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The Trade-Off Between Intracell and Intercell Moves in Group Technology Cell Formation

Gajendra Kumar Adil, Shailesh J. Mehta School of Management, Indian Institute of Technology-Bombay, Powai, Mumbai, India. *E-mail:* gkadil@som.iitb.ernet.in
Divakar Rajamani, i2 Technologies, Inc., Irving, Texas, USA

Abstract

In cellular manufacturing, machines are organized into compact and independent product-based group technology (GT) cells. Production in smaller GT cells not only reduces travel distances but also facilitates better material and production control. Cell compactness and cell independence are two basic requirements of efficient GT cells. Most cell formation procedures consider maximizing cell independence as the objective. In doing so, these procedures impose an upper limit on cell size as a threshold value for cell compactness. This paper views cell compactness and cell independence in terms of intercell and intracell move costs. The trade-off between intracell and intercell move costs is explained in detail. A nonlinear mathematical model and simulated annealing algorithm are developed that minimize the total intracell and intercell move costs. In the calculation of move costs, production quantity, effect of cell size on intracell move, effect of sequence of operations, and multiple nonconsecutive visits to the same machine are considered. The results are compared with published results.

Keywords: *Group Technology, Cellular Manufacturing, Cell Formation, Intracell Moves, Intercell Moves*

Introduction

Production in a large plant having a process (job shop) layout can be very inefficient due to the excessive travel of parts. In addition, material control is extremely difficult primarily because parts need to travel between autonomous shops (or departments). In fact, in a typical job shop a part spends 95% of the time in traveling and waiting.[1] The time thus lost increases manufacturing lead time considerably.

Gain in production efficiency is possible by adopting cellular manufacturing. In cellular manufacturing, machines are organized into compact and independent product-based group technology (GT) cells. Production in smaller GT cells not only reduces travel distances but also facilitates better material and production control. Practitioners have reported several advantages of GT cells. According to a survey[2] of 32 US companies, the five most common reasons for establishing group technology (GT) cells were to reduce WIP inventory, reduce setup time, reduce manufacturing lead time, reduce material handling, and to improve output quality. All these reasons received an average importance score exceeding 4 when rated on a scale from 1 (marginally important) to 5 (extremely important).

Burbidge,[3] based on his experience with 33 companies, states that most benefits of cellular manufacturing are primarily achieved because the machines required for processing the parts are in close proximity to one another under one foreman. The closeness of machines in a cell allows for closed scheduling (smaller transfer batch), leading to lower inventories and shorter manufacturing lead time.

Cell compactness and cell independence are two basic requirements of efficient GT cells. The travel distances are reduced when cells are compact. Similarly, independent GT cells, in which parts complete all their operations within a cell, offer benefits in terms of simplified material flow and better production control. However, quite often both the requirements are contradictory. When cells become smaller, the chances of a part completing all of its operations within a cell are reduced, thereby making the cells more dependent. Most cell formation procedures consider maximizing cell independence as the objective. Often, cell compactness is treated as a constraint by specifying a maximum allowable cell size. These approaches may not determine compact cells. For instance, consider a system comprising seven parts and eight machines, for which a part-machine matrix is shown in *Figure 1*.

The data contains three completely independent and compact GT cells: {M1, M2, M3, M4}, {M5, M6}, and {M7, M8}. However, if the objective is to maximize cell independence with a maximum allowable number of machines in a cell equal to four, a solution of two completely independent GT

Parts	Machines							
	Cell 1				Cell 2		Cell 3	
	M1	M2	M3	M4	M5	M6	M7	M8
P1	1	2	4+	3				
P2	2	3	1	4				
P3	4	3	2	1				
P4					1	2		
P5					2	1		
P6							1	2
P7							1	2
+ indicates part P1 goes to machine M3 for 4th operation in its routing								

Figure 1
Part-Machine Matrix for a System That Can Be Decomposed into Three Completely Independent Machine Cells (Groups)

cells—{M1, M2, M3, M4} and {M5, M6, M7, M8}—is an alternate optimum solution. With this approach, it is not possible to differentiate between a more compact three-cell solution and a less compact two-cell solution. The reason for the above is that cell compactness is considered as a constraint rather than an objective.

This paper views cell compactness and cell independence in terms of intracell move cost and intercell move cost, respectively. Part movements in a cellular manufacturing system are of two types: (i) intracell moves and (ii) intercell moves. If the machines required for processing two consecutive operations on a part are located in the same cell, then the part move between these two operations is an intracell move. However, if the required machines are in two different cells, the part move between the two operations forms an intercell move.

When a system is decomposed into smaller GT cells, the expected travel distance of an intracell move decreases for the following reasons. Some or all of the machines not required by a part in the cell are likely to move to the other cells, and this avoids extra part travels (passes) that were present in the original system. However, when the system is decomposed into smaller GT cells, a single cell may not contain all the resources (that is, machines) that a part needs to complete all of its operations. This requires parts travelling to more than one cell, or in other words, total intercell moves increase.

For the purpose of illustration, consider the example shown in *Figure 2*. Six parts are to be produced that require one or more of the five machines for processing. The part routings are shown in *Figure 2a*. Consider two arbitrarily selected cell configurations: (i) a one-cell configuration (*Figure 2b*) and (ii) a two-cell configuration (*Figure 2c*). For simplicity, a straight-line layout of the machines in a cell with a spacing of unit distance between two consecutive machines is considered. With the layout and routing information, one can compute the distance traveled by each part.

***Case 1** (Figure 2b)*. There is a single cell. All of the part operations are completed within the cell; thus, all the moves between operations are intracell moves. The average distance traveled per intracell move is computed. Part P1 has its first operation in machine M1, followed by operation 2 in machine M3. Part P1 has to pass machine M2. Thus, part P1 has to move two units for performing the two operations (or one intracell move). Similarly, parts P2, P3, P4, P5, and P6 will travel 4, 2, 4, 4, and 2 units, respectively. Thus, the average distance traveled in one intracell move can be computed as follows:

Average distance traveled per intracell move = (Total intracell distance traveled by all the parts)/(Number of intracell moves occurred)

= (18)/(9) = 2 units

No intercell move occurred.

***Case 2** (Figure 2c)*. There are two GT cells. Cell 1 contains machines M1 and M3. Cell 2 contains machines M2, M4, and M5. Note that the machine selection for cells is arbitrary. All the parts except parts P4 and P5 complete all their operations within a single cell. Intracell distances traveled by parts P1, P2, P3, P4, P5, and P6 are 1, 3, 1, 1, 2, and 1 units, respectively. Therefore, the average intracell move distance in this case is as follows:

= [(1) + (1 + 2) + (1) + (1) + (2) + (1)]/[1 + 2 + 1 + 1 + 1 + 1] = 1.28 units

In addition, there are two intercell moves of parts (one each for part P4 and P5) between the two cells.

The intracell move distance is reduced from 2 units per move in Case 1 to 1.28 units per move in Case 2 for the assumed machine layout. Thus, intracell distance moved is a measure of cell compactness. Note that the intracell move distance is a function of machine layout in the cell(s). The number of intercell moves has increased from 0 in Case 1 to 2 in Case 2. The number (or, alternatively, the