

Optimum Number of Cells for a Member of a Family in an Area of Stochastic Demand

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ABSTRACT

Under stochastic demand setting, cellular manufacturing system is planned and assessed according to its profitability. The approach in this paper is composed of five stages. First, the cellular system is studied by defining processing time information and component demand according to the matrix of the part-machine and the demand data. The cellular system is then configured or planned through the following steps: the determination of means, variance and standard deviation of the capacity specifications for parts of the network, the determination of the probabilities of demand coverage for the part network and the determination of the intended usage of cells. Secondly, the estimated revenues from the cellular architecture are calculated second, the overall production costs of part family open cells are estimated taking into account various scenarios of potential unit shortages. Fourthly, the expected profits generated by open cells are decided, and finally the decision is made on the optimal design that yields the greatest profits with its related likelihood of demand coverage. The results show that while five manufacturing cells satisfy the expected part family demand, three manufacturing cells produce the system's highest income.

Keywords

Cellular Manufacturing System Design, Demand Coverage Probability, Expected Profit, Expected Shortage Cost, Stochastic Demand.

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Introduction

Metrofanis implemented community technology (GT) as a manufacturing ideology to improve productivity in the manufacturing sector. Based on their processing similarity, pieces are essentially grouped into component groups, and related machines are grouped to form a cell. Formed manufacturing cells process a certain family of parts to increase the pace of production, reduce costs and save time. Cellular manufacturing (CM) is a community technology framework which involves the selection which processing of similar parts on the cells in production. Süer et al., reported that parts are grouped into part-families and then allocated to cells on the basis of similarity in manufacturing processing. The cellular manufacturing method (CMS) has different advantages and disadvantages [1], [2]. Askin and Standridge described SCM's advantages as reducing lead times and set-up times, reducing inventory work-in-process, reducing material handling costs, improving product quality and easier quality control, increasing individual accountability, reducing labor costs and increasing employee satisfaction. At the other hand, Hyer addresses the drawbacks of SCM as relocating equipment, load balancing issues between individual cells, aversion to one operator-multiple machines and conventional dedication to dedicated set-ups. CMS style can be either layered or traditional [3]–[5].

Literature Review

The cellular manufacturing system design under uncertainty has been discussed in literature. Seifoddini studied the probabilistic nature of the product mix and developed a mathematical model to design manufacturing cells with the

objective of minimizing the inter-cell material handling cost. Jeon and Leep studied the uncertainty in cellular manufacturing systems in which a mixed-integer programming model was used to obtain the number of machines of cells for the current and future periods considering the demand uncertainty. Saidi-Mehrabad & Ghezavati utilized the queuing theory to design a cellular manufacturing system under uncertainty. The authors provided a model that consists of servers (machines) and customers (parts) with the objective of minimizing the total cost of underutilization, idleness, and subcontracting [6]–[8]. Süer et al., studied the demand fluctuation in cellular manufacturing and they stated that if the actual demand is less than the expected value, the cells are underutilized; otherwise, cells are overutilized and demand is not met. Süer et al., proposed layered system design that consists of dedicated, shared and remainder cells. In the same study, they developed a heuristic procedure to determine the minimum number of cells by forming dedicated, shared and remainder cells based on their expected utilization and demand coverage probabilities. The methodology consisted of five phases: identifying part families, determining cell configuration, determining cell types, determining operational parameters and values of performance measures and performing statistical analysis to identify the best design. Eğilmez et al., proposed a stochastic mathematical model in which probabilistic demand and capacity requirements for the products were considered. Eğilmez et al., developed a mathematical model to design a stochastic cellular manufacturing system considering uncertain production rates and demand of products [8]–[10]. In their study, they aimed to minimize the number of cells and machines subject to a maximum overutilization risk level. Eğilmez and Süer studied the impact probabilistic demand for the products and processing times of the manufacturing

processes on cellular manufacturing system design and control. In this paper, the research shows a contribution to the literature by determining the optimal number of cells based on profits generated.

Problem Considered

The cellular manufacturing system studied, that includes 39 parts and 18 machines required to process parts, is inspired by a fashion jewellery manufacturing industry. The processing times in minutes for each part on its corresponding machine are generated randomly generated between minutes. The machine that has the maximum processing time (i.e. the slowest machine) is called a bottleneck machine. Moreover, each part moves through machines in one direction and set-up times for the parts are assumed to be zero. A cell has a capacity of 40 hours/week considering that an operator works for 8 hours per day (1 shift consideration) and 5 days per week. Computer efficiency is believed to be 100%. For each part, weekly demand is assumed to follow normal distribution where the mean value for each part is generated randomly between (100, 1140) units and the standard deviation is considered to

be considered for analysis in this article. Bottleneck processing time (BPT) for each family component is calculated in minutes. Parts 20 belonging to the component family are processed on machines M1, M2, M3, M7, M10 and M18 with processing times (0.8), (1.5), (0.6), (1.7), (1.7) and (1.9) minutes, respectively, according to Table 1. The maximum time on machine M18 is (1.9) minutes, which is considered the bottleneck machine in part 20 production line. Part 20 also has stochastic demand with mean (110) units and normal (28) variance.

Methodology

The methodology is comprised of five phases as shown in Figure 1. The phases are designing the cellular manufacturing system under stochastic demand environment, determining the expected revenue generated by the cellular design, the total expected manufacturing costs of cells open for the part family, the expected profits generated by cells open and finally the decision is made regarding the optimal design that yields the largest profits with its associated demand coverage probability.

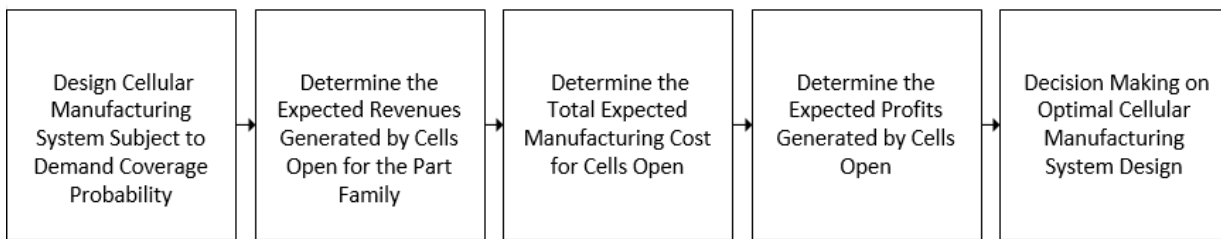


Figure 1. The Methodology Used

Cellular Manufacturing Systems Design (Determining Cell Configuration):

In this section, the cellular manufacturing system is configured or designed based on three steps. Step 1. Determining means, variance and standard deviation values for capacity requirements for parts in a family. Values of mean and standard deviation of demand for each part in a family are converted from units into hours using Equations (1) and (2). Equation 1 finds the mean capacity requirements and Equation 2 finds the variance of capacity requirements for each part. For a part family, the mean capacity requirements are calculated by summing the mean values of capacity requirements for all parts involved in that part family. The variance of the specifications for capacity is also determined by summing all variance values for each component. The standard deviation (SDCR) of component family capacity requirements is determined by taking the square root of capability condition variance.

Stage two. Determining the probability of demand coverage for a component unit. When the mean and standard deviation values for part family capability specifications are determined, the probabilities of covering part family demand are calculated by Equation (3).

In this paper, the standard costing technique based on the expected utilization for cells open. The technique is used and summarized by the following steps:

1. Determine the weekly capacity required for part *i*

part-family according to the ratio between the mean

capacity requirements for part and part-family.

2. Determine the number of units produced of part *i*

part family when cells open according to the Capacity Required and bottleneck processing time.

3. Determine the weekly labor costs for cells open. This can be obtained by the number of operators in cells,

4. hourly wage per an operator and the weekly capacity available for a cell which is considered as (40) hours

per week.

5. Determine the weekly labor cost of the portion of the mean capacity requirements for part *i* part-family

6. Determine the labor cost per unit of part in part family when open by dividing the weekly labor cost of for part when the number of units produced

7. The total of weighted average labor cost for part family when cells open is computed

The term is determined based on material cost for each part in the family. It is assumed that there are three types of materials needed and they are X, Y and Z. The cost for each unit assumed to be the minimum obtained for X, Y and Z with \$1.80, \$2.30 and \$2.10, respectively. As for the term, it is assumed to be (5%) of the total weighted average costs for labor and material. Eventually, to determine the selling price for part family, it is assumed.

Conclusion

Within this segment, the results of the weekly profits produced by the design of the cellular system of production are evaluated within order to make the decision on the optimal cellular design. To meet the anticipated demand, the part family design of the cellular fabrication system needs five cells. Results show that the number of cells most efficient is the determinant of the selected optimal design. Two targets are achieved: optimal cellular architecture and the likelihood of Demand Coverage (DCP). Table 7 reveals that 3-cell architecture with 77 percent DCP yields the largest component family income with a range of \$42,875.33-\$ 46,371.60 values. Potential studies may involve study of several families.

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