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Abstract

Despite the potential advantages of cellular manufacturing, most plants with cells have only partially converted their systems. This study examines factors that limit cell penetration within plants using a mail survey of cell users. The existence of service processes, lack of a strong champion who would push the design and implementation of more cells, and low cost of tracking non-cell parts/ products on the plant floor were found to be significant predictors of cell penetration for plants with cells and no plans for further cells. Factors limiting penetration in plants planning to implement further cells could not be determined.

Disciplines

Manufacturing | Operations and Supply Chain Management | Technology and Innovation

Comments

FACTORS LIMITING CELL PENETRATION IN MANUFACTURING PLANTS

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ABSTRACT

Despite the potential advantages of cellular manufacturing, most plants with cells have only partially converted their systems. This study examines factors that limit cell penetration within plants using a mail survey of cell users. The existence of service processes, lack of a strong champion who would push the design and implementation of more cells, and low cost of tracking non-cell parts/ products on the plant floor were found to be significant predictors of cell penetration for plants with cells and no plans for further cells. Factors limiting penetration in plants planning to implement further cells could not be determined.

INTRODUCTION

Most plants that have installed cellular manufacturing have converted their system from one that was functional in nature (i.e., a job shop) and the primary reasons for doing so can be traced to a desire to reduce manufacturing lead time, reduce cost, improve quality, or increase flexibility (Wemmerlöv and Hyer 1989; Wemmerlöv and Johnson 1997). Thus, plants adopt cellular manufacturing in an effort to improve both the efficiency and the effectiveness of the organization. Despite the potential advantages, most plants that have adopted the cellular concept have only partially converted their system to cells and a remainder functional layout is used to produce the parts/products not in cells. Understanding the factors that limit the degree of cell penetration within plants would assist researchers and practitioners alike in understanding where manufacturing cells are applicable. This study addresses this issue using data from a mail survey of cell users.

PREVIOUS EMPIRICAL STUDIES

There are few large scale empirical studies of plants that use cellular manufacturing. Burbidge (1979) provides implementation experiences and some benefits statistics for a small number of firms. Dale (1978) and Willey and Dale (1977, 1979) collected 'before and after' data on 28 firms with cells. Harvey (1993) conducted a study of 11 plants using a combined case study and survey approach. Wemmerlöv and Hyer (1989) and Wemmerlöv and Johnson (1997) present results from mail surveys of 32 and 46 cell users, respectively. While these studies provide a variety of information on the use of cells, including implementation experiences and performance improvements, none were focused on the factors that influence the degree of cell penetration. Thus, this study provides new information about the use of cellular manufacturing and factors that determine its applicability.

METHODOLOGY

A mail survey was sent to 527 plants located in Illinois, Indiana, Iowa, Minnesota, Michigan, and Wisconsin. Each plant had at least 200 employees, was primarily engaged in metal machining or metal fabrication work, and had a primary SIC code within the Industrial and Commercial Machinery Group. Individuals selected to receive the survey usually had titles of Plant Manger, VP of Operations, VP of Engineering, Director of Operations, Operations Manager, Production Manager, or Engineering Manager. A follow-up survey was sent four weeks later to those plants that did not respond to the initial survey.

One hundred seventy-eight of the 527 questionnaires were returned. Of these, 20 came back due to incorrect address, one plant had closed, three plants did not want to participate, two plants were continuous process facilities, one plant did only light hand assembly work, and one survey was returned from a location where no manufacturing was performed. In total, 150 usable surveys were received for a response rate of (178-28) / (527-28) = 30%. Complete details of the survey are contained in Johnson (1998).

CHARACTERISTICS OF RESPONDING PLANTS

One hundred eighteen (78.7%) of the responding plants had at least one cell and of these plants, 88 (74.6%) had plans to install more cells over the next two years. In contrast, only eight of the 32 plants without cells (25%) had plans to install cells.

Plants with cells produced a wide variety of products, including engines and engine components; agricultural equipment and components; mining and construction machinery and components; lawn and garden equipment and components; air and fluid handling and flow control devices; power transmission components; refrigeration and food service equipment; water and water filtration equipment; heating and cooling products and components; fire protection equipment; metal removal tools and

equipment; equipment for the paper industry; printing equipment and components; packaging equipment and components; tools and tool storage units; painting equipment; electrical/electronic products; and molded rubber and plastic products.

The number of cells of all types ranged from 1-150 and averaged 14.4 per plant, the number of machining cells ranged from 0-81 and averaged 8.6 per plant, and the number of assembly cells ranged from 0-150 and averaged 5.2 per plant.

For those plants with cells, 64% (61%) spent less than 50% of all direct labor (machine) hours in cells. The percent of direct labor hours spent in cells ranged from 1-100% and averaged 41.4%. The percent of machine hours spent in cells ranged from 0-100%, averaged 41.2%, and is highly correlated with the percent of direct labor hours spent in cells (r=0.77, n=108, p=0.00). Fifty-five percent of all plants spent 30% or less of all direct labor and/or machine hours in cells. Although 27% (30%) of all plants spent more than 70% of all direct labor (machine) hours in cells, most plants had relatively low cell penetration.

FACTORS LIMITING CELL PENETRATION

Analysis of all plants with cells

Respondents to the survey were asked to evaluate how important each of 18 factors were in having prevented the use of cellular manufacturing for parts or products not produced in manufacturing cells (using a 5-point Likert scale with 1=low importance and 5=high importance). These factors were 1) could not identify part families with enough demand volume to form cells, 2) lack of time to design and implement more cells, 3) could not identify part families with enough demand stability to form cells, 4) the remaining parts/products required one or more service processes which made them difficult to put into cells, 5) could not cost justify further cells, 6) material handling cost, time, and/or distance wasn't a problem for the remaining parts/products, 7) cost of tracking the remaining parts/products on the plant floor wasn't a problem, 8) equipment needed for further cell formation was too costly to move, 9) lack of a strong champion who would push further cell implementation, 10) quality wasn't a problem for the remaining parts/products, 11) lead time wasn't a problem for the remaining parts/products, 12) cost wasn't a problem for the remaining parts/products, 13) further cell formation would reduce the plant's flexibility to adjust to short term changes in product mix, 14) equipment required for further cell formation required frequent repair and had low reliability, 15) the remaining workforce didn't have the skill level necessary to perform multiple cell tasks, 16) high work force resistance to further cell formation, 17) management unwilling or

unable to risk further change to the organization, and 18) previous cell experiences weren't positive. The largest average factor score was 2.98, indicating that no factor was universally important for all plants.

Two stepwise linear regression analyses were performed on these data, with the percent of direct labor hours and the percent of machine hours spent in cells used as dependent variables, respectively, to determine the relative impact of each factor on these dependent variables, given all other factors. The regression equation for the percent of direct labor hours spent in cells was significant (F=4.59, n=96, p=0.01) and had an adjusted R^2 of 0.10. The regression equation for the percent of machine hours spent in cells was also significant (F=4.99, n=93, p=0.01) and had an adjusted R^2 of 0.08. However, in both cases, residual analyses indicated serious violation of the normality assumption. Since the amount of variation explained by either model was quite small and since the residual normality assumptions were violated, no further efforts were spent in this direction.

The small amount of variance explained by the regression equations suggested that other factors may have limited the degree of cell penetration in these plants. However, the data used included both plants that did <u>and</u> did not plan to install more cells in the next two years. Plants that had no plans to implement further cells may have reached the threshold of cell applicability and factors limiting penetration in those plants may differ from factors limiting penetration in plants that had plans to implement more cells. Combining both plant types in the same regression model may hide the factors that are limiting the degree of penetration in each type of plant (if indeed these factors differ).

Analysis of plants with plans to implement more cells

Two stepwise linear regressions were performed on the plants with cells and plans to implement more cells. The first regression used the percent of direct labor hours spent in cells as the dependent variable while the second regression used the percent of machine hours spent in cells. The regression for the percent of direct labor hours spent in cells was significant (F=5.12, n=78, p=0.00) and had an adjusted R^2 of 0.14. The regression for the percent of machine hours spent in cells was also significant (F=4.38, n=76, p=0.02) and had an adjusted R^2 of 0.08. However, as before, an analysis of the residuals indicated the normality assumption was seriously violated and no further efforts were spent on these models.

Analysis of plants without plans to implement further cells

Stepwise linear regressions were next performed on the plants with cells that did not plan to implement more cells. The regression for the percent of direct labor hours spent in cells was significant (F=6.04, n=18, p=0.01), and had an adjusted R^2 of 0.47. Factor 5 (β=12.76, T=2.98, p=0.01), Factor 14 (β=23.38, T=3.10, p=0.01), and Factor 16 (β=-25.14, T=-2.57, p=0.02)

were all found to be significant indicators of the degree of cell penetration. The intercept term was not statistically significant. The constant variance assumption was reasonably well satisfied and multi-collinearity was not a problem. Mild violation of the normality assumption did exist, although the violation was much less severe than when the entire data set was used. Given the relatively large amount of variance explained by the model and the exploratory nature of this research project, the model was considered to be an acceptable fit.

The model indicated that work force resistance to further cell formation (Factor 16), was the most significant predictor of the percent of direct labor hours spent in cells. The greater the perceived work force resistance to cells, the smaller the percent of direct labor hours spent in cells. The direction of this relationship is as expected and this finding emphasizes the need to get worker acceptance in order to implement cellular manufacturing.

Poor reliability of equipment needed for further cell formation (Factor 14), was the next greatest predictor of cell penetration. The higher the rating on this factor, the greater the percent of direct labor hours spent in cells. While this might seem counterintuitive, a potential explanation for the direction of this relationship may exist. Equipment with poor reliability is more likely to limit further cell formation in plants with high cell penetration since the amount of equipment left to choose from to form additional cells (and which likely has lower reliability than the equipment chosen for the first cells) is less than if the same plant had low cell penetration. Thus, poor equipment reliability is less likely to limit cell formation in plants with low cell penetration unless a majority of the equipment in a plant has poor reliability.

Finally, the inability to cost justify further cells (Factor 5), was the least significant predictor of the percent of direct labor hours spent in cells, with plants ranking this factor more important having higher cell penetration. This relationship also seems counterintuitive if viewed in isolation but makes sense when viewed in the context of the entire regression model. The most important factor limiting the adoption of further cells for plants with low cell penetration was worker resistance to cells. Overcoming this resistance was more likely to be considered a change management problem than a cost justification issue. In contrast, plants with high cell penetration had less worker resistance to cells and other factors related to cost justification issues play more of a role. In addition, it is more difficult to justify additional cells as penetration increases since the most obvious cells, those with low cost and high impact, have likely been implemented.

To investigate this issue further, bivariate correlations were computed between Factor 5 and the remaining factors for this same group of plants. The only factors found correlated with Factor 5 were Factor 17 ($r=0.42$, $n=21$, $p=0.06$), and Factor 4 ($r=0.40$, $n=21$, $p=0.08$). While the reasons for the correlation between Factors 5 and 17 are unclear, it is clear that putting "service process" into cells may require duplication of equipment, which directly relates to cost justification.

The regression for the percent of machine hours spent in cells was significant ($F=12.96$, $n=17$, $p=0.00$), and had an adjusted R^2 of 0.69. Factor 4 ($\beta=16.45$, $T=5.78$, $p=0.00$), Factor 7 ($\beta=-6.77$, $T=-2.75$, $p=0.02$), and Factor 9 ($\beta=-13.99$, $T=-4.13$, $p=0.00$), were all found to be significant indicators of the percent of machine hours spent in cells. The intercept term was also statistically significant ($\beta=29.77$, $T=2.57$, $p=0.02$). The constant variance assumption was reasonably well satisfied and multicollinearity was not a problem. Mild violation of the normality assumption did exist, although the violation was much less severe than when the entire data set was used. Given the relatively large amount of variance explained by the model, and the exploratory nature of this research project, the model was considered to be an acceptable fit.

The need for processing parts in service centers (Factor 4), was the most significant predictor of cell penetration, with plants considering this factor more important in preventing further cell adoption having a higher percentage of machine hours in cells. This relationship was in the expected direction. Since plants with higher cell penetration had most of their equipment in cells, equipment not in cells may consist of one-of-a-kind service processes that are difficult to incorporate into cells unless the processes are duplicated. In contrast, plants with low cell penetration are less likely to consider this a major obstacle unless most of processes in the plant are considered service processes.

Lack of a strong champion who would push the design and implementation of more cells (Factor 9), was the next greatest predictor of cell penetration, with those plants rating this factor more important having a lower percentage of machine hours in cells. Since the implementation of cellular manufacturing requires changes to both the layout of equipment on the shop floor and a change to the organizational culture, a strong champion is needed if this type of change is to be undertaken. Thus, this relationship is in the expected direction.

Finally, the low cost of tracking the remaining parts/products on the plant floor (Factor 7), was the least significant indicator of cell penetration, with plants rating this factor higher having a lower percentage of machine hours in cells. Material tracking is correlated with Factor 6 ($r=0.74$, $n=21$, $p=0.00$), Factor 10 ($r=0.75$, $n=21$, $p=0.00$), Factor 11 ($r=0.44$, $n=21$, $p=0.05$), and Factor 12 ($r=0.62$, $n=21$, $p=0.00$), for this group of plants, but it is unclear why material tracking was a significant predictor while these other performance related metrics were not.

References available upon request from Danny J. Johnson.