Team-based cellular manufacturing: A review and survey to identify important social factors

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Abstract

In today's competitive environment, team-based cellular manufacturing (TBCM) is a process which offers global manufacturers improved performance and helps them meet their strategic commitments through product and volume flexibility, lower costs and improved customer response times. TBCM is a well-known strategy in removing many of the inefficiencies experienced in functional batch-type manufacturing environments. Evidence now indicates that some organisations have achieved results that are less than anticipated and that firms which struggle to achieve the full benefit from TBCM may in fact be experiencing problems with the social factors associated with manufacturing cells. As a socio-technical process, team-based cellular manufacturing requires careful attention to both its technical and human aspects. Academics and practitioners alike have focused on the technical factors such as cell layout, machine order, family part grouping, and workflow balancing. The adoption of TBCM changes the social relationship and interactions among employees and their supervisors. Given the potential impact on employee's attitudes, motivation, and retention, these social changes call for effective management in a number of areas including HRM, employment relations and industrial structure. This study presents a review of the various human factors involved in manufacturing cells and tests the importance of each. A survey of managers, team leaders and operators working within CM systems helps to distinguish between technical and human aspects and identifies the level of importance of a number of human factors such as training, communication and teamwork.

Keywords: Cellular manufacturing, Team-based, Human factors, Survey

Introduction

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 such benefits as reducing delivery lead times and work-in-process inventory, while improving product quality and worker productivity. While much of the early work on CM focused on the technical issues (machine order, family part grouping, workflow balancing), it is now accepted that the implementation and ongoing success of CM involves the consideration of both technical and human aspects. Udo & Ebiefung (1999) found that both technical and social changes take place when a company adopts advanced manufacturing systems such as team-based cellular manufacturing (TBCM). They point out that, if an organisation focuses solely on the technical issues from the outset of a manufacturing project implementation and at the expense of the human issues, its performance will be less favourable than if it pays attention to both sets of issues. Under traditional batch-type functional manufacturing conditions employees have well-defined responsibilities for a single operation or machine. The very nature of cells requires that a pool of individually skilled machine operators be grouped together to share work in the cell. Over the past 10-15 years a small number of studies have started to address in greater depth the human dimensions of cellular manufacturing (Huber & Brown, 1991; Huq, 1992; Shafer et al, 1995; Wemmerlov & Johnson, 1997; Udo & Ebiefung, 1999; Norman et al, 2002; Olorunniwo & Udo, 2002) but interestingly, the term 'teams' or 'teamworking' have only gained increased prominence in the more recent CM literature (Askin & Huang, 2001; Park & Han, 2002; Bidanda et al, 2005). It is now accepted that a number of fundamental social changes do occur when companies convert from functional manufacturing layouts to manufacturing cells. Given the potential impact on employee's attitudes, motivation, and retention, these social changes call for effective management in a number of areas including supervision, HRM, employment relations and industrial structure.

This study aims to provide answers to two areas which have not been adequately addressed in the literature. The first part of the study seeks to determine the level of influence that technical and human aspects may play within TBCM systems, and secondly, a list of human factors associated with TBCM are tested to determine which are the most important factors within TBCM systems. The distinction being made in this paper between CM and TBCM is that TBCM represents cells which have two or more operators working within them, whereas CM can include cells with single operators or a number of cells operated by a single person.

Literature review

Cellular manufacturing

In today's competitive environment many companies are endeavouring to improve their manufacturing performance. It is now widely accepted that cellular manufacturing (CM) is one such method that manufacturers can use to help meet their strategic commitments, through product and volume flexibility, lower costs and improved customer response times. CM is based on operators processing part families, or collections of similar parts, in cells, or clusters of dedicated machines that may be dissimilar in function (Wemmerlov & Hyer, 1987). The benefits of CM include reduction in setup times, material handling, work-in-process, cycle time, and tooling requirements (Huber & Hyer, 1985; Olorunniwo, 1997; Gunasekaran, McNeil, McGaughey, & Ajasa, 2001). Furthermore, the implementation of CM has been shown to achieve significant improvements in product quality, space utilization, control of operations, scheduling, and employee morale (Huber & Brown, 1991; Wemmerlov & Johnson, 1997; Park & Han, 2002). 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 United States and the United Kingdom (Johnson & Wemmerlov, 2004: 272)) there is also evidence that TBCM has not been successful in some organisations. Companies converting to TBCM often struggle with implementation and achieve results that are less than anticipated (Udo & Ehie, 1996; Wemmerlov & Johnson, 1997; Yauch, 2000; Johnson & Wemmerlov, 2004). Evidence now indicates that firms who struggle to achieve the full benefit from CM may in fact be experiencing problems with the social factors associated with CM (Huber & Brown, 1991; Hyer et al, 1999; Park & Han, 2002).

Technical vs social aspects of cellular manufacturing

There exists a significant and growing body of academic research exploring various technical facets of cell formation and design (Singh, 1993; Kazerooni, 1997; Shambu & Suresh, 2000; Albadawi et al, 2005). These include areas such as machine sequence, workflow balancing, machine-part families, and cell capacity using mathematical or simulation methodologies. Hyer et al (1999) explain that most of this technically focused research adopts a micro-level focus, investigating one or a few issues within this large and complex process, and giving only a limited attention to the significant human dimensions. This has led to the situation where we know a great deal about certain steps in the technical design of cells, but lack a well-developed and broadly-focused theory of cell design and its human consequences.

While many of the decisions inherent in cell system design are technical in nature (e.g., how work should be scheduled through the cell), there are significant human dimensions to cell design (e.g., how cell operators will be selected, trained and rewarded). Hyer et al (1999) conclude that many of the problems and failures in cellular manufacturing systems occur at the interface between the technical and social subsystems. Norman et al (2002) state that manufacturing companies can establish a strategic competitive advantage by placing a greater importance on the human elements early in the design and implementation process. The authors explain that the vast majority of the cell formation literature places primary emphasis on grouping similar parts and machines. Once the cells are designed, secondary consideration is given to the assignment of workers to the cells. At this stage, the human element has typically only considered workers in terms of their labour capacity and/or technical skills. Norman et al argue that, in this setting, human skills such as communication, problem solving, teamwork, leadership, and conflict resolution can become just as important as technical skills, such as mechanics, mathematics, machining and inspection.

In a study of implementation experiences, Wemmerlov & Johnson (1997: 46) concluded by making the following point, "the picture that emerges from this study is clear – restructuring the factory to adopt cellular manufacturing should not be viewed merely as a technical, engineering-dominated problem but as a change process where the people element dominates". Where socio-technical systems such as cellular manufacturing are involved, both aspects need to be considered to maximise success. What is not clear is the level of influence that either aspect has on TBCM systems. Is one aspect considered more important or has a greater influence on the on-going success of manufacturing cells? This study will endeavour to provide a better understanding to this unanswered questioned.

Human factors in cellular manufacturing

Wemmerlov & Johnson (2000) argue that a major contributing factor why the full benefits of CM have not been achieved is the fact that the research literature on cellular manufacturing over the last 15 years has to an overwhelming degree focused on the development of technical procedures to solve the cell formation problem (machine order/layout, family part grouping, work flow sequence). A number of early studies attempted to develop social system factors for CM (Fazakerley, 1974; Huber & Hyer, 1985; Majchrzak, 1988; Brown & Mitchell, 1991), but it is considered that the work of Huber & Brown (1991) was one of the first major pieces of literature to make strong links between the technical and social issues of CM. The authors use a socio-technical systems (STS) framework to highlight the relevant human issues. While the STS theory presents an overall framework to consider and discusses various topics linked closely to human factors such as teamwork, some doubt remains on its suitability for use by practitioners. Huber & Brown may well be supporting this point when they suggest that from the standpoint of the academician, it provides a needed theoretical grounding for CM and suggests areas for future research.

Shafer et al (1995) explored the effects of CM on workers' perceptions and attitudes and found that the direct effects of CM had a negative effect on workers attitudes with CM worker expressing less job satisfaction, weaker organisational commitment, weaker intentions to stay with the organisation, greater role conflict, and greater role ambiguity than their functional counterparts. The authors state that the findings seem to be consistent with Majchrzak's (1988) suggestion that some employees may have difficulty adapting to CM and that their results follow along the same lines as Fazakerley (1974), who suggested five categories of personnel problems when group technology is introduced:

1. Uncertainty and insecurity.
2. A lack of understanding by management of group technology principles.
3. A lack of group feeling within the cells.
4. A tendency to become complacent and less innovative, and
5. Difficulties associated with the wage system.

While the concerns expressed by Majchrzak's and Fazakerley refer to problems likely to arise during or shortly after implementation of CM, the findings of Shafer et al suggest that such problems are still evident after two years of CM being implemented.

In one of the first large-scale empirical studies of CM users, Wemmerlov & Johnson (1997) surveyed 46 plants to determine reasons for establishing CM, types of operations performed, problems faced and lessons learned during implementation. Some of the human issues expressed by operators dealt with a lack of acceptance of the cell concept, an unwillingness to make decisions or to run more than one cell machine at a time, labour unrest due to removal of 'easy' work, long learning periods, problems with creating a team environment, and unmet expectations. From the survey results the authors were able to determine a list of factors considered to be of significant importance to cell operation and implementation. These factors included both 'hard' (technical) issues and 'soft' (people) issues. The results showed the number of 'soft' issues exceeded the 'hard' ones. Therefore, coupled with other results, the authors suggested that this indicated that successful change is more dependent on organisational than technological factors. The human related factors included; planning for the conversion, education and training, implementation time, measurement and reward systems, top management support, employee involvement, operator/cell leader selection, and job rotation.

Udo & Ebiefung (1999) analyse the data from 98 manufacturing companies to investigate the associations between human factors and the success of advanced manufacturing systems (AMS). In this study, the 8 human factors tested were split into three components namely: self-interest (morale, satisfaction, reward systems, and belief in AMS), top management (top management commitment, response to workers' concerns and Effective facilitator), and preparation (training). The results of this study show that the eight human factors considered in their study have positive associations with AMS benefits. The authors conclude by stating that while other factors may play major roles in realization of AMS benefits, socio-technical or human factors have been shown to be essential ingredients for AMS success.

Park & Han (2002) carried out an empirical investigation in four Korean manufacturing plants to determine performance obstacles in cellular manufacturing. The authors explained that performance obstacles are factors in the work environment that restrict productivity by inhibiting workers in the execution of task responsibilities. Therefore, it is thus crucial to identify and reduce those obstacles for more effective cellular manufacturing implementation. The study aimed to identify performance obstacles in the area of human, organisational, and technological factors to which attention should be devoted in the future for successful cellular manufacturing implementation. The study identified 46 items and these were sorted into seven classifications, as suggested by the critical incident sorting procedure. The seven classifications were analysed into two important aspects, soft (human and organisational factors) and hard (technological factors). The four 'soft aspects' identified were; training and education, information, teamwork skill, and supervision.

Olorunniwo & Udo (2002) found that a number of fundamental social changes occur when companies convert from functional (batch or job shop) manufacturing layout to manufacturing cells. In CM, employees are moved from segregated work groups (eg all press operators work in the same department, all lathe operators in same department) into cells that combine jobs and workers from several specialized skill areas. Cell team members have to work together, though each may have originally been under different pay or reward system, or possess different levels of training, skills, and experience. In essence, conversion to CM changes the social interactions among employees and their supervisors. These social changes require careful attention because of their potential impact on employee attitudes, motivation, and retention

The very nature of team-based manufacturing cells dictates that individuals will be required to work together to maximise the benefits that cells can provide manufacturers. The issue of teamwork within cells is closely interlinked with a number of the other social factors such as; communication, training, conflict management, autonomy, and worker assignment strategies. Huang (1999) explains that the team concept is not a panacea. The team does not work well if we just simply pull together a group of people together and say "go forth and do good things" (p.31). It takes hard work both from the team members and the managers to build successful teams. Hence, it is important to study the characteristics of cellular worker teams from the viewpoint of the team building process, job and team training, team member interactions, and impact of the team member characteristics on team performance. While it is clear that teamworking is an important factor in the success of manufacturing cells, this study will give some form of quantification to the level of this importance.

In a recent study, Bidanda et al (2005) conducted a comprehensive evaluation of the various human factors associated with CM. The authors reviewed both the CM and the advanced manufacturing technologies (AMT) literature. Adding support to the lack of research is this field, Bidanda et al states "while cellular manufacturing is a popular research area, there is a singular absence of articles that deal with the human elements in cellular manufacturing" (2005: 509). The results of their literature review identify eight broad areas of human issues in CM: worker assignment strategies, skill identification, training, communication, autonomy, reward/compensation system, teamwork, and conflict management. Having reviewed the CM implementation literature, the Bidanda et al study offers a comprehensive list of human factors associated with TBCM. For a detailed description of the eight factors see Bidanda et al, (2005: 509-516).

A number of authors (Wemmerlov & Johnson, 1997; Udo & Ebiefung, 1999; Olorunniwo & Udo, 2002; Bidanda et al, 2005) have agreed with the observation made by Huber & Brown (1991), that more empirical research is needed to investigate the impact of sociological variables on the implementation of manufacturing processes such as cellular manufacturing. While cellular manufacturing has been a popular research area, the study of its human aspects has not been as fruitful. This study will use the key human factors associated with TBCM identified above and measure which factors are considered the most important within a TBCM system.

Methodology

The data used for this study was collected via a questionnaire survey designed to provide information about the importance of human issues in team-based cellular manufacturing. The distinguishing factor between cellular manufacturing (CM) and team-based cellular manufacturing (TBCM) is that TBCM requires two or more operators to be working within a manufacturing cell. A sample size of 175 participants involved in team-based cellular manufacturing took part in the survey. Survey participants included three sub-groups: managers, team leaders, and operators. A brief summary of the four medium to large organisations involved in the study are as follows:

- Company 1 (sites 1 & 2) – Electrical accessories manufacturer (Australian) (2300 employees)
- Company 2 – Sanitary ware manufacturer (Australian) (2000 employees)
- Company 3 – Automotive components manufacturer (Australian) (800 employees)
- Company 4 – Electrical accessories manufacturer (Switzerland) (380 employees)

The aim of this study is to provide answers for two research questions. Firstly, in an attempt to determine the level of influence that technical or human factors may have on TBCM, participants were asked to distinguish between technical and human aspects of team-based cellular manufacturing and determine the level of influence either aspect may have on TBCM systems. The second objective was to test the importance of a list of human factors which are associated with TBCM and establish which factors are considered the most important within a TBCM system. The list of human factors used in this study were complied by Bidanda et al (2005) and the list encompasses most of the social issues presented in the literature.

To help overcome language barriers the survey was converted to the common language used within that region of Switzerland and a senior employee who was fluent in both the native language and English was used to explain the survey to each participant. Statistical program SPSS was used to analyse data and the means were compared to determine the ranking for each factor.

Findings

Participants were asked to rate which problem (between technical and human) they had encountered the most often while working in cells. A list of technical and human problems were provided to help participants understand the difference between each issue. The scale used to rate this question was as follows; 1 – mostly technical, 2 – more technical, 3 – same, 4 – more human, 5 – mostly human.

Table I – Source of problem: Technical or Human (Company)

Company	N	Mean	SD
Company 1 – site 1	42	2.05	0.909
- site 2	23	2.91	0.793
Company 2	6	2.33	0.816
Company 3	40	2.15	1.027
Company 4	61	2.66	1.124
Total	172*	2.41	1.042

*Of the 175 participants, 3 operators fail to answer this question (N=172)

The results showed that the problem being experienced within manufacturing cells is skewed toward 'technical' issues (mean 2.41) (see Table 1). The mean for each of the four companies and five sites surveyed fell within 2 (being more technical) to 3 (experiencing the same amount of problems for both issues). Of the 172 participants, 52% indicated that they had experienced either 'more technical' or 'mostly technical' problems involving CM systems. Of the remaining 48% of participants, 34 % indicated that they had experienced the same amount of problems for both aspects leaving only 14% to indicated that they had experienced 'more human' or 'mostly human' problems. It is worth noting that the maximum and minimum mean values for the survey occurred between the two sites of the same company, 2.05 to 2.91.

Table II – Source of problem: Technical or Human (Position)

Position	N	Mean	SD
Manager	10	3.00	1.054
Team Leader	23	2.65	1.027
Operator	139	2.33	1.031
Total	172*	2.41	1.042

*Of the 175 participants, 3 operators fail to answer this question (N=172)

When comparing the data for the different positions held within the companies (see Table 2), operators indicated that they experienced more technical problem than human issues within manufacturing cells with a mean of 2.33. For team leaders the mean increases to 2.65 (indicating less technical and more human issues than operators) and for managers the mean value is 3.00. For managers the amount of problems they experience between technical and human issues are the same. The results indicate that people in leadership or management positions within a cellular environment experience increased human issues as compared to operators of the cells.

In regards to the second research objective, participants were ask to rank the eight (8) human factors from 1=most important to 8=least important. Each factor was characterised by a short description to help participants understand the various factors being ranked.

The overall rankings of human factors for the various companies/sites (see Tables 3 & 4) indicate three sub-groupings of the eight human issues listed. The three factors ranked most important (means between 2.79 and 3.47) were 'communication', 'teamwork', and 'training'. The next sub-group (means between 4.38 and 4.83) was 'skill identification' and 'worker assignment strategies'. The final group (means between 5.34 and 5.75) were, 'conflict management', 'autonomy', and 'reward/compensation'.

Table III – Results of Human Factors for various Companies

Company		Communication	Teamwork	Training	Skill Identification	Worker Assignment Strategies	Conflict Management	Autonomy	Reward/ Compensation System
Company	Rating	3	2	1	4	6	7	8	5
1 – site 1	Mean	3.36	3.22	2.84	4.07	5.27	5.73	6.16	4.58
N=45	SD	1.967	1.917	1.796	1.876	1.876	2.168	1.999	2.369
Company	Rating	3	2	1	4	6	5	7	8
1 – site 2	Mean	3.09	2.43	2.04	4.39	5.35	5.30	5.78	7.09
N=23	SD	1.411	1.441	1.894	1.725	1.641	1.769	1.380	1.703
Company	Rating	2	5	1	3	4	8	7	6
2	Mean	2.33	3.50	1.50	2.67	3.00	4.67	4.5	4.17
N=6	SD	2.338	1.871	0.548	2.251	1.789	2.160	1.871	2.483
Company	Rating	1	3	2	4	5	7	8	6
3	Mean	2.30	2.87	2.55	4.4.	4.93	6.18	6.30	6.17
N=40	SD	1.636	1.682	1.431	1.692	1.774	1.631	1.682	1.693
Company	Rating	1	2	7	6	4	5	3	8
4	Mean	2.64	3.82	5.26	4.77	4.44	4.57	4.23	6.00
N=61	SD	2.122	2.370	1.914	1.970	2.172	1.987	1.978	2.302
Total	Rating	1	2	3	4	5	6	7	8
	Mean	2.79	3.26	3.47	4.38	4.83	5.34	5.41	5.75
N=175	SD	1.925	2.025	2.197	1.890	1.977	2.024	2.049	2.275

When comparing the individual companies and sites to the overall rankings the following differences are observed. Of the three top ranked factors, the biggest difference occurred with the European company (Company 4) which ranked ‘training’ as the 7th most important factors while the Australian companies/sites ranked ‘training’ either 1st or 2nd . Another notable difference was Company 2 ranking ‘teamwork’ as the 5th most important factors. While ‘teamwork’ ranked highly overall, one possible reason for this lower ranking may be due to the fact that the cells in this company were only 2-3 person cells as compared to the surveys overall average of 6 people per cell. The low number of participants (N=6) for Company 2 also make it difficult to draw meaningful comparisons on an individual level.

Table IV – Human Factor Ranking: Companies

Rank	Respondent Category					
	Company 1 - Site 1	**Company 1 - Site 2**	**Company 2**	**Company 3**	**Company 4**	**All Companies**
1	Training	Training	Training	Communication	Communication	Communication
2	Teamwork	Teamwork	Communication	Training	Teamwork	Teamwork
3	Communication	Communication	Skill Identification	Teamwork	Autonomy	Training
4	Skill Identification	Skill Identification	Worker Assignment Strategies	Skill Identification	Worker Assignment Strategies	Skill Identification
5	Reward/ Compensation	Conflict Management	Teamwork	Worker Assignment Strategies	Conflict Management	Worker Assignment Strategies
6	Worker Assignment Strategies	Worker Assignment Strategies	Reward/ Compensation	Reward/ Compensation	Skill Identification	Conflict Management
7	Conflict Management	Autonomy	Autonomy	Conflict Management	Training	Autonomy
8	Autonomy	Reward/ Compensation	Conflict Management	Autonomy	Reward/ Compensation	Reward/ Compensation

The overall ranking of ‘skill identification’ and ‘worker assignment strategies’ at 4th and 5th respectively seem a true reflection as all individual companies/sites ranked both between 3rd and 6th. When comparing differences within the three least important factors the notable difference again occurred in the European company (Company 4) when it ranked ‘autonomy’ as the 3rd most important while the other companies/sites (Australian) ranked ‘autonomy’ either 7th or 8th most important.

Table V – Results of Human Factors for various Job Positions

Position		Communication	Teamwork	Training	Skill Identification	Worker Assignment Strategies	Conflict Management	Autonomy	Reward/ Compensation System
Manager	Rating	3	1	2	4	6	7	5	8
	Mean	3.50	2.60	3.40	4.20	4.80	5.50	4.60	7.40
N=10	SD	2.068	1.776	2.675	1.549	2.150	1.509	2.011	1.265
Team	Rating	1	2	3	4	5	6	7	8
Leader	Mean	2.13	3.17	3.30	3.70	4.26	5.04	5.30	5.87
N=23	SD	1.687	1.922	2.285	2.225	1.764	2.121	1.987	2.222
Operator	Rating	1	2	3	4	5	6	7	8
	Mean	2.85	3.32	3.50	4.51	4.93	5.37	5.49	5.62
N=142	SD	1.935	2.061	2.163	1.840	1.995	2.048	2.062	2.302
Total	Rating	1	2	3	4	5	6	7	8
	Mean	2.79	3.26	3.47	4.38	4.83	5.34	5.41	5.75
N=175	SD	1.925	2.025	2.197	1.890	1.977	2.024	2.049	2.275

When comparing the three respondent categories; managers, team leader, operators (see Tables 5 & 6), the overall results is strongly influence by the high number of operators (81%) of the total participants. The rankings given to the eight human factors by both ‘team leaders’ and ‘operators’ was the same. While the rankings were the same, the mean value for each factors for ‘team leaders’ was higher (indicating greater importance) except for ‘reward/compensation system’. The biggest difference between these means occurred for ‘communication’ (2.13 to 2.85) and ‘skill identification’ (3.70 to 4.51). The notable difference in the rankings occurred between ‘managers’ and the other two positions. Manager considered ‘teamwork’, ‘training’ and ‘communication’ as the top three factors while team leaders and operators ranked ‘communication’, ‘teamwork’ and ‘training’ as their top three.

Table VI – Human Factor Ranking: Job Position

Rank	Respondent Category			
	Managers	**Team Leaders**	**Operators**	**All Groups**
1	Teamwork	Communication	Communication	Communication
2	Training	Teamwork	Teamwork	Teamwork
3	Communication	Training	Training	Training
4	Skill Identification	Skill Identification	Skill Identification	Skill Identification
5	Autonomy	Worker Assignment Strategies	Worker Assignment Strategies	Worker Assignment Strategies
6	Worker Assignment Strategies	Conflict Management	Conflict Management	Conflict Management
7	Conflict Management	Autonomy	Autonomy	Autonomy
8	Reward/ Compensation	Reward/ Compensation	Reward/ Compensation	Reward/ Compensation

Discussion

In regards to the Question 1, the biggest difference occurred between the two sites of the same company (Company 1). This significant difference may in some way be explained by each sites attitude to training. At Site 1 the training records (both past and future needs) of each operator were displayed in a strategic position within the plant for all employees to observe. While such a method was not evident at Site 2, many employees at Site 2 openly complained about the lack of coordinated training within the plant. Support for this issue was also evident in Question 2 when participants at Site 2 ranked training (mean value of 2.04) higher than any other company or site. When questioned about employee training at Site 2, management stressed that adequate training had been provided. Another notable difference between the two sites of the same company occurred with the ranking of 'reward/compensation system'. While Site 2 operators were unhappy about the lack of training, it was not the case in regards to reward/payment. Site 2 participants clearly ranked the issue of payment as the least important (mean 7.09). At site 1 it was ranked the 5th most important with a much higher mean of 4.58.

In regards to the three respondent categories (job positions), the two notable differences was that managers ranked 'autonomy' the 5th most important while the other two positions put it at 7th. Secondly, while all three positions ranked 'reward/compensation system' the least important factor, the mean of 7.40 by managers was the lowest mean recorded in the survey, indicating the very low importance given to reward/payment issues by managers.

When looking for notable differences between countries the two factors to stand out was the low ranking for 'training' (ranked 7th) and the high ranking of 'autonomy' (ranked 3rd) from the European results. Without further research it would be difficult to state the reasons for these differences but the following point will be made. The surveys distributed to participants in the Swiss company were converted to the common language of the factory being Swiss-German. It was observed that many operators were experiencing some problems understanding the Swiss-German language being used, even with the use of a senior and long time employee of the company to help explain the survey questions. While many of these workers were not native to Switzerland, it was interesting to note that so many workers (including younger people) would experience such a problem with the native/common language. It would seem that some literacy training would be beneficial the company, considering that operators needed to work within a team environment in manufacturing cells. A second point which may have some influence on the high 'autonomy' ranking is that operators may feel more comfortable working in smaller groups or even alone due to this literacy issue. It could also be argued that cultural differences may affect various outcomes when comparing differences between the two countries.

The results of this survey clearly indicate that human factors play a significant role in the overall success of team-based cellular manufacturing. When analysing which individual human factors are important to TBCM it is shown that communication, teamwork and training rank the highest while reward/compensation ranked lowest.

In determining the importance of human factors such as skill identification, worker assignment, training, reward etc. in different companies and countries, it must be noted that these issues are rarely 'neutral' in nature, and their interpretation will be shaped by the industrial context of the firm and/or country. It is therefore acknowledged that some of the differences in the results between the four companies may well be shaped by the industrial context in which they operate. The non-testing of this issue in this research provides the opportunity for further research in this area and in human factors in general.

Conclusions

Team-based cellular manufacturing has a lot to offer global manufacturers by reducing both costs and inefficiencies within their manufacturing processes. While the focus of research has been on the technical side of this socio-technical process, it is now clear that greater effort must be placed on the human aspects to improve the benefits and success of this form of manufacturing. This study found that while technical issues still play a major role in the on-going problems experienced in cellular manufacturing, human issues account for a significant proportion of problems within cells. The study goes on to identified the various human factors associated with TBCM and tests the importance of each. While communication, teamwork and training were ranked as the most important factors, it is hoped that these findings will better inform practitioners on the human aspects of CM and provide future direction in areas such as employment and industrial relations.

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