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Abstract

Justification of conversions to cellular manufacturing must show that cells are either a more cost effective way to obtain the improvements desired, or that the desired performance improvements cannot be achieved through improvements to the existing system. Although the model-based literature that compares the throughput time performance of functional and cellular layouts has identified conditions that are important for these conversion decisions, the question remains whether the underlying factors in these studies are the same as those relied on by industry when making cell conversion decisions. If not, what other factors should be considered? This study uses information obtained from case studies of four manufacturing plants to address these issues.

Disciplines

Operations and Supply Chain Management

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IMPROVING MANUFACTURING PERFORMANCE: CONDITIONS FAVORING THE USE OF CELLULAR MANUFACTURING

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ABSTRACT

Justification of conversions to cellular manufacturing must show that cells are either a more cost effective way to obtain the improvements desired, or that the desired performance improvements cannot be achieved through improvements to the existing system. Although the model-based literature that compares the throughput time performance of functional and cellular layouts has identified conditions that are important for these conversion decisions, the question remains whether the underlying factors in these studies are the same as those relied on by industry when making cell conversion decisions. If not, what other factors should be considered? This study uses information obtained from case studies of four manufacturing plants to address these issues.

INTRODUCTION

Most plants implement manufacturing cells to improve key performance measures, especially those related to manufacturing lead time, WIP and finished goods inventory levels, and quality (Wemmerlöv and Hyer 1989, Harvey 1993, Suri, Wemmerlöv, Rath, Gadh, and Veeramani 1996, Wemmerlöv and Johnson 1997). At the most basic level, converting to a cellular method of work organization requires the identification of part families with sufficient volume to permit the dedication of equipment and labor to form the cells. However, sufficient part family volume is not enough, by itself, to justify the conversion to cells. Such justifications must also show that cells are either a more cost effective way to obtain the improvements desired, or that the desired performance improvements cannot be obtained with the existing system.

Most plants that implement cellular manufacturing (CM) convert from a work organization that is functional in nature. The model-based comparative literature illustrates that a functional layout can outperform a cellular layout (Johnson and Wemmerlöv 1996, Shafer and Charnes 1997, and Johnson and Wemmerlöv 1998). This suggests that firms should seek performance improvements within existing work organizations under some conditions, while conversions to cells is the best way to achieve the improvements under other conditions. While the model-based comparative literature identifies conditions that may be important, the question remains whether the underlying factors demonstrated in these studies are the same as those relied on by industry when making cell conversion decisions. If not, what other factors should be considered? Understanding the full set of factors considered in such conversion decisions would help us understand when reorganization to cells is the preferred choice, thus providing information on when and where manufacturing cells are applicable (Wemmerlöv and Hyer 1987).

Unfortunately, research on the applicability of cellular manufacturing is quite sparse and empirical research in this area is severely lacking. Most of the studies to date consist of descriptive accounts of conversion efforts or modeling analysis of hypothetical systems. While these studies have enhanced our understanding of cellular manufacturing, information is missing on the factors that determine when and where cells should be used to improve performance versus seeking improvements in the existing system. This study uses information obtained from four case studies to address this gap in the research literature.

LITERATURE REVIEW

A review of the relevant literature on the applicability of cellular manufacturing is available from the authors.

RESEARCH METHOD

There were two phases to the research design. In the first phase, a mail survey was used to provide preliminary information about factors affecting cell adoption from a broad population of plants and to identify potential case study plants. In the second phase, four plants were selected for further analysis. Semi-structured interviews and on-site observations of the current manufacturing system at each of these four plants were used to gain a detailed understanding of the problems facing the firms in their previous manufacturing systems, to understand why the systems hindered performance improvement, and to understand how and why these problems were overcome by the conversion to cells. Further information on the survey design, response rate, and the methodology used to select the case study plants can be obtained from the authors.

The total amount of time spent at each plant ranged from 16 to 25 hours over the course of two or three visits. The names of three plants and the products they produce have been disguised for confidentiality reasons. These plants are referred to as CIC, SMP, and RC. Significantly more time was spent at the fourth plant, Ingersoll Cutting Tool Company (ICTC), as members of an action research team investigating the feasibility of using cells at the plant (see Johnson and Wemmerlöv 1998).

OVERALL PLANT CHARACTERISTICS

CIC, ICTC, and RC were primarily involved with machining and metal removal processes while SMP was primarily involved with sheet metal fabrication. All plants were small to medium sized in terms of square footage, number of plant employees, and number of machines (financial data are not revealed at the request of the plants). ICTC is the only plant that designed and manufactured a majority of orders to customer specifications. SMP and RC manufactured some customized products, but the majority of the items were standard. In contrast, all of CIC's production consisted of standard (i.e., non-customized) parts.

MANUFACTURING SYSTEMS BEFORE CELLS

SMP, ICTC, and RC all had pure functional layouts in place before the implementation of cells. Most workers were trained to operate more than one machine of the same type but did not typically operate machines of other types. CIC had some departments based on the type of processes performed (e.g., heat treat, washing, and lapping), while other departments were semi-dedicated to the partial processing of specific part types and contained all the equipment for those processes. However, within each part-oriented department, the equipment was arranged according to function. In addition, most workers at CIC were cross-trained to operate multiple machine types within the same department and were moved around as needed. Some machine operators at CIC and RC simultaneously ran multiple machines of the same type. In contrast, machine operators at SMP and ICTC only ran one machine at a time.

Parts were processed in large lots at CIC, SMP, and RC, with batch sizes ranging from 2 to 6 months of supply. Several pallets were required to hold a batch of parts and material handlers moved the pallets to the next operation (a production batch required several pallets while a transfer batch was a single pallet). Each of these plants had a master schedule based on forecasts and firm customer orders that fed an MRP system. In contrast, batches sizes were less than 10 units at ICTC. A reorder point system was used to release make-to-stock jobs while engineer-to-order jobs were released as soon as the design, NC programming, and process routing work had been completed.

PREVIOUS MANUFACTURING PROBLEMS

The problems faced by each plant prior to the conversion to CM can be grouped into five categories: throughput time and inventory, quality, production planning and control, safety, and miscellaneous. The most frequent problems were related to throughput time and inventory and were the primary reasons the plants in this study implemented cells. The next largest group of problems was quality-related. The remaining problems were each mentioned by a single plant.

FACTORS CHANGED TO SOLVE PROBLEMS

Batch throughput time and inventory reduction

According to our analysis, inadequate capacity was the primary cause of the long lead times at ICTC (Johnson and Wemmerlöv 1998). This led to the acquisition of new equipment. In addition, worker and equipment dedication to smaller product families increased worker expertise, probably causing a decrease in the processing time per piece, and resulting in a corresponding reduction in batch throughput time. However, both of these actions could have been accomplished in either a functional or a cellular system at ICTC.

Although setup time reduction directly reduced batch throughput time in all four plants, setup reduction at CIC, SMP, and RC allowed production batch sizes to be reduced without causing capacity problems at the machines (batch sizes were not changed at ICTC). However, setup reduction can often be achieved in either a functional or a cellular system and CIC, SMP, and RC had accomplished this action to some extent before cells were implemented.

Production and transfer batch size reduction are powerful batch throughput time reduction tools (Karmarkar 1987; Jacobs and Bragg 1988; Suresh 1992; Shafer and Charnes 1993; Suresh and Meredith 1994). While production and transfer batch sizes can theoretically be reduced in either a functional or a cellular system, such reductions in the functional layouts at CIC, SMP, and RC would have had increased the amount and cost of material handling, material tracking, scheduling, and/or information system transactions required.

When cells were implemented at CIC and SMP, the close proximity of equipment in the cells reduced the number of times a batch of parts had to be moved. Small transfer batches were feasible between cell equipment since parts were transferred either manually or by use of a conveyor. Both changes reduced the load on the material handling system and the total batch throughput time. At SMP, it also reduced damage to sheet metal components that had been caused by lifting products in and out of containers at each operation. The close proximity of equipment and personnel in the cell improved the visibility of all steps in the production process contained in the cell, resulting in improved control and execution of the production schedules. In addition, material tracking, scheduling, and information systems transactions were no longer needed between operations within the cells, reducing the load and the associated cost of operating these systems.

If CIC, SMP, and RC would have continued to improve the functional systems that were in place - while simultaneously reducing production and transfer batch sizes - increases in material handling, material tracking, scheduling, and information systems capacity (and their associated costs) would have been required to handle the increased load. In fact, it wouldn't have been economically feasible to implement small transfer batch sizes in the functional systems, due to the increase in material handling, material tracking, scheduling, and information system requirements this would entail. Cells allowed the plants to reduce, or at least contain, the increase in cost as batch sizes were reduced and small transfer batch sizes were implemented. In contrast, none of these factors were primary concerns at ICTC due to the already small batch sizes, small number of machines, and the relatively small size of the plant.

Quality and process improvement

Transfer batch size reduction, improvements in production control/schedule execution, and the increase in worker cross-training were also used to reduce the amount of scrap and rework required. Transfer batch reduction allowed defective parts to be quickly caught at the next operation, stopping production so the problem could be corrected. This reduced the amount and cost of scrap and rework.

The impact of cross-training in the cellular systems was two-fold. First, it allowed each worker to understand the impact of their task on the next task in the production sequence, making them more cognizant of how their work affected the quality of the entire product. Second, cross-trained workers in multi-operator cells permitted dynamic balancing of capacity. Workers at faster operations could assist workers at slower operations, decreasing the overall cycle time of the cell and increasing output. While cross-trained workers could have been used in the functional layout, the spatial separation of equipment and workers would have hindered the degree to which the operators could assist each other. Thus, the potential benefits of cross-trained workers would have been less in the functional system.

ICTC provides an interesting contrast to the situations in place at CIC, SMP, and RC. Overloaded equipment was the main factor causing the long throughput times and high WIP inventory levels. Increased production capacity was needed in order to solve this problem, regardless of the choice of manufacturing system. Batch sizes were already small and it was not reasonable to expect they could be further reduced. This condition virtually eliminated any throughput time improvement resulting from the use of one-piece flow. Move times were already low and neither material handling nor material tracking was considered a problem due to the relatively small plant size. Some difficulties had been experienced in the production control/schedule execution area but this was mainly caused by insufficient capacity. Finally, scheduling was not a significant problem due to the relatively small number of machines. As a result, reductions in setup times, run times, and processing time variability were the main factors that could reduce throughput time.

However, capacity can be added, and setup and run time be reduced, in both functional and cellular systems. Why then, did ICTC decide to implement cells? The answer to this question lies in the desire to increase worker cross-training and worker responsibilities for a greater number of process steps. These changes were seen as ways to increase the skill level and flexibility of the employees on the shop floor and to improve the quality of the work. The managers at ICTC were firm believers in the value of teamwork and the potential improvement that could come from a more integrated organization where workers had increased responsibilities for a larger portion of the manufacturing process. Cells were also seen as a way to control the costs of material handling and scheduling that could escalate if ICTC continued to grow.

CONCLUSIONS

Some of the improvements achieved at CIC, SMP, ICTC, and RC could undoubtedly have been achieved in the functional system. For example, CIC, SMP, and RC could have reduced production and transfer batch sizes, ICTC could have added capacity and cross-trained the workers in the functional system, etc., and each action would have reduced batch throughput time to some degree. However, based on our analysis of these plants, the same degree of improvement could not have been accomplished at CIC, SMP, and RC without a significant increase in material handling, material tracking, scheduling, coordination and information system costs. Thus, in these case study plants, cells were required to simultaneously achieve all of the plants' objectives.

REFERENCES

Full references available upon request.