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Application of Project Management Approaches for Planning in Make-to-Order Production

[1]Houshang Taghizadeh and [2]Amin Zeinalzadeh

[1]Department of Management, Tabriz Branch, Islamic Azad University, Tabriz, Iran
[2]Young Researchers Club, Tabriz Branch, Islamic Azad University, Tabriz, Iran

Abstract: Customer satisfaction is one of the most important issues of success of companies in make-to-order production. A typical evaluation guideline for customer satisfaction level is to deliver orders in due time or before the due time reaches. Achievement of such purpose is required an appropriate method of production in company's scheduling management department. In this paper, it is intended to implement companies project scheduling approach for production planning of make-to-order. For this purpose, in the first part of paper, some theoretical concepts were investigated. Then based on literature for the problems associated with make to order were briefly reviewed. Afterwards, a sample company that produces light industrial machinery is chosen which has received a new order. After gathering the necessary data for the placement of order, the method for converting this data in the form of project management inputs was explained and based on gained knowledge the detailed production scheduling was achieved.

Key words: Production planning · Make to order production · Project management

INTRODUCTION

Manufacturing companies differ in the way they meet their demand. Some deliver products to their clients from finished goods inventories as their production anticipates customers' orders; others, however, manufacture only in response to customers' orders. Orders for the products tend to be on a make-to-order, make-to-print or engineer-to-order (MTO) basis. Often order being specific to a particular customer with intermittent or no repetition of demands for the same product [1].

A typical measure of the customer satisfaction is customer service level, i.e., the fraction of customer orders filled on or before their due dates [2]. This cannot be achieved without using appropriate production management methods and in particular production planning techniques.

Extensive researches have been carried out concerning planning of orders that the most of these researches are presented in mathematical models. These models vary according to objective functions and constraints of each company and in great deal, lack of perfect understanding of these parameters can decrease efficiency of these models. In addition, in the case of non-linear problems; presentation and solution of these models are not easy to obtain. Considering these factors, application of mathematical models is not a common method used for planning of orders received by company unless the companies employ expert individuals in the fields of production planning and operation research. Not using the production planning techniques can cause irreparable costs for companies.

This study aims to take a step for solving problems of production planning by the use of easier techniques. Orders received by a company have the properties of a project and it means certain activities with the required resources should be performed. In order to achieve an objective which is the completion of an order. In this research, the method for converting the production planning date to the project scheduling data and preparing a detailed production scheduling have been presented.

In addition to simplicity, the efficiency of the production planning will increase in the dynamic environment by the use of this method. Since new orders may be received during production or an order may be canceled and companies can upgrade their production planning scheduling using such approach.

Corresponding Author: Houshang Taghizadeh, Department of Management, Tabriz Branch, Islamic Azad University, Tabriz, Iran.

Pre-Assumptions:

- The machinery is limiting factor of planning in the company since it is impossible to increase the number of machines in the current situation. While work forces can be employed for the required machineries; as a result, different available machines in the company are only considered. The resource pool and human resources can be easily defined in the same manner as needed.
- The standard time for operation of each part consists of setup time and machining time. Since the machines in the workshop under study are placed very close to each other; the transportation time is very little and ignored. In the case of large transportation time, it should also be considered in the planning.

Theoretical Principles: In this section, some of the basic concepts which are used in production planning are briefly explained.

Manufacturing Methods: Factories or organizations choose a manufacturing method for producing product or providing services with the view of various factors; such as flexibility, degree of customization, capital intensity ration, etc. In general, these methods can be classified as follows:

Continuous Production: In this mode of operation, there are industries which continuously produce and manufacture without interruption. Machines are designed and arranged in a way to produce one or small number of similar products. Oil and cement industries are perfect examples of continuous operation.

Batch Production: This method is used for manufacturing a group of components, but machines should be setup before production of each batch. The manufacturing process is interrupted once a set of operation is accomplished. Such mode of operation is more labor intensive. A good example of batch production can be manufacturing of sports shoes.

Job (Make to Order Production): In this method, factories receive orders from customers and they manufacture these orders with regard to customer demands and within the framework of standards. Preparation of food ingredients and mixture of food components and permissible food additives for food industry can be an example of this type.

Methods for Production Planning: Some techniques used for planning of systems are as follows:

Graphical Method: This is one of the methods which it is being utilized widely. The objective of this method is to find a schedule which can satisfy the product demanded with the lowest cost within a specific period.

Management Coefficient Model: The historical data and statistics about human resources, production capacity and inventory level are used in this model. This information is analyzed so that regression equations could be achieved which they represent the historical data in the best manner. Then, scheduling can be performed by application of the obtained equations.

Parametric Production Planning: In this model, an estimate of planning variables is made and the mentioned variables are combined in a way so that the minimum cost is obtained.

Search Decision Model: In this method, the best combination of planning variables is obtained with the aid of computer. Computer continues to search different combinations until the trend of cost reduction is achieved and also a desired schedule is earned.

Linear Programming Method: Among optimization models, linear programming model is one of the desired models which has the most suitable application in production planning, especially in continuous and mass production.

Transportation Model: There are some problems associated with production planning which are solved using linear programming model but because of the special cases of these problems, it is not economical to be implemented in the model. Therefore, such problem is converted to transportation model with a simple change.

Trail and Error Method: A production planning can be obtained using demand data of each period (e.g. monthly period) by trial and error method based on condition that production capacity is also considered.

Scope of Planning Activities in Make to Order Production: There are various manufacturing processes, raw material and deadline for each order in make to order production. The main objective of planning is to assign the necessary resources for producing the product or providing the service with regard to customer demand. Some of the activities in planning of this system are stated as follows:

Aggregate Planning: In this stage of planning, the input resources and efficiency of the system are defined in general. Detailed decisions are not made in this step.

Planning of Machine Loading: After aggregate planning is determined, the planning of machine loading which is more detailed would be specified. This plan separately defines the load of different workshops of a company. In this plan, orders are assigned to different workshops and workload of each workshop is exactly defined. Techniques such as, Gantt chart, resource assignment method can be useful in this stage.

Priority Sequencing: The sequence for completion of orders which wait in queue is defined in this step.

Detailed Scheduling: Start and finishing time of activities in different workshops are computed and delivery time of each order is well defined.

Literature Review: Extensive research have been carried out for solving production planning of make to order problems. Some of the works are briefly mentioned in this paper. Kim *et al*. [3] addressed the integrated problem of process planning and scheduling in workshop with flexible manufacturing systems. Due to production flexibility, their tasks are possible to generate many feasible process plans for each job. Petrovic *et al*. [4] presented a new tool for multi-objective workshop scheduling problems. The tool encompasses an interactive fuzzy multi-objective genetic algorithm (GA) which considers aspiration levels set by the decision maker (DM) for all the objectives. Rego and Duarte [5] proposed a new heuristic algorithm for the JSSP that effectively combines the classical shifting bottleneck procedure (SBP) with a dynamic and adaptive neighborhood search procedure. Wang and Yu [6] conducted a flexible workshop scheduling problem with machine availability constraints. Each machine is subject to preventive maintenance during the planning period and the starting times. The maintenance activities are either flexible in a time window or fixed beforehand. Naderi *et al*. [7] investigated scheduling job shop problems with sequence-dependent setup times under minimization of make span. They developed an effective metaheuristic, simulated annealing with novel operators, to potentially solve the problem. Chung *et al*. [8] considered a kind of job shop scheduling problems with due-date constraints, where temporal relaxation of machine capacity constraint is possible through subcontracts. In practice, this kind of problem is frequently found in manufacturing industries where outsourcing of manufacturing operation is possible through subcontract. Chiang and Fu [9] addressed the job shop scheduling problem to minimize the number of tardy jobs considering the sequence dependent setup time. This problem is taken as a sequencing problem and a family of approaches with different levels of intricacy is proposed. Gröflin and Klinkert [10] investigated insertion problems in a general disjunctive scheduling framework capturing a variety of job shop scheduling problems and insertion types. Insertion problems arise in scheduling when additional activities have to be inserted into a given schedule. Lee and Dagli [11] discussed genetic algorithms and artificial neural networks to the solution of scheduling problems. Kis [12] studied an extension of the job shop scheduling problem where the job routings are directed acyclic graphs that can model partial orders of operations and that contain sets of alternative sub-graphs consisting of several operations each. He developed two heuristic algorithms for the problem: a tabu search and a genetic algorithm. Tarantilis and Kiranoudis [13] described a new metaheuristic method for solving the job shop scheduling problem of process plants, termed as list-based threshold accepting (LBTA) method. The main advantage of this method over the majority of other metaheuristics is that it produces quite satisfactory solutions in reasonable amount of time by tuning only one parameter of the method. Hoitomt *et al*. [14] explored the use of lagrangian relaxation to schedule job shops, which include multiple machine types, generic precedence constraints and simple routing considerations. Redwine and Wismer [15] developed a mixed integer programming model for scheduling orders in a steel mill. They employed decomposition algorithm for solving the model. Sawik [2] proposed a new algorithm based on mixed integer programming formulations for reactive scheduling in a dynamic, make to order manufacturing environment. Mula *et al*. [16] reviewed some of the existing literature of production planning under uncertainty. Their objective was to provide the reader with a starting point about uncertainty modelling in production planning problems aimed at production management researchers. As it can be easily noticed there are many investigations performed in the field of make to order scheduling and each of them concentrates on one or more aspects of this problem like uncertainty, sequencing, or machine availability constraint. Furthermore, different heuristic, metaheuristic or exact algorithms are employed to solve these problems. This paper aims to use project management techniques in scheduling of orders in companies; a fairly simple and practical approach in dynamic environment.

Research Methodology

Brief Description of the Company: The company considered for the study is a workshop which produces industrial machinery according to customer offer. The productions of this company are mainly used in food industry. Therefore, quality assurance is an important factor in controlling the activities of this company. In addition to quality, time is the next main aspect as customers want the project to be completed in an appointed time. Since orders accepted by the company have the nature of a new project, planning department aims to control time through project management techniques and methods. Afterwards, selling department takes the necessary actions to contract with customer according to time scheduled by the planning department.

Steps of Production Planning in Company: Upon receiving a new order, engineering department evaluates the order from the viewpoint of technical and financial issues. If there is possibility to make this order in the company; in addition, it is financially acceptable, the company with contract with the customer, otherwise the order is rejected. After accepting the order, the engineering department prepares the manufacturing drawings for the parts which should be made in the company and there is no document provided by customer for them. Afterwards, the required operations for manufacturing of each part are determined and the standard time of each operation as well. A route sheet is prepared for each part based on this information which it is relatively a time consuming step. Then, planning department schedules the order considering the availability of resources (machines are considered as limiting factor), the sequence of operations, the manufacturing time and relevant factors. Parts which cannot be manufactured in the company are purchased. Fig. 1 represents these steps briefly.

Gathering the Required Data for a Sample Order: The company has received a new order which is a subassembly of a food industry machine. The code for this order is "09" and each of the parts in this order is defined with "09XX" which "XX" is a cardinal number. Table 1 indicates a sample rout sheet.

The information of route sheets for all parts of this order is summarized in Table 2 which presents the route and standard machining time briefly. In this table, the numbers below and above the diameter in each cell indicate respectively the sequence of operation and machining time. Part 0918 and 0921 will be purchased.

Converting the Data in the Form of Project Input Information: In order to employ project management approach, the following information is required and this information is obtained from following sources:

- Defining the project: The main objective for executing of this project is to manufacture the components of a subassembly in a food industry machine.
- Developing the list of project activities: The manageable work packages which identified individuals are responsible for their execution and resources are assigned for performing them, are considered as project activities. These activities can be defined by route sheets, for example, "cutting groove" in Table 1 is one of the project activities.
- Determining the relationships between activities: There are two types of relationships between activities in this project.

- Natural dependencies: There are logical and technological relationships between activities due to the special properties of activities. For example in Table 1, grinding operation should be done after milling operation; these relationships are finish to start, i.e. grinding can not be started before finishing the milling. As a result, sequence of operations in route sheets can be used for defining this type of dependency between activities.
- Resource dependencies: This type of dependency is created by resource constraints. Machinery is required for executing of each operation. This can be easily determined from column "Machine name" in route sheet (Remember that according to pre-assumptions, machinery is considered as limiting factor and other resources can be added at need). After assigning the required resources to each operation, the production planning will be affected in scheduling because of limitation in maximum units and working hour of each resource.
- Establish the duration for each activity: Column "Standard time" in route sheet can be used for estimating the duration of each activity (If there is a significant transportation time, it can be added as a lag time to natural dependency, for example, a lag = 0.5 for finish to start dependency means a delay equal to 0.5 between two activities which is required for transportation, setup, etc). This information is summarized in Table 3 which can be used for scheduling by project management approach.

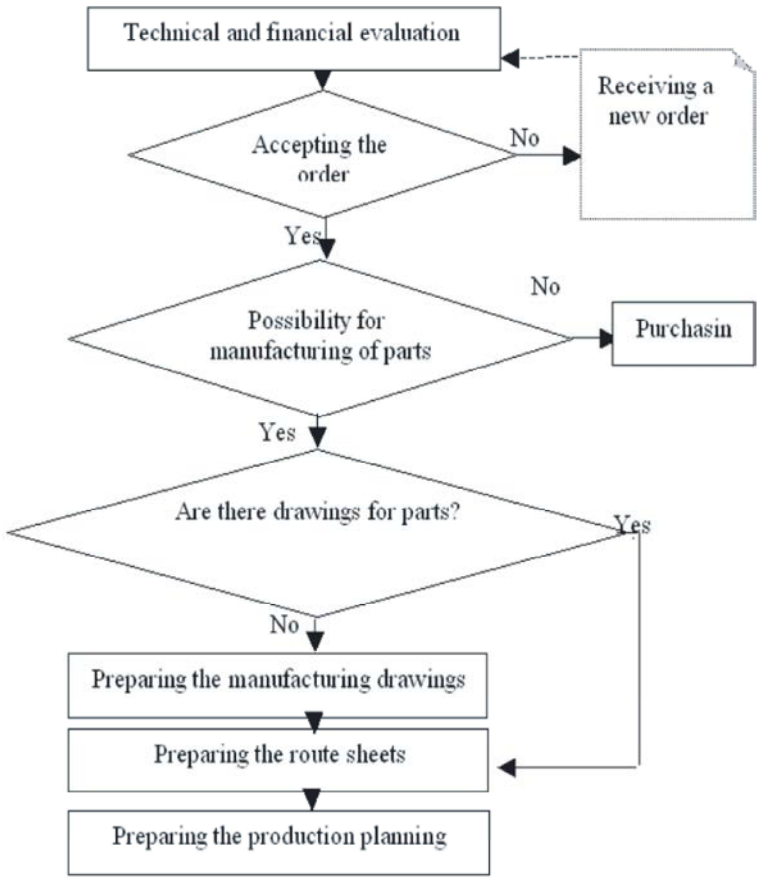

Fig. 1: Step of Production

Table 1: Route sheet for part 0901

Part name: Heater		Part Code: 0901	
Operation No.	Operation description	Machine name	Standard time (hour)
1	Cutting groove	Big milling	15
2	Shaping the upper surface	Grinding	2

Scheduling the Order by Project Management Approach: MS-Project 2003 which is an application software for project management is used for scheduling in this research. The input data in Table 3 is entered into MS-project. In addition to this data, resource information should also be defined. There are two shifts in each working day; the first one is from 8:00 a.m. to 12:00 p.m. and the second one from 1:00 p.m. to 5:00 p.m. where there is a one hour allowable gap between two shits for resting, preparation, repairing and so on. In addition, the company normally works with six working days and Friday is a non-working day. Therefore, resources can be scheduled within this period of time. Table 4 represents the availability of the resources briefly. This information is also entered into the resource sheet of MS-project.

As explained before, the requirement of activities to resources can be identified in column "Resource name" of Table 3. Table 4 indicates the availability of each resource. For example, there are two big milling machines with the specified six working hours which it means this resource can be scheduled up to twelve hours in a day. If the amount of work scheduled for this resource is more than this limit, there will be over-allocation and this problem should be resolved using methods which are called '"leveling". Different tasks can be performed for resolving over-allocation; some of them are explained below:

- Overtime working: According to the top-management policies, overtime work is not accepted at present.

Table 2: The production information for order 09

	Machine							
Part code	Big milling		Lathe		Small milling		Grinding	
0901	1	15					2	2
0902	1	14					2	2
0903	1	2	2	2			3	1
0904	1	3	2	2			3	1
0905	1	2	2	2.5			3	1
0906	1	4.5					2	2
0907	1	4.5					2	2
0908					1	2		
0909					1	5		
0910			2	1	1	1		
0911	1	12					2	0.5
0912					1	8		
0913	1	10						
0914	1	5						
0915	1	5						
0916	1	2.5						
0917	1	2.5						
0918	-		-		-		-	
0919					1	4.5		
0920					1	2		
0921	-		-		-		-	
0922			1	1				
0923			1	2				

Table 3: The input data for project management

Activity ID	Activity name	Activity Duration (Hour)	Predecessor	Resource name
1	Milling 0901	15	-	Big milling
2	Grinding 0901	2	1	Grinding
3	Milling 0902	14	-	Big milling
4	Grinding 0902	2	3	Grinding
5	Turning 0903	2	-	Big milling
6	Turning 0903	2	5	Lathe
7	Grinding 0903	1	6	Grinding
8	Turning 0904	3	-	Big milling
9	Turning 0904	2	8	Lathe
10	Grinding 0904	1	9	Grinding
11	Turning 0905	2	-	Big milling
12	Turning 0905	2.5	11	Lathe
13	Grinding 0905	1	12	Grinding
14	Milling 0906	4.5	-	Big milling
15	Grinding 0906	2	14	Grinding
16	Milling 0907	4.5	-	Big milling
17	Grinding 0907	2	16	Grinding
18	Milling 0908	2	-	Small milling
19	Milling 0909	5	-	Small milling
20	Milling 0910	1	-	Small milling
21	Turning 0910	1	20	Lathe
22	Milling 0911	12	-	Big milling
23	Grinding 0911	0.5	22	Grinding
24	Milling 0912	8	-	Small milling
25	Milling 0913	10	-	Big milling
26	Milling 0914	5	-	Big milling
27	Milling 0915	5	-	Big milling
28	Milling 0916	2.5	-	Big milling
29	Milling 0917	2.5	-	Big milling
30	Milling 0919	4.5	-	Small milling
31	Milling 0920	2	-	Small milling
32	Turning 0922	1	-	Lathe
33	Turning 0923	2	-	Lathe

Table 4: Resource availability

Resource name	Max units	Working time	Max workload per day
Big milling	2	From 8:00 a.m. to 5:00 p.m.	16 hours
Lathe	1	From 8:00 a.m. to 5:00 p.m.	8 hours
Small milling	1	From 8:00 a.m. to 5:00 p.m.	8 hours
Grinding	1	From 8:00 a.m. to 5:00 p.m.	8 hours

Table 5: Detailed scheduling of the project before leveling

Activity ID	Task Name	Duration	Early Start	Early Finish	Late Start	Late Finish	Slack
0	production planning	2.38 day	Sat 8:00 AM	Mon 11:00 AM	Sat 8:00 AM	Mon 11:00 AM	0h
1	Milling 0901	15h	Sat 8:00 AM	Mon 9:00 AM	Sat 8:00 AM	Mon 9:00 AM	0h
2	Grinding 0901	2h	Mon 9:00 AM	Mon 11:00 AM	Mon 9:00 AM	Mon 11:00 AM	0h
3	Milling 0902	14h	Sat 8:00 AM	Sun 5:00 PM	Sat 9:00 AM	Mon 9:00 AM	1h
4	Grinding 0902	2h	Mon 8:00 AM	Mon 10:00 AM	Mon 9:00 AM	Mon 11:00 AM	1h
5	Turning 0903	2h	Sat 8:00 AM	Sat 10:00 AM	Sun 3:00 PM	Sun 5:00 PM	14h
6	Turning 0903	2h	Sat 10:00 AM	Sat 12:00 PM	Mon 8:00 AM	Mon 10:00 AM	14h
7	Grinding 0903	1h	Sat 12:00 PM	Sat 1:00 PM	Mon 10:00 AM	Mon 11:00 AM	14h
8	Turning 0904	3h	Sat 8:00 AM	Sat 11:00 AM	Sun 2:00 PM	Sun 5:00 PM	13h
9	Turning 0904	2h	Sat 11:00 AM	Sat 1:00 PM	Mon 8:00 AM	Mon 10:00 AM	13h
10	Grinding 0904	1h	Sat 1:00 PM	Sat 2:00 PM	Mon 10:00 AM	Mon 11:00 AM	14h
11	Turning 0905	2h	Sat 8:00 AM	Sat 10:00 AM	Sun 2:30 PM	Sun 4:30 PM	13.5h
12	Turning 0905	2.5h	Sat 10:00 AM	Sat 12:30 PM	Sun 4:30 PM	Mon 10:00 AM	13.5h
13	Grinding 0905	1h	Sat 12:30 PM	Sat 1:30 PM	Mon 10:00 AM	Mon 11:00 AM	14h
14	Milling 0906	4.5h	Sat 8:00 AM	Sat 12:30 PM	Sun 1:30 PM	Mon 9:00 AM	12.5h
15	Grinding 0906	2h	Sat 12:30 PM	Sun 8:30 AM	Mon 9:00 AM	Mon 11:00 AM	10.5h
16	Milling 0907	4.5h	Sat 8:00 AM	Sat 12:30 PM	Sun 1:30 PM	Mon 9:00 AM	12.5h
17	Grinding 0907	2h	Sat 12:30 PM	Sun 8:30 AM	Mon 9:00 AM	Mon 11:00 AM	10.5h
18	Milling 0908	2h	Sat 8:00 AM	Sat 10:00 AM	Mon 9:00 AM	Mon 11:00 AM	17h
19	Milling 0909	5h	Sat 8:00 AM	Sat 1:00 PM	Sun 3:00 PM	Mon 11:00 AM	14h
20	Milling 0910	1h	Sat 8:00 AM	Sat 9:00 AM	Mon 9:00 AM	Mon 10:00 AM	17h
21	Turning 0910	1h	Sat 9:00 AM	Sat 10:00 AM	Mon 10:00 AM	Mon 11:00 AM	17h
22	Milling 0911	12h	Sat 8:00 AM	Sun 3:00 PM	Sat 12:30 PM	Mon 10:30 AM	4h
23	Grinding 0911	0.5h	Sun 3:00 PM	Sun 3:30 PM	Mon 10:30 AM	Mon 11:00 AM	4.5h
24	Milling 0912	8h	Sat 8:00 AM	Sun 10:00 AM	Sun 11:00 AM	Mon 11:00 AM	9h
25	Milling 0913	10h	Sat 8:00 AM	Sun 12:00 PM	Sun 9:00 AM	Mon 11:00 AM	7h
26	Milling 0914	5h	Sat 8:00 AM	Sat 1:00 PM	Sun 3:00 PM	Mon 11:00 AM	14h
27	Milling 0915	5h	Sat 8:00 AM	Sat 1:00 PM	Sun 3:00 PM	Mon 11:00 AM	14h
28	Milling 0916	2.5h	Sat 8:00 AM	Sat 10:30 AM	Mon 8:30 AM	Mon 11:00 AM	16.5h
29	Milling 0917	2.5h	Sat 8:00 AM	Sat 10:30 AM	Mon 8:30 AM	Mon 11:00 AM	16.5h
30	Milling 0919	4.5h	Sat 8:00 AM	Sat 12:30 PM	Sun 3:30 PM	Mon 11:00 AM	14.5h
31	Milling 0920	2h	Sat 8:00 AM	Sat 10:00 AM	Mon 9:00 AM	Mon 11:00 AM	17h
32	Turning 0922	1h	Sat 8:00 AM	Sat 9:00 AM	Mon 10:00 AM	Mon 11:00 AM	18h
33	Turning 0923	2h	Sat 8:00 AM	Sat 10:00 AM	Mon 9:00 AM	Mon 11:00 AM	17h

Table 6: Detailed scheduling of the project after leveling

Activity ID	Task Name	Duration	Early Start	Early Finish	Late Start	Late Finish	Slack
0	production planning	5.5 day	Sat 8:00 AM	Thu 12:00 PM	Tue 10:00 AM	Thu 12:00 PM	0h
1	Milling 0901	15h	Sat 11:00 AM	Mon 12:00 PM	Tue 11:00 AM	Thu 10:00 AM	22h
2	Grinding 0901	2h	Mon 1:00 PM	Mon 3:00 PM	Thu 10:00 AM	Thu 12:00 PM	22h
3	Milling 0902	14h	Sat 12:00 PM	Mon 12:00 PM	Tue 10:00 AM	Wed 5:00 PM	20h
4	Grinding 0902	2h	Mon 3:00 PM	Mon 5:00 PM	Thu 10:00 AM	Thu 12:00 PM	20h
5	Turning 0903	2h	Sat 10:00 AM	Sat 12:00 PM	Wed 4:00 PM	Thu 9:00 AM	37h
6	Turning 0903	2h	Sat 12:00 PM	Sat 2:00 PM	Thu 9:00 AM	Thu 11:00 AM	37h
7	Grinding 0903	1h	Sun 8:00 AM	Sun 9:00 AM	Thu 11:00 AM	Thu 12:00 PM	35h
8	Turning 0904	3h	Sat 8:00 AM	Sat 11:00 AM	Wed 10:30 AM	Wed 2:30 PM	34.5h
9	Turning 0904	2h	Sat 11:00 AM	Sun 10:30 AM	Wed 2:30 PM	Thu 11:00 AM	32.5h
10	Grinding 0904	1h	Sun 10:30 AM	Sun 11:30 AM	Thu 11:00 AM	Thu 12:00 PM	32.5h
11	Turning 0905	2h	Sat 8:00 AM	Sat 10:00 AM	Wed 11:30 AM	Wed 2:30 PM	35.5h
12	Turning 0905	2.5h	Sat 10:00 AM	Sun 9:30 AM	Wed 2:30 PM	Thu 11:00 AM	33.5h
13	Grinding 0905	1h	Sun 9:30 AM	Sun 10:30 AM	Thu 11:00 AM	Thu 12:00 PM	33.5h
14	Milling 0906	4.5h	Mon 1:00 PM	Tue 8:30 AM	Wed 2:30 PM	Thu 10:00 AM	17.5h
15	Grinding 0906	2h	Tue 8:30 AM	Tue 10:30 AM	Thu 10:00 AM	Thu 12:00 PM	17.5h
16	Milling 0907	4.5h	Mon 1:00 PM	Tue 8:30 AM	Wed 11:30 AM	Wed 5:00 PM	15.5h
17	Grinding 0907	2h	Tue 10:30 AM	Tue 1:30 PM	Thu 10:00 AM	Thu 12:00 PM	15.5h
18	Milling 0908	2h	Mon 1:30 PM	Mon 3:30 PM	Thu 10:00 AM	Thu 12:00 PM	21.5h
19	Milling 0909	5h	Sat 8:00 AM	Sat 1:00 PM	Wed 4:00 PM	Thu 12:00 PM	39h
20	Milling 0910	1h	Sat 1:00 PM	Sat 2:00 PM	Wed 4:30 PM	Thu 8:30 AM	35.5h
21	Turning 0910	1h	Sun 10:30 AM	Sun 11:30 AM	Thu 11:00 AM	Thu 12:00 PM	32.5h
22	Milling 0911	12h	Tue 8:30 AM	Wed 1:30 PM	Tue 4:30 PM	Thu 11:30 AM	7h
23	Grinding 0911	0.5h	Wed 1:30 PM	Wed 2:00 PM	Thu 11:30 AM	Thu 12:00 PM	7h
24	Milling 0912	8h	Sun 8:00 AM	Sun 5:00 PM	Wed 1:00 PM	Thu 12:00 PM	28h
25	Milling 0913	10h	Tue 8:30 AM	Wed 10:30 AM	Wed 10:00 AM	Thu 12:00 PM	9.5h
26	Milling 0914	5h	Wed 10:30 AM	Wed 4:30 PM	Wed 4:00 PM	Thu 12:00 PM	4.5h
27	Milling 0915	5h	Wed 1:30 PM	Thu 9:30 AM	Wed 4:00 PM	Thu 12:00 PM	2.5h
28	Milling 0916	2.5h	Wed 4:30 PM	Thu 10:00 AM	Thu 9:30 AM	Thu 12:00 PM	2h
29	Milling 0917	2.5h	Thu 9:30 AM	Thu 12:00 PM	Thu 9:30 AM	Thu 12:00 PM	0h
30	Milling 0919	4.5h	Mon 8:00 AM	Mon 1:30 PM	Wed 4:30 PM	Thu 12:00 PM	23.5h
31	Milling 0920	2h	Mon 3:30 PM	Tue 8:30 AM	Thu 10:00 AM	Thu 12:00 PM	19.5h
32	Turning 0922	1h	Sun 11:30 AM	Sun 1:30 PM	Thu 11:00 AM	Thu 12:00 PM	31.5h
33	Turning 0923	2h	Sat 8:00 AM	Sat 10:00 AM	Thu 10:00 AM	Thu 12:00 PM	42h

- Increasing the number of resources: This means that new machines should be purchased in the company but increasing the capacity is not practical for the company.
- Decreasing the work-loading of resources: In this method, some tasks of resources with over-allocation are assigned to other resources for executing, if possible. For example, in this project it should be examined whether small milling can perform operations of big milling machine.
- Leveling: The over-allocation is resolved using activity slack which is the amount of time an activity can be delayed without delaying the project finish date subject to there would be the least increase in the project completion time. Heuristic algorithm is used in MS-Project for this purpose named "Automatic Leveling" and our project is scheduled with this tool.

Detailed scheduling is one of the basic outputs of planning which it indicates the start, duration and finish for each activity. Since project management approach is employed for planning of this order, late start and finish of activity could be easily computed for this order and total slack as well. This additional information creates a better choice for management to decide on the date for performing an activity within the interval of early and late start of activity based on the status of the resources. Tables 5 and 6 indicate the detailed scheduling of the project respectively for before and after leveling. Activity with indicator (ID) '0' stands for project summary task which summarizes the project start and finish date. By comparison between Table 5 and 6, it is noticed that project completion time will be increased from 2.38 days to 5.5 days by implementing the resource leveling. In other words, it is necessary to define and level the limiting resources in the project for the purpose of achieving an exact schedule.

Table 7: Resource usage for each machine

Resource name	work	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Big milling	82h	12h	16h	16h	16h	16h	6h
Milling 0901	15h	3h	8h	4h			
Milling 0902	14h	2h	8h	4h			
Turning 0903	2h	2h					
Turning 0904	3h	3h					
Turning 0905	2h	2h					
Milling 0906	4.5h			4h	0.5h		
Milling 0907	4.5h			4h	0.5h		
Milling 0911	12h				7.5h	4.5h	
Milling 0913	10h				7.5h	2.5h	
Milling 0914	5h					5h	
Milling 0915	5h					3.5h	1.5h
Milling 0916	2.5h					0.5h	2h
Milling 0917	2.5h						2.5h
Lathe	10.5h	6h	4.5h				
Turning 0903	2h	2h					
Turning 0904	2h	1h	1h				
Turning 0905	2.5h	1h	1.5h				
Turning 0910	1h		1h				
Turning 0922	1h		1h				
Turning 0923	2h	2h					
Small milling	22.5h	6h	8h	8h	0.5h		
Milling 0908	2h			2h			
Milling 0909	5h	5h					
Milling 0910	1h	1h					
Milling 0912	8h		8h				
Milling 0919	4.5h			4.5h			
Milling 0920	2h			1.5h	0.5h		
Grinding	11.5h		3h	4h	4h	0.5h	
Grinding 0901	2h			2h			
Grinding 0902	2h			2h			
Grinding 0903	1h		1h				
Grinding 0904	1h		1h				
Grinding 0905	1h		1h				
Grinding 0906	2h				2h		
Grinding 0907	2h				2h		
Grinding 0911	0.5h					0.5h	

Table 8: Direct required budget for completing project in 5.5 days

Resource\ Cost	Standard rate (rials/h)	Overtime rate (rials/h)	Standard work (hr)	Overtime work (hr)	Standard cost	Overtime cost	Total direct cost
Big milling	150000	210000	82	0	12300000	0	12300000
Lathe	100000	140000	10.5	0	1050000	0	1050000
Small milling	120000	168000	22.5	0	2700000	0	2700000
Grinding	80000	112000	11.5	0	920000	0	920000
Overall sum	-	-	126.5	0	16970000	0	16970000

Table 9: Direct required budget for completing project in 5 days

Resource\ Cost	Standard rate (rials/h)	Overtime rate (rials/h)	Standard work (hr)	Overtime work (hr)	Standard cost	Overtime cost	Total direct cost
Big milling	150000	210000	76	6	11400000	1260000	12660000
Lathe	100000	140000	10.5	0	1050000	0	1050000
Small milling	120000	168000	22.5	0	2700000	0	2700000
Grinding	80000	112000	11.5	0	920000	0	920000
Overall sum	-	-	120.5	6	16070000	1260000	17330000

Analysis of Project Completion Time and Cost: The customer has suggested in the case of finishing the order at the end of the fifth day, a sum of 500000 rials (The rial is the currency of Iran, approximately equivalent to 1/10000 US dollar) will be paid as a reward to company. Table 7 indicates the resource usage for each machine separately.

By examining the resource usage in Table 7, it can be known that the big milling machine has been scheduled for six hours on day 6 and the other machines are scheduled to finish their tasks by the end of the fifth day or sooner according to this report. As a result, the activities assigned to the big milling machine in the last day should be completed before this day in order that project could be finished in the due time.

According to the scheduling done by MS-project, the project completion time is 5.5 days which the machines are planned to perform their tasks during an eight-hour shift per each day. Project direct cost can be computed considering the standard rate of each resource and their usage in project. Table 8 summarized the required budget for completion of project in 5.5 days.

In the above table, 'standard cost' is the product of 'standard rate' and 'standard work'; overtime cost also can be computed by multiplying the relevant columns. Finally, 'total direct cost' is the addition of 'standard cost' and 'overtime cost'.

Management has decided to evaluate the over-time policy for crashing the project time and in case the extra cost which is imposed by this policy is economical in comparison with the reward considering by the customer, the company will accept to schedule the project to be finished in 5 days, otherwise the project scheduling will remain unchanged. For this purpose, the milling of parts '0915', '0916' and '0917' are scheduled on day 5 in over-time hours; it should be observed if these tasks schedule during normal working hours, there will be an over-allocation in the resource usage. Table 9 indicates direct required budget for completing the project in 5 days.

The difference of budget required for finishing the project by the end of the fifth day is 360000 rials which can be obtained by subtracting the overall sum of required budget in 5.5 days from 5 days, i.e. 16970000 from 17330000.Since this extra cost of 360000 rials is less than the award of 500000 rials, the company will accept to sign this contract with the customer.

CONCLUSIONS

With reviewing the results obtained from application of project management in planning of make to order production, it is concluded that:

- If companies employ the project manage approach for scheduling of their orders, additional information such as the amount of slack for each operation will be computed in addition to the detailed scheduling which it helps the managers to have a better control over the activities based on the criticality of them.
- In the case the historical data exists, more useful techniques like project evaluation and review technique (PERT) can be utilized which the planning can be more confident.
- A detailed scheduling of resources will be obtained which it consists of the loading for each resource in different working times and managers can adjust the policies for human resources and machines using these reports.
- An estimate of the required budget will be achieved with assigning the fixed and resource costs to each activity. Furthermore, the effect of inflation and different wages can be applied in the budget by using soft-wares like MS-Project.
- Resource leveling and resource smoothing are two useful techniques for resolving the problems caused by over-allocation which the first technique is for keeping the usage within the max unit of each resource and the second technique is for reducing the fluctuation in usage.
- Time-cost tradeoff can be performed for the orders accepted by the company which it means to schedule the order considering normal and crash time, normal and crash cost and penalty for tardiness and reward for fulfilling before the due time.
- After the start of the project, actual data and changes can be imported; as a result, the scheduling will be updated and that is to say a dynamic state in the scheduling.
- It is possible to schedule several orders simultaneously in the case of using soft-wares such as Primavera or MS-project.

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