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Towards an integrated model of operation allocation and material handling selection in cellular manufacturing systems

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Abstract

An integrated approach to operation allocation (OA) and material handling systems selection (MHSS) in cellular manufacturing systems is presented. The OA model assigns the operations of a set of part types to a group of machines, and provides this information as input to the MHSS model. The MHSS model allocates equipment for handling the parts between machines as well as at a machine. This information is then fed back as an input to the OA model. An iterative algorithm is developed to solve the two models sequentially, and a numerical example is provided to demonstrate the applicability of the models.

Keywords: Operation allocation; Material handling system selection; Cellular manufacturing systems; Integer programming

1. Introduction

Manufacturing is a set of functions that are coordinated to manufacture a product. Each function contributes to the final product but also adds to the total costs, which ultimately determine the success of a manufacturing organization to remain competitive. Since all the manufacturing functions are interdependent, it is necessary to view manufacturing as an integration of the various sub-systems with information flow playing a crucial role.

Material handling (MH) is one of the manufacturing functions that has been the focus of attention for many researchers (e.g., Hassan et al., 1985; Matson et al., 1990; Noble and Tanchoco, 1994; Chu et al., 1995; Kim and Eom, 1997; Choi and Noble, 2000). This is due to the fact that it accounts for a substantial share of the total manufacturing costs of a product. Tompkins et al. (1996) estimate that, in a typical manufacturing operation, MH accounts for 25% of the number of employees, 55% of all factory space, and 87% of production time, and that MH costs represent between 15% and 70% of the total cost of manufacturing a product. Certainly, MH is one of the first areas to examine in cost reduction activities.

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In recent years, increased demand for flexibility in manufacturing systems has led to the development of flexible and cellular manufacturing systems (FMS and CMS). Such systems provide a high degree of flexibility to manufacturing operations, but the benefits they promise cannot be fully achieved until all the manufacturing functions are integrated into the design of the system. This subject has drawn a great deal of attention from the research community (e.g., Nadoli and Rangaswamy, 1993; Rembold and Tanchoco, 1994; Noble et al., 1998).

As a key component of manufacturing systems, MH predominantly interacts with the facility layout and system control/scheduling problems. The material handling system (MHS) design problem as a whole requires that the logical and physical aspects of material flow be combined by means of MH equipment and that the design be justified from both performance and economic perspectives. Since MHS is an integrating component of a manufacturing system, all complexity inherent in the manufacturing operations is transferred to the MHS. Associated with the MHS design problem is the complexity of the economic justification process. The design is of no value if it is economically infeasible. Therefore, the MHS design problem must include economic considerations. However, much of the recent research relegates the economics of the design to a secondary issue that is evaluative in nature (Gupta and Dutta, 1994).

This work represents the second step in an attempt at integrating the MHS design into the overall design of a CMS, which centers around the selection of machines and the allocation of operations to the machines. The current work takes into account the various MH operations that take place during manufacturing, both at the processing machines and in-between. It attempts to determine a set of MH equipment compatible with the required MH operations and the characteristics of the part types. It is an attempt at integrating the operation allocation (OA) problem and the material handling systems selection (MHSS) problem as first proposed by Paulo (2002) and Paulo et al. (2002).

Section 2 presents a literature review of some of the relevant work published in recent years that deal with the OA and the MHSS problems. In Section 3 the OA and MHSS models are developed and an algorithm to solve them is presented. To demonstrate the applicability of the models, a numerical example and a discussion of its solution are presented in Section 4. Finally, a discussion of the implementation of the model and some concluding remarks are presented in Section 5.

2. Literature review

In this section, a review of the more recent and pertinent literature on the OA and the MHSS problems is presented. In as much as the present work employs a modeling approach to the problem, the literature review would emphasize the mathematical programming approaches that have been developed primarily in the context of FMS and CMS.

The OA problem in FMS and CMS has been studied by many researchers. Damodaran et al. (1992) proposed a mixed-integer-programming model for the OA problem in the context of multi-machine and multiple cell operations. The objective function minimizes the refixturing costs, MH, and processing costs. The allocation of operations is effected by the trade-off between refixturing and MH.

Taboun and Ulger (1992) presented a multi-objective 0–1 integer-programming formulation for OA in FMS. The model considers various objectives such as minimizing the processing, handling, tool setup, fixturing/refixturing, and penalty costs of under-utilization and over-loading of machining centers.

Atmani et al. (1995) proposed a 0–1 integer-programming model that jointly considers OA and cell formation in cellular manufacturing. The objective function minimizes the operation costs, refixturing costs and transportation costs.

Joines et al. (1996) proposed an integer program for the design of CMS and developed a stochastic solution technique using genetic algorithms (GA). The GA approach simultaneously groups the parts and machines into part families and cells, and assigns them to each other. The approach offers improved design