operators continued to develop with growing evidence of self-management, problem solving, increased communication and rotation strategies within the cell and in and out of the cell. It is worth noting that these changes occurred without any change to the reward/compensation system for the cell operators.

At the end of the project the department manager recognised the important contribution that operators could make to the implementation process and the increased likelihood of success and ownership of the finished cell. He stated that it had been a positive move to involve the operators from the beginning of the project.

4.5. **Phase V - Implementation**

The physical implementation of the new cell was conducted over a number of stages to reduce to effect on the department’s day-to-day operations. First, an area for the new cell had to be cleared and floor maintenance undertaken. Secondly, new electrical and pneumatic services needed to be put in place to accommodate the new cell and its equipment. Thirdly, the five machines of the cell were moved into the cell location and connected to services. Fourthly, the materials handling conveyor, packaging stations and storage areas were fitted and located within the cell. Lastly, a number of trials and adjustments were conducted to fine-tune the overall operation of the cell. To minimize the disruption to the department, work was arranged around low-demand periods and on weekends when the plant was closed. In what could be described as the on-going support for the implementation framework, it was
observed that considerable effort was made to communicate the various changes that were occurring during this phase.

4.6. Phase VI - Continuous improvement

While the company was very pleased with the substantial reduction in costs and a dramatic improvement in product quality, it was the continuous improvement phase of the project that generated the greatest discussion and interest. The company was surprised and excited about the value-adding potential of this phase within a cellular manufacturing environment. This value-adding potential came in form of three main areas; process improvements, product design improvements, and input into new product development. Within a short period time of the cell being operational, suggestions by operators to make the manufacturing process more efficient and improved product design were implemented by the company. Adding to this has been a number of suggestions put forward by operators concerning a range of new products being developed. Cellular manufacturing has allowed the operators to view the manufacture of a product in a holistic way from raw material to finished good, as had not been the case under a functional batch-type environment. The company is currently devising an incentive/reward scheme to encourage operators to make suggestions that benefit the overall competitiveness of the company.

In discussion which followed the completion of the project it was accepted that the implementation framework had played a valuable role in the successful implementation of the cell. It was agreed that the framework provided an understandable, logical, step-by-step guide to the various phases needed to implement cellular manufacturing. Members of the project team said they often referred to the framework to check if all areas had been covered at a particular phase and to see what needed to be done next. A fact that supported this issue was, that as the project progressed, an increasing number of discussions involved the words used in the implementation framework such as the various phase descriptions, or members spoke directly about the decisions which needed to be addressed within a particular phase.

5. Conclusions

Most studies in cellular manufacturing implementation focus on cell design and human factors. While both are important elements of the implementation process, other factors also need to be considered. This paper proposes a sequential model to implement cellular manufacturing that combines a series of six phases into an integrated, logical process. The benefits of using this framework to implement CM in manufacturing organisations are many. Firstly, the framework provides a structured, holistic view of the implementation process and the decisions that need to be considered. Secondly, departmental managers need to justify the cost and benefits of the change and how the change aligns with the strategic direction of the organisation. Thirdly, by justifying the feasibility of the change, managers and project team members gain an underlying understanding of the project and the implementation process. Fourthly, by involving the operators who will be working within the new environment, resistance to change is reduced and the overall implementation process is enhanced by the input of shop floor members. Finally, the flow-on from the interactions and participation in the new environment provided cell members with
the opportunity to be innovative in the manufacturing and product improvement processes.

This comprehensive framework adds to the evolving understanding of the CM implementation process. It also provides practitioners with an effective method to implement a manufacturing strategy which will not only improve their competitiveness but will also allow operators to become a value-adding link in respect to process and product development.

References


