Chapter 2
Mathematical Modeling and Genetic Algorithms for Product Sequencing in a Cellular System

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ABSTRACT

This chapter considers a product-sequencing problem in a synchronized manufacturing environment, which is using a uniform time bucket approach for synchronization. This problem has been observed in a jewelry manufacturing company and is valid in other labor-intensive cellular environments. The scheduling problem handled has two aspects: first, determining manpower allocation; second, sequencing the products in order to minimize the number of periods where available manpower is exceeded. The number of operators needed in a time bucket may exceed the available manpower level as different products have different manpower requirements for different processes. A mathematical model is developed for the manpower allocation part of the problem. To perform product sequencing, two methods are used, namely mathematical modeling and genetic algorithm. A new five-phase GA approach is proposed, and the results show that it outperforms the classical GA. Several experiments have been conducted to find better GA parameters as well. Finally, GA results are compared with mathematical model results. Mathematical Modeling finds optimal result in a reasonable time for small problems. On the other hand, for the bigger problems, genetic algorithm is a feasible approach to use.

INTRODUCTION

The main concept in cellular manufacturing is to complete a product in a single manufacturing unit instead of moving the work from one functional department to the other. This is possible by grouping similar products together into product families and then manufacturing them in their dedicated cells. Each cell ideally consists of all of the machines needed to manufacture the family it is assigned. Kay and Suresh (1998) summarize the benefits of cellular manufacturing as follows:

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- Less work-in-process (WIP) inventory and thus less space
- Smaller and predictable leadtimes
- Smaller setup times because of similarities of products in families
- Smaller lot production
- Simpler work flow
- Simpler and better control since there is no operation-wise division in responsibilities as in process layout

There are various issues related to cellular control and they can be classified as Family Sequencing, Family Scheduling, Cell Loading, Product Sequencing, Cell Scheduling, Crew Size Determination, and Manpower Allocation to Operations (See Süer, Saiz, & Gonzalez,1999; Süer, Cosner, & Patten, 2009). Family Sequencing is performed to determine the sequence of families in cells. Family Scheduling goes one step further and determines the start and completion of families on cells. Cell Loading is the assignment of products to its feasible cells. Product Sequencing determines the sequence by which the products are run in a cell. Cell Scheduling determines not only product sequence but also start and completion times of products on machines in cells. Crew Size determination deals with number of workers to be assigned each cell. Manpower Allocation determines the number of workers assigned to machines/operations in each cell. This chapter focuses on product sequencing and manpower allocation decisions in a labor-intensive cell.

Another important classification in scheduling is deterministic versus stochastic scheduling. In deterministic scheduling, it is assumed that all parameters are known exactly. This is hardly the case in most manufacturing systems and therefore most scheduling results cannot be exactly implemented. On the other hand, stochastic scheduling allows this variation to be included in the schedules. Static scheduling assumes that set of jobs (workload) remain predictable whereas dynamic scheduling assumes that set of jobs to be processed varies significantly from one period to another.

This chapter deals with product sequencing and manpower allocation decisions in a labor-intensive cell that adapted synchronous manufacturing principles. Süer and Gonzalez (1993) defined synchronous manufacturing as: "A systematic way that provides a perfect flow of material through the production system by making it available for the right resource at the right time using a periodic approach with the objective of simplifying the scheduling task and minimizing the work-in-process inventory and the flow time."

Süer and Gonzalez (1993) implemented synchronous manufacturing in a jewelry manufacturing plant. They explain that there was a desperate need for synchronization. The main reason was that there were different schedules everyday and implementation of them was heavily dependent on the planners, schedulers, supervisors and employees. After the implementation of the uniform time bucket approach, they were able to convert this dynamic and stochastic scheduling problem into a static and deterministic problem which made scheduling a lot easier to implement. Jobs started and finished at regular intervals, and then in this periodic fashion, the need to prepare a different schedule everyday was eliminated.

The objective of this chapter is to sequence products in such a synchronized flow environment such that the number of time periods where available manpower is exceeded is minimized. More details about problem definition are discussed in Problem Statement Section. Both mathematical modeling and genetic algorithm approaches are employed to solve this problem.

BACKGROUND

The problem discussed in this chapter was observed in a jewelry manufacturing company. The cells in this manufacturing environment are labor-intensive, i.e., continuous operator atten-