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Time-phased creation of hybrid manufacturing systems

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Abstract

This paper develops a comprehensive method for transforming pure functional manufacturing shops into hybrid production systems that comprise both cellular and functional areas. The facility redesign approach first derives the layout of the work centers within each cell and then places the cells within existing departments according to a time-phased implementation plan. The incremental cell implementation is dictated by budget constraints that limit the allowable investment in each fiscal period. The goal is to maximize the net benefit from cell implementation, expressed as the difference between the savings in material handling effort and the cost of machine rearrangement. An explicit enumeration scheme provides the optimal intra-cell layout. The problems of cell placement and implementation sequence are integrated in an integer programming formulation. The decomposition of the mathematical model motivates a space search approach, which generates an optimal solution. All algorithms are integrated and used to transform the functional shop of a large manufacturer into a hybrid production area. The results illustrate that substantial benefits can be realized even with a conservative multiperiod implementation plan.
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Keywords: Facility layout; Hybrid cellular & functional manufacturing systems; Planning for cellular implementation

1. Introduction

A typical job shop is organized along functional departments, with like processes/machine tools grouped together (Francis et al., 1992). While this shop organization provides a flexible layout that is readily adaptable to changes in the work mix, it results in increased move and queue times, thus large manufacturing cycle times and production costs (Ham et al., 1985). To minimize the inter-departmental flow and the non-value-added material handling effort, cellular manufacturing systems have been proposed (King, 1980). These systems comprise groups of machines that process families of parts (in terms of part attributes or routings), and require the clustering of machines into semi-independent groups (cell formation)-see Fig. 1.

A plethora of mathematical programming and heuristic approaches have been developed to solve the cell formation problem (Kusiak and Chow,

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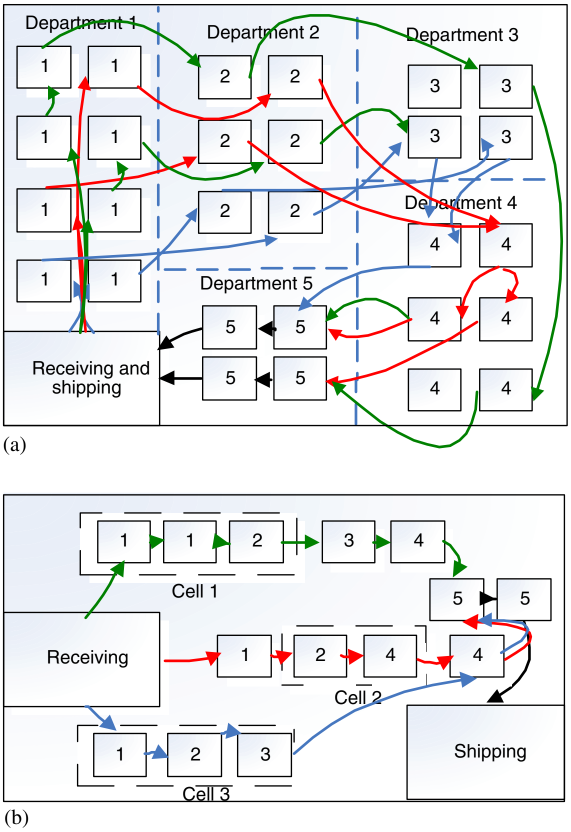

Fig. 1. Functional departments vs. manufacturing cells.

1988). The majority of these algorithms are based on part similarities and other group technology considerations (Wemmerlov and Hyder, 1986), or require material flow and machine capacity information (Harhalakis et al., 1990). Recently, genetic algorithms (Hicks, 2004) and fuzzy decision-making (Gungor and Arkan, 2000) have also been proposed for the cell formation problem, which continues to intruigue researchers and practioners. Furthermore, several studies have addressed the advantages of cellular systems with respect to production effectiveness (see, e.g., Al-Mubarak et al. (2003) and D'Angelo et al. (2000)).

Given the logical aggregation of work centers into cells, the layout of the resources within each cell must be designed. The intra-cell design problem has received relatively smaller attention compared to cell formation, and has been typically treated as a quadratic assignment problem (QAP) (Heragu, 1992). The usual objective is the minimization of the cumulative product of the material flow and the distance between the cell's work centers. For a comprehensive survey of heuristics to solve the intra-cell design problem see Kusiak and Heragu (1987). In several industrial applications however, it has been observed that solving the general QAP for intra-cell layout results in unordered clusters of machines which do not facilitate the flow of parts through the cell (Lu, 1993). Thus, additional constraints or different objectives are necessary to drive the solution towards the three intra-cell layout types usually desired in modern manufacturing systems, i.e., linear single and double row and U shaped arrangements (see Heragu (1992) and Hassan (1995)).

The final stage in the design of a cellular facility is the determination of the location of the cells on the shop floor. The problem has been treated as a QAP as well, with various objectives (Francis et al., 1992; Meller, 1994; Gomez et al., 2003), usually targeting minimal inter-cell material handling. However, since most of the flow is confined within the cells, minimization of inter-cell material handling may not be the most appropriate objective, since the associated cost is minimal by design (cell formation) for pure cellular configurations (Liang and Taboun, 1995).

Most design methods for cellular manufacturing systems developed to-date address a clean-slate problem, i.e., they assume that any change in the shop area is feasible or may be performed with negligible costs. Thus, they concentrate independently on the clustering or layout problems, and ignore significant implementation issues (Logendran, 1993). However, if we addresses the reconfiguration of an existing facility from a functional arrangement to a cellular system, several cost factors and inherent constraints have to be considered simultaneously. For example, newly formed cells may incur substantial machine relocation costs, or may comprise machines that cannot be placed in close proximity. Furthermore, the relocation of some machines may be infeasible due to their weight or permanent base. Also, redistribution of machines to departments must be

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