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# Integrated multi-period cell formation and subcontracting production planning in dynamic cellular manufacturing systems

Nima Safaei [a,*], Reza Tavakkoli-Moghaddam [b]

[a] C-MORE, Department of Mechanical and Industrial Engineering, University of Toronto, 5 King's College Road, Toronto, ON, Canada M5S 3G8
[b] Department of Industrial Engineering and Department of Engineering Science, College of Engineering, University of Tehran, Tehran, Iran

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ABSTRACT

In this paper, an integrated mathematical model of the multi-period cell formation and production planning in a dynamic cellular manufacturing system (DCMS) is proposed with the aim of minimizing machine, inter/intra-cell movement, reconfiguration, partial subcontracting, and inventory carrying costs. This paper puts emphasis on the effect of the trade-off between production and outsourcing costs on the re-configuration of the cells in cellular manufacturing systems (CMSs) under a dynamic environment, in which the product mix is different from a period to another resulting in the operational dynamism in the cells. The proposed model is verified by a number of numerical examples and related sensitivity analysis.



## 1. Introduction

Most production environments involve the changes in operating parameters, such as the product demand over time. In such a case, managing the production resources and balancing them between successive time periods with the aim of minimizing the production costs is known as "production planning (PP)". Cellular manufacturing systems (CMSs) are one of the well-known and efficient alternatives for the production environment with high variety and high volume of products. The main goal of CMSs is to minimize the throughput time, setup cost and also the material handling costs in the shop floor. However, for more reality, some of the PP alternatives, such as facility capacity, machine cost, inventories holding, backorders and subcontracting, have been considered to form the manufacturing cells in the recent researches. In general, integrating the concepts of the CMS design and PP is to be a fundamental requirement for modelling and simulating the real production environments. Actually, fluctuations in product mix, volume and introduction of new products are the key aspects that justify the integration of the CMS and PP. Despite the fact that the design of production systems depends on how planning the production resources, it is rare to find previous work integrating the concepts of the CMSs design and PP from the operational point of view.

The objective of a typical PP problem is to minimize the total production-related costs, such as variable production costs, inventory costs, and shortage costs, over the fixed planning horizon. The main constraints of the PP problem are as follows: (1) inventory balance equation for making the inventory and/or shortages balanced with those from the previous period, production quantity, and demand quantity and (2) capacity constraints which ensure that the total workload for each resource (labour, machine, etc.) does not exceed the capacity in each period (Kim and Kim, 2001).

Because of the dynamic nature of PP problems, the integration of the CMS and PP makes the problem very complex and computationally hard. The reason is that the cell reconfiguration is the most important operational aspect of the CMS design in the dynamic environment that must be considered in a real integrated model.

* Corresponding author. Tel.: +1 4169787602; fax: +1 4169783453.
*E-mail address:* safaei@mie.utoronto.ca (N. Safaei).

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The concept of the dynamic cellular manufacturing system (DCMS) is first introduced by Rheault et al. (1995). In the traditional CMS any changes in the product demand over time is ignored from product redesign and other factors. It assumes that the product mix and part demand is constant for the entire planning horizon. The product mix refers to a set of part types to be produced at each period. In the dynamic environment, a planning horizon can be divided into smaller periods where each period has different product mix and demand requirements. Consequently, the formed cells in the current period may not be optimal and efficient for the next period. To overcome disadvantages of the traditional CMS, the concept of the DCMS is introduced. In DCMS, The length of the planning horizon directly depends on the natural of the product. For example, if we encounter the season products, like clothing or heater/cooler equipments, the planning horizon may consist of two six-month periods or four three-month periods. The DCMS is related to reconfiguration of manufacturing cells including part families and machine groups at each period. Reconfiguration involves swapping the existing machines between each pair of cells, called machine relocation, adding new machines to cells including machine replication, and removing the existing machines from cells.

A schema of the cell reconfiguration in the DCMS for two consecutive periods is schematically shown in Fig. 1. The system contains of two manufacturing cells for each period. Because of the processing requirements, machine 3 must be relocated from cell 1 to 2 and machine 7 from cell 2 to 1 at the beginning of period 2. Also, machine 8 must be added to cell 2 at the beginning of period 2 while machine 1 will not be used during period 2. In this case, either machine 1 keeps in the same cell or moves to another cell because of the cell size limitation. Considering the maximum cell size is equal to 4, machine 1 moves to the outside of cell 2 and machine 8 is replaced by that. Thus, the above reconfiguration requires three machine relocations.

In a DCMS, the decision maker (DM) wants to know how big the changes of the cell configuration from a period to another are. As it is pointed out earlier, these changes are caused by the fluctuations in the production and outsourcing requirements. In this case, the DM must make an appropriate decision between the available alternatives, such as adding a new machine, relocating the machines between current cells, subcontracting some parts and hiring/firing the workers, to keep a balance between production and outsourcing costs. Making such a decision can be critical and risky in the cost-intensive production systems, such as DCMS, because it can significantly affect the cell configuration during the given horizon planning. Hence, the current paper is developed to put emphasis on the effect of the trade-off between production and outsourcing costs on the re-configuration of the cells in DCMSs.

Material handling is the most important operational aspect of the CMS. In practical, the material handling cost in the CMS is divided to two main groups: inter and intra-cell movements. It is rare to find any previous work considering both inter and intra-cell movements in the DCMS simultaneously, especially, considering the operation sequence. Among the researches related to the DCMS, only Wicks and Reasor (1999), Defersha and Chen (2006a), Safaei et al. (2006) and Safaei et al. (2008) considered the operation sequence for inter-cell movements. Additional advantage of the research by Safaei et al. (2008) considered both intra-cell and inter-cell movements by assuming the operation sequence. Among the previous studies, Sankaran and Kasilingam (1993) formulated an integer programming model which uses a stepwise linear function to represent the cost of intra-cell moves. Ranges of cell sizes, in terms of the number of machines contained in a cell, are defined. As cells become larger and fall into the next range, there is a stepwise increase in the cost of an intra-cell move. However, their model does not consider the effect on which demand variability may have on the system.

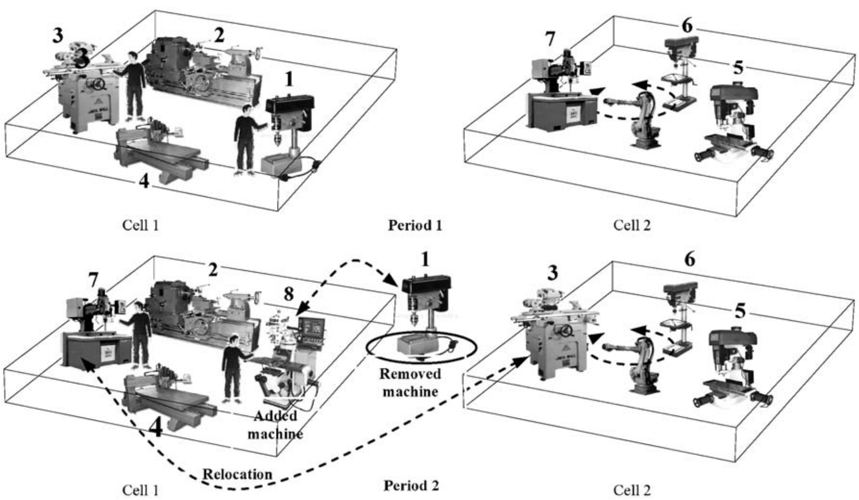


**Fig. 1.** A schema of the cell re-confirmation in DCMS.