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Mathematical Modeling of Production Scheduling Problem: A Case Study for Manufacturing Industry

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Abstract

Mathematical formulations for production scheduling environment are very complex task. These complex real life problems cannot be solved by traditional exact solvers to get good quality solutions within feasible time. Inspired by a real-world case study in the manufacturing industry, this paper provides an efficient mathematical model for short-term production scheduling. This model can be easily modified for flexibility and dynamic nature of manufacturing industries. This mathematical model can be optimized by modern optimization methods.
Keywords: Mathematical Modeling, Scheduling, Production Scheduling, Optimization

I. INTRODUCTION

Scheduling problem is very hard and complex to formulate and solve optimization problem. It mainly deals with finding the best sequences for processing jobs on available machine. Scheduling ensures the material flow throughout the production system. Scheduling is an important tool in manufacturing industries and engineering. It can have a major impact on the productivity of a process. In manufacturing, one of the main purposes of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment. The main aim of production scheduling is to maximize the efficiency of the operation and reduce the production costs.

Scheduling requires the combination of many different kinds of data. Constructing a schedule requires mathematical models of processes, definition of objectives and relation between constrains, definition of relationships between tasks and resources. Schedules assign resources to tasks or tasks to resources at specific times. Tasks or activities may be anything from machining operations, quality check, and maintenance to development of software modules. Resources include machines, people, and raw materials. Typical objectives include minimizing the makespan, minimizing the production cost, or minimizing the Lateness.

Production scheduling is a very complex task. Traditionally the production scheduling is being done manually by ones experience and knowledge. It is the fastest method of production scheduling. But there are lots of drawbacks of this method. Manual production schedule do not guarantee the optimal solution as it totally depends on one's choice. Also such experienced engineers are now getting old so it is very difficult to find such skilled and experienced engineer. Therefore it is necessary to find alternative and optimum method of production scheduling. The best alternative is to represent the manufacturing activity in different mathematical model and optimize these models mathematically. In recent decades many researcher have used computers for solving very complex problems with some algorithm. In this study similar type of problem is translated into mathematical model.

II. LITERATURE REVIEW

In last few decades many efforts had been made to represent the manufacturing facility into a mathematical model. These models are of different types depending upon the type of production facility. One of them is time based model. Time is the main parameter in this model. The main objective of this type of model is reduction of time required to produce final product. Other types of models are sequence based model. The main objective of these types of model is to determine the optimal and feasible processing sequence. The hybrid type of problem can also be formulated by combination of these two models.

Some of the successful attempts of mathematical formulation and optimization are listed here. B. Naderi and A. Azab (2014) formulate the Operation-position based model; Operation-sequence based model, and heuristic models for Distributed job shop environment. They also developed the Evolutionary algorithm to solve these models [1]. Xinyu Li,Liang Gao (2010) formulated a mathematical model of integrated process planning and scheduling. They have developed an evolutionary algorithm based method for integration and optimization. They also compared feasibility and performance of their proposed method with some previous works [2]. J. Behnamiana (2015) solved the mixed integer linear programming by the CPLEX solver. Their problem was for small size instances scheduling. And they also compared their obtained results by heuristic method with two genetic algorithms in the large size instances [3]. Cheol Min Joo (2015) derived a mathematical model for unrelated parallel machine scheduling problem by considering sequence and machine dependent setup times and machine dependent processing times [4]. Xiao-Ning Shen, Xin Yao (2015) constructed a mathematical model for the multi objective dynamic flexible job shop scheduling problem [5]. Hlynur Stefansson (2011) have studied scheduling problem from a pharmaceutical company. They decompose the problem into two parts and they compared the discrete and continuous time representations for solving the individual parts. They also enlisted pros and cons of each model [6]. Z.X. Guo (2013) formulated the multi objective order scheduling problem with the consideration of multiple plants, multiple production departments and multiple production processes. A Pareto optimization model is developed to solve the problem [7].

III. PROBLEM FORMULATION

Production scheduling assumptions includes a set of m machines and a set of n job. Each job has its own set of process. These processes can be processed on particular machine. The problem is to schedule jobs on machines so as to optimize an objective or objectives. The most common objective is minimize makespan, i.e., the maximum time required to finish the jobs. It is assumed that machines and jobs all are always available. The setup times can be neglected or added into processing times. A machine can process only one job at a time.

A. Assumptions:

It is not possible for any researcher to formulate the exact mathematical model of any production facility. In order to solve this problem, the following assumptions are made:

- Each machine can handle only one job at a time.
- All jobs and machines are available at beginning of the process.
- After a job is processed on a machine, next job is immediately loaded on machine.
- Setup and cleaning time is added in processing time.

B. Parameters:

The following parameters and indices are used:

- n Total number of jobs (i= 1,...., n)
- m Total number of machine (j= 1,2,..., m)
- t_{ij} The processing time of i_{th} job on j_{th} machine
- T_j Total available machine time on j_{th} machine
- P_{ij} The processing cost of operation on i_{th} job on j_{th} machine
- L_{ij} Number of workers required to finish i_{th} job on j_{th} machine
- α_{ij} A binary variable. 1 if j_{th} machine can process i_{th} job, otherwise 0.
- β_{ij} A binary variable. 1 if j_{th} machine is selected to process i_{th} job, otherwise 0.

C. Objectives:

In today's competitive world it is not possible to have only single objective. There are lots of factors which affects the performance of the final product thus optimizing only parameter will not be accepted. Simply we cannot prepare a schedule which takes least time to complete the job but cost associated is very high or a plan with least processing cost but takes more time than due date of the product. To overcome such problems a schedule which satisfy all the objectives simultaneously should be prepared.

Some main objectives are formulated below which greatly affects the performance of the final product. Depending upon the variables, these objectives may be of maximization or minimization type.

- Minimizing the make span which is the completion time of last operation of all the jobs:

$$\text{Minimize makespan} = \text{Max} \sum_{j=1}^{m} \sum_{i=1}^{n} t_{ij} \times \alpha_{ij} \times \beta_{ij} \qquad (1)$$

- Minimize the overall processing cost. It is the cost associate with the processing of the i_{th} job on j_{th} machine:

$$\text{Minimize processing cost} = \sum_{j=1}^{m} \sum_{i=1}^{n} P_{ij} \times \beta_{ij} \qquad (2)$$

- Minimizing the total workers required:

$$\text{Minimize workers required} = \sum_{j=1}^{m} \sum_{i=1}^{n} L_{ij} \qquad (3)$$

D. Constraints:

Not all resources are unlimited and it is not possible that they will available for all time. Machines cannot be available all time. Machine should be shut them down for maintenance purpose. Sometime tool failure may occur. Thus it is necessary to define certain constraints for the mathematical model.

1) *Constraints For The Above Model Are As Follows:*

Production scheduling is complex task. For real life problem it is very difficult to formulate and optimize. But these complex problems can be solved by splitting the huge problem into small problems and optimizing them separately. After result of all the problems are obtained, they can be combined to form the optimized production schedule.

- Total processing time should be less than total available machine time:

$$\sum_{j=1}^{m} t_j \leq T_j \quad (4)$$

- Job cannot be processed at two different machines at same time:

$$\sum_{j=1}^{m} \sum_{i=1}^{n} \beta_{ij} = 1 \quad (5)$$

- Positive constraints

$$t_{ij}, T_j, P_{ij} > 0 \quad (6)$$

$$L_{ij} \geq 0 \quad (7)$$

IV. CONCLUSIONS

Day by day the complexity of production environment is increasing. Due to this complexity it is very difficult to define the manufacturing facility in mathematical form. Mathematical formulation can be made easy by splitting the large problem into pieces and solving them separately.

From literature review it can be concluded that most of the research related to production scheduling is concentrated on finding out the optimum sequence or study related to makespan and cost. Very few attempts have been made for optimizing the labour.

Mathematical modeling can be very difficult if the parameters and relation between them is not known. In this study the mathematical model of the manufacturing firm is successfully formulated. This mathematical model can be further modified to obtain desired flexibility.

V. FUTURE STUDY

Formulating mathematical model is difficult but solving it can be more difficult. Sometimes the formulated model gives infeasible solution and sometimes it takes huge time to solve. Such types of problems can be solved by modern evolutionary algorithms such as Genetic Algorithm, Tabu search, Ant colony optimization etc.

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