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DYNAMIC SCHEDULING OF DIFFERENT PRODUCTS ON A PRODUCTION LINE

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***Abstract*—This Paper deals with the production-scheduling problem concerning the customer demand. It considers manufacturing system in make-to-order environment. It deals with number of products produced in specific sequence in a production line. Although dynamic models for scheduling and control received less attention in research than static, this research took a hybrid approach, where the model input was the customer demand, machines outputs, working environment and work in progress. The model output is a static schedule. If it is not acceptable, then it runs the dynamic optimization module to reach acceptable solution. Also the dynamic module will reschedule production if there is any changes occur in delivery times or production planning. The model was built around a plastic sacks factory and it gives satisfactory results, but it is suitable for other similar industries.**

Keywords: **Dynamic scheduling, Real-time scheduling, Modeling, Algorithms, task, Manufacturing**.

I. INTRODUCTION

Scheduling of production in industry has objectives such as minimizing the time required to complete all the tasks (the make-span), minimizing the number of orders completed after their committed due dates, maximizing customer satisfaction by completing orders in a timely fashion, maximizing plant throughput, maximizing profit or minimizing production costs. Scheduling decisions to be determined include the optimal sequence of tasks taking place in each unit, the amount of material being processed at each time in each unit and the processing time of each task in each unit (Zukui Li, Marianthi Ierapetritou,.2008).

Dynamic scheduling has considered significant number of real-time events and their effects considering various manufacturing systems, including single machine system, Parallel machine system, flow shops, job shops and flexible manufacturing systems (Amer M. Mohieldin Kamel Fahmy,2014). In each of these scheduling methods, an objective function, including the minimum total make-span to complete all the selected tasks, and/or the minimum mean flow of theses selected tasks, is selected for identifying the optimal schedule (J. Sun, D.Xue, 2001).

Proper scheduling leads to increased efficiency and capacity utilization, reduced time required to tasks and consequently increased profitability of an organization (Pinedo M. 2002).

Dynamic scheduling categorizes in many categories including, completely reactive scheduling, predictive-reactive scheduling, Robust Predictive-reactive Scheduling, Robust pro-active scheduling. Also dynamic scheduling uses some of the following techniques in solving the scheduling problem; dispatching rules, heuristics, meta-heuristics (tabu search, simulated annealing, and genetic algorithms), Artificial Intelligence (knowledge-based systems, fuzzy logic, neural networks, and multi-agent systems (B. Naderi, S.M.T. Fatemi Ghomi , M. Aminnayeri, 2010).

Mathematical formulations for production scheduling environment are very complex task. These complex real life problems cannot be solve by traditional exact solvers to get good quality solutions within feasible time. Inspired by a real-world case study in the manufacturing industry (Ganesh M. Junghare, Manish J. Deshmukh. 2015).

There is a large class of mathematical programs in which the constraints can be divided into a set of conjunctive constraints and one or more sets of disjunctive constraints. A set of constraints is called conjunctive if each one of the constraints has to be satisfied. A set of constraints is called

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disjunctive if at least one of the constraints has to be satisfied but not necessarily all. In the standard linear program all constraints are conjunctive. The fact that the integer variable x_jk has to be either 0 or 1 can be enforced by a pair of disjunctive linear constraints: either $x_jk = 0$ or $x_jk = 1$. This implies that the problem 1 | prec | w_jC_j can be formulated as a disjunctive program as well Michael L. Pinedo,(2008), Scheduling Theory, Algorithms, and Systems.

The search of an optimal solution of a production scheduling problem starts by developing algorithms for generating the optimal sequence to complete the required tasks considering either only one processor (machine) or multiple processors (machines) (K.R Barker. 1974). Dynamic scheduling has considers significant number of real-time events and their effects and various manufacturing systems, including single machine
system, parallel machine system, flow shops, job shops and flexible manufacturing systems. Real- time events have been classified into two categories:

Resource-related: machine breakdown, operator illness, unavailability or tool failures, loading limits, delay in the arrival or shortage of materials, defective material (material with wrong specification), etc.

Job-related: rush jobs, job cancellation, due date changes, early or late arrival of jobs, change in job priority, changes in job processing time, etc.

Dynamic scheduling to be defined under four categories completely reactive sche)duling, predictive-reactive scheduling, robust, predictive-reactive scheduling, and robust pro-active scheduling (Djamila Ouelhadj · Sanja Petrovic, 2008). Also (A. S. Santos, 2014), (Ouelhadj D., 2009) and (Chao Lu, 2017b) agree with that categories.

II. DATA STRUCTURE

In this research a plastic sags factory with seven product families and variable demand in batch size was used for building the dynamic model. Each family of sage has similar tasks, runs through specific machines and has the same processing sequence and processing times. The main data required include the arrival pattern, processing times for all products in each of the workstation and numbers of machines in every stations.

Detailed data was collected including size of sacks, setup, speeds of all machines, and number of machines for any products on weaving station. Also machine failure data is collecting, real time for production, which is 18 hours per days (3 shift), 6 days per week (26 days per month), and master production schedule (MPS), which was generated from customer orders of sales forecasts made by the sales department. Table 1 is MPS showing products quantities and their timing required.

Sequence No.	Products (families)	Number of sacks
1	Cement family	470
2	Flour family	80
3	Seeds family 1	130
4	Seeds family 2	95
5	Others family 1	40
6	Others family 2	40
7	Others family 3	40

Table -1 Master production schedule (MPS). Number of sacks to be produce in thousands

A. Calculation of processing times:

1. Weaving station:

The speeds for processing all families were measured by calculating the time of weaving a role of 6000 meter. Table 2 shown total processing times in weaving station.

Table -2 total processing time in weaving station

Products (families)	Nu. Of mcs	Setup time (min)	Pro time (min)	Pro time of roll (min)
1	12	15	200	215
2	2	12	1304	1316
3	3	11	1053	1064
4	2	11	1579	1590
5	1	12	2857	2869
6	1	16	2222	2238
7	1	12	2857	2869

2. Lamination station:

Only two families need lamination the sequences of the families through the system which shown in Table 3.

Table -3 processing time in lamination station

Families	Speed of m/c (m/min)	Pro time of roll (min)
Cement family	100	60
Others family 1	100	60

3. Printing station:

This station can works with speed up to 200 m/min but for control reasons it works with 100 m/min. Hence gives flexibility in scheduling. Table 4 shown speed of printing machine and processing time of roll.

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Table -4 processing time in printing station

Families	Speed of m/c (m/min)	Pro time of roll (min)
Cement family	**100**	**60**
Flour family	**100**	**60**
Seeds family 1	**100**	**60**
Seeds family 2	-	-
Others family 1	**100**	**60**
Others family 2	**100**	**60**
Others family 3	-	-

4. Starcon station:

This station produce only cement family sacks with mean speed is 36 m/min. and processing time of roll was 167 minute.

5. Autocon station:

Discrete size and special sacks are categorized under other families> They are produce in this station with deferent mean values of speeds depends on the length of sacks. Table 5 shown the speed of autocon machine and processing times of roll for families.

Table -5 processing time in autocon station

Families	Speed of m/c (m/min)	Pro time of roll (min)
Cement family	**278**	**21.6**
Flour family	**256**	**23.4**
Seeds family 1	**333**	**18**
Seeds family 2	**208**	**28.8**
Others family 1	**294**	**20.4**
Others family 2	**256**	**23.4**
Others family 3	**278**	**21.6**

B. Calculation of processing times:

The uptime and downtime for each machine monitored and recorded over a period of three months. Processing and failure times of production.

Tables 6, shown summation of up and down times in hours for machines. Then calculation the failure time per day (18 working hours) as an average.

Table -6 summation of up and down times

Stations	Uptime hrs	Downtime hrs	Failure time/day hrs
lamination	**888.35**	**44.83**	**0.9**
printing	**500**	**45.3**	**1.63**
starcon	**455.7**	**42.08**	**1.66**
autocon	**613.5**	**58.85**	**1.7**

C. Analyses of collection data

From the above data table 7 was drawn, which shown the processing times of roll in all station.

Then the processing times for a role is calculated for all stations. This is Shawn in table 8.

Table -7 processing times of roll in all station

Families	Weaving	Lamination	Printing	Starcon	Autocon
Cement family	**215**	**60**	**60**	**167**	-
Flour family	**1316**	-	**60**	-	**278**
Seeds family 1	**1064**	-	**60**	-	**256**
Seeds family 2	**1590**	-	-	-	**333**
Others family 1	**2869**	**60**	-	-	**208**
Others family 2	**2238**	-	**60**	-	**294**
Others family 3	**2869**	-	-	-	**256**

Table -8 production day in roll

Families	Total time	Work minutes	Production day(roll) (ratio)
Cement family	**502**	**1080**	**2.15**
Flour family	**1654**	**1080**	**0.653**
Seeds family 1	**1380**	**1080**	**0.783**
Seeds family 2	**1923**	**1080**	**0.562**
Others family 1	**3197**	**1080**	**0.34**
Others family 2	**2592**	**1080**	**0.42**
Others family 3	**3125**	**1080**	**0.35**

Total times (in a day) for families in all stations are calculated, the processing times added after multiplying the ratio of production day (roll) for products in the total processing times. Failure time then subtracted. Table 9 shows the summation of processing and failure times of production.

Table -9 Summation of processing and failure times of production roll in stations

Families	Weaving	Lamination	Printing	Starcon	Autocon
Cement family	**462**	**176**	**178**	**457**	-
Flour family	**859**	-	**54**	-	**204**
Seeds family 1	**833**	-	**64**	-	**226**
Seeds family 2	**894**	-	-	-	**210**
Others family 1	**976**	**27**	**27**	-	**80**
Others family 2	**940**	-	**34**	-	**152**
Others family 3	**1004**	-	-	-	**101**

By using winQSB (job scheduling) software, data and machine sequences were input then solving the problem with minimizing makespan. The results are two Gannt chart for products and machines sequences, figure 1 and figure 2 shown them. From Gannt chart, the wait for all products in machines is measured, denoted and added as a coulomb in table 11 and then summation with the processing and failure times.

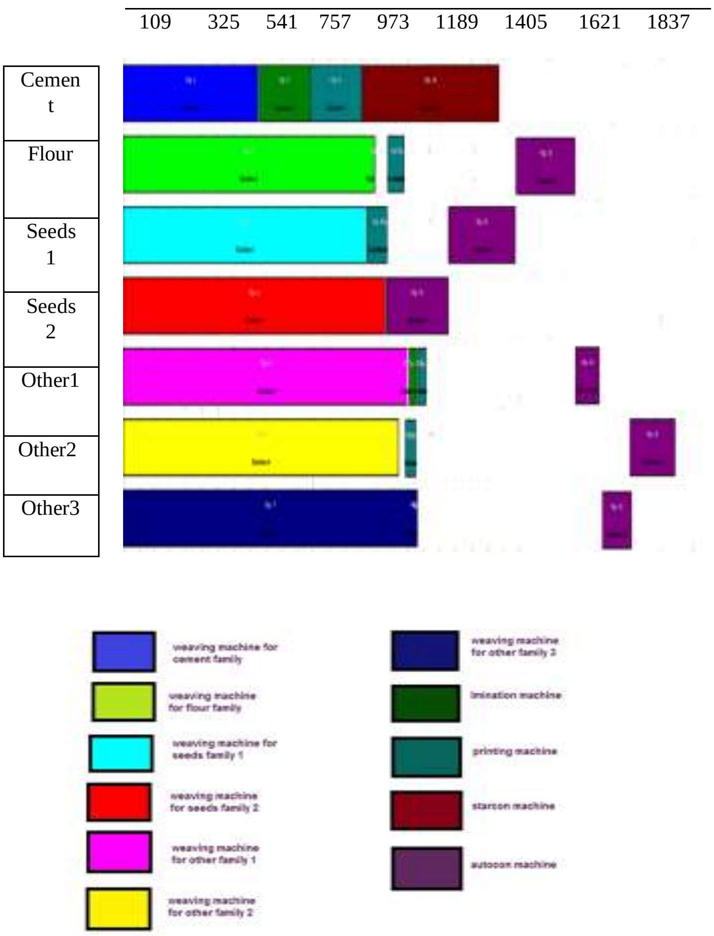

Fig. 1. Gannt chart for products in all machines

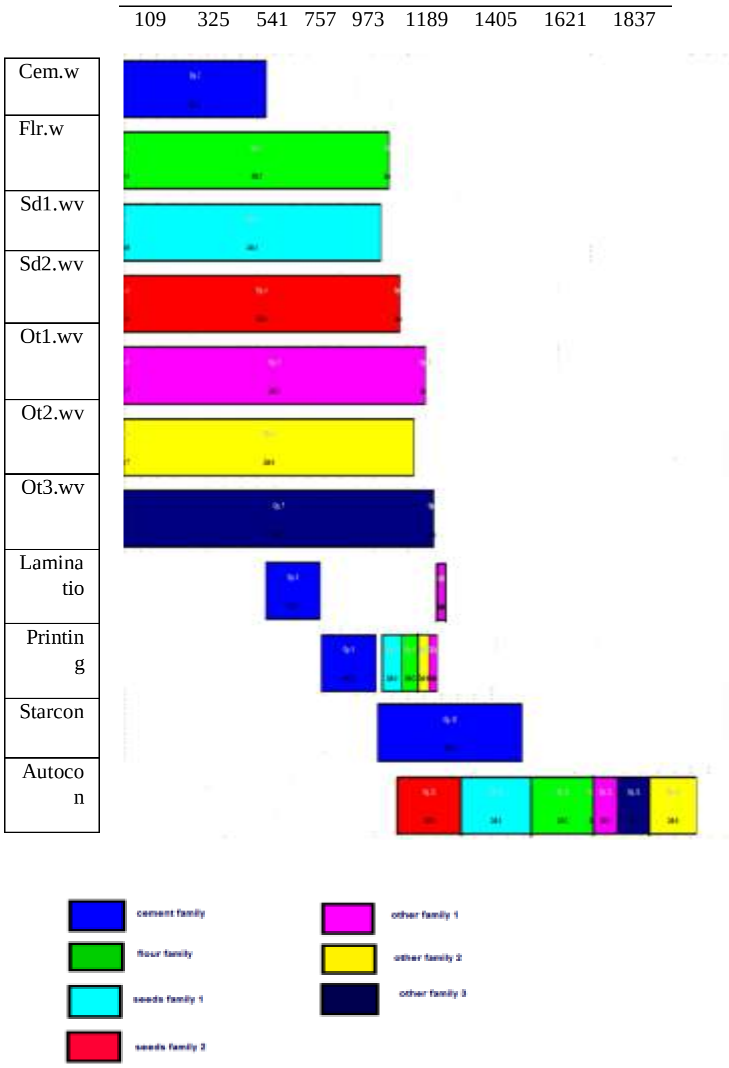

Fig. 2. Gannt chart for machines sequences for all products

III. PRODUCTION SEQUENCE

Table 10 shown the machine required and sequence of production process of each family.

Table -10 the sequences of families through the system

Fam/	Station 1	Station 2	Station 3	Station 4	Station 5
1	Weaving	Lamination	Printing	Starkon	Balling
2	Weaving	Printing	Autocon	Balling	
3	Weaving	Printing	Autocon	Balling	
4	Weaving	Autocon	Balling		
5	Weaving	Lamination	Printing	Autcon	Balling
6	Weaving	Printing	Autocon	Balling	
7	Weaving	Autocon	Balling		

Table -11 the total time of wait and failure in all station for products

Families	Wait time in all stations	Failure time in all stations	Total time (min)
Cement family	0	194	194
Flour family	417	37	454
Seeds family 1	207	52	259
Seeds family 2	0	23	23
Others family 1	504	23	527
Others family 2	741	37	778
Others family 3	610	11	621

To calculation the failure and wait time for roll, dived the total time of wait and failure over the ratio of roll. Table 12shown the failure and wait time for roll.

Table -12 the failure and wait time for roll

Families	Total time (min)	Roll ratio	Failure and wait times for roll (min)
Cement family	194	2.15	90
Flour family	454	0.653	695
Seeds family 1	259	0.783	331
Seeds family 2	23	0.562	41
Others family 1	527	0.34	1550
Others family 2	778	0.42	1852
Others family 3	621	0.35	1774

Total times for roll calculated by summation of failure and wait times for roll, and total processing time for roll. Table 13shown total times for roll.

The Production day (roll) was given by dividing available time per day (1080min) over the total time for roll, table 14 shown the production day for roll.

To calculate days of production for all products in sacks, multiple new ratio of production day for roll*6000(number of meters in roll*26(days of work in month) divided by length of sack. To calculation the number of days for production use the value of number of sacks to produced from (MPS) and multiple it in 26,

then divide by production in sacks per month. Table 15 shown the production in sacks, and days of production.

Table -13 total time for roll

Families	Failure and wait time for roll (min)	Total time in all stations	Total time for roll (min)
Cement family	90	502	592
Flour family	695	1558	2253
Seeds family 1	331	1380	1711
Seeds family 2	41	1923	1964
Others family 1	1550	3197	4747
Others family 2	1852	2592	4444
Others family 3	1774	3125	4899

Table -14 production day in roll

Families	Total time for roll (min)	Available time per day (min)	New production day (roll) ratio
Cement family	592	1080	1.812
Flour family	2253	1080	0.480
Seeds family 1	1711	1080	0.754
Seeds family 2	1964	1080	0.550
Others family 1	4747	1080	0.228
Others family 2	4444	1080	0.243
Others family 3	4899	1080	0.221

Table -15 monthly production in days .

Families	Ratio	Production per month (sacks)	Production In days
Cement family	1.812	474540	25.7
Flour family	0.480	83200	25
Seeds family 1	0.754	130728	25.9
Seeds family 2	0.550	95333	25.1
Others family 1	0.228	39500	26.3
Others family 2	0.243	63180	16.5
Others family 3	0.221	38211	27.2

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IV. MODEL BUILDING

Model was build with MATLAB software through the following steps:

First: input the data in Table 10, which represent the total of processing and failure times of production rolls per day in all stations as a matrix in new command editor. Write algorithms command to calculate the summation of the times in every station, Categories products to three clusters as cluster 1 contain job 1& job 5, cluster 2 contain job 2, job 3, and job 6, and cluster 3 contain job 4& job 7. Figers 3, 4, and 5 shown these clusters with plotted times (min) against machines.

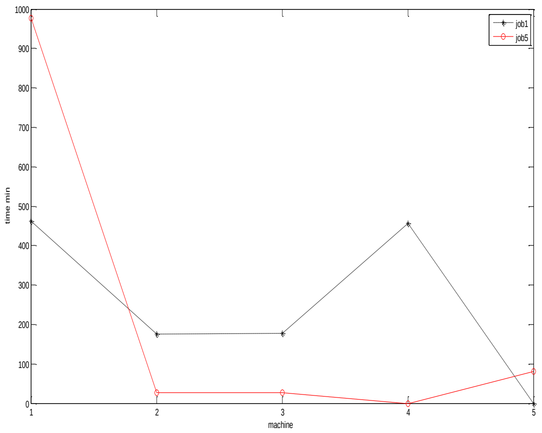

Fig. 3. Cluster 1. job 1& job 5

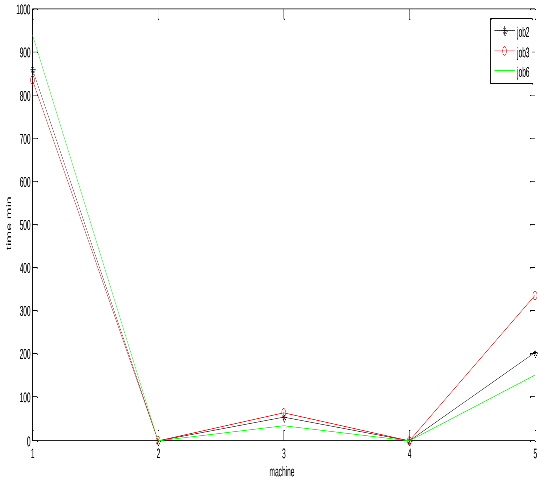

Fig. 4. Cluster 2. job 2, job 3& job 6

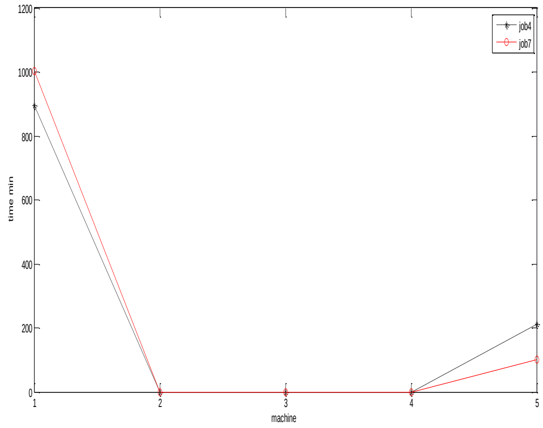

Fig. 5. Cluster 3. job 4 & job 7

Second: Calculation of the waiting time for all products.

Third: : input the data in Table 8 which represent the total of processing times of production of one roll in all stations as a matrix in the command editor above. Write algorithms command to calculate the summation of the times for one roll in every station. Then add the failure and wait times per one roll to the processing times.

Fourth: write a command to enter the number of sacks produced in the month from Table 1. The model generates number of days for any input product.

Fifth: Extra section on the model will process products with minimum and maximum wait time (early delivery and late delivery date) to optimize the scheduling times of the system.

V. RESULTS AND DISSCUTION

The model was build around the shown example, but it can dynamically optimize the production Scheduling, if data full or partially been changed. For the example above and after run the program in the MATLAB software, output of the model for cement sacks was static, which had no wait, and the production in month was 474540 sacks, that take 25.7 days, which acceptable by the factory levels.

The remaining products had early date for delivery, and late date for delivery. All products were acceptable in early date for delivery, but five products (on other 2) were not acceptable in the late date for delivery, and need rescheduling. Table 16.

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Table -16. Result of dynamic scheduling for products

Date	Input for flour sacks 80000	If days ≤26 Then Acceptable Otherwise Not Acceptable	Seeds 1	Seeds 2	Other 1	Other 2	Other 3
Early date for delivery (days)	21	Acceptable	36	36	30	17	33.5
Late date for delivery (days)	31	Not Acceptable	26	25	24	15.5	25.5
Rescheduling date for delivery (days)	26	Rescheduling	31	26	26.5	16.5	27.5
Date	**Input for Seeds 1 sacks 130000**	**If days ≤26 Then Acceptable Otherwise Not Acceptable**	**Seeds 2**	**Other 1**	**Other 2**	**Other 3**	**flour**
Early date for delivery (days)	26	Acceptable	25	26.5	16.5	27.4	25
Late date for delivery (days)	39.4	Not Acceptable	26	21	14.4	24	23
Rescheduling date for delivery (days)	26	Rescheduling	25	26.5	16.5	27.4	25
Date	**Input for Seeds 2 sacks 95000**	**If days ≤26 Then Acceptable Otherwise Not Acceptable**	**Other 1**	**Other 2**	**Other 3**	**flour**	**Seeds 1**
Early date for delivery (days)	26	Acceptable	26.4	16.5	27.3	24.6	29
Late date for delivery (days)	36	Not Acceptable	25	15	23	21	26
Rescheduling date for delivery (days)	26	Rescheduling	26.4	16.5	27.3	24.6	29
Date	**Input for other 1 sacks 40000**	**If days ≤26 Then Acceptable Otherwise Not Acceptable**	**Other 2**	**Other 3**	**flour**	**Seeds 1**	**Seeds 2**
Early date for delivery (days)	18	Acceptable	16.4	28	28	35.8	31
Late date for delivery (days)	28.3	Not Acceptable	15.5	25	23	27	26
Rescheduling date for delivery (days)	26	Rescheduling	16.5	27	25	30	28
Date	**Input for other 2 sacks 40000**	**If days ≤26 Then Acceptable Otherwise Not Acceptable**	**Other 3**	**flour**	**Seeds 1**	**Seeds 2**	**Other 1**
Early date for delivery (days)	11	Acceptable	27	26	34	26	28.3
Late date for delivery (days)	17	Acceptable	27	25	26	25	26.3
Date	**Input for other 3 Sacks 40000**	**If days ≤26 Then Acceptable Otherwise Not Acceptable**	**flour**	**Seeds 1**	**Seeds 2**	**Other 1**	**Other 2**
Early date for delivery (days)	19	Acceptable	29	37	31	26	16.5
Late date for delivery (days)	28	Not Acceptable	25	31	26	21	15
Rescheduling date for delivery (days)	26	Rescheduling	26	33	29	24	15.5

VI. CONCOLUSION

This work focuses on solving the problem of scheduling of a production line with dynamic scheduling model. The model inputs similar to any other production scheduling process. The data then submitted in a model built using MATLAB software. The first run of the model shows results where more rescheduling was required. In the second run an acceptable scheduling was reached. The model prove to be successful for the example shown and can suitable to solve similar problems in other plants.

VII. ACKNOWLEDGEMENT

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