A Study on Development of Production Planning for Manufacturing Execution System

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Abstract- *In production planning, scheduling is a process of determining when an activity should start or end, depending on its duration, predecessor activity (or activities), predecessor relationships, resource availability, and target completion date of the project. Present system does not have this system. If one wants to know start and end time of the job, then one has to do manually which is time consuming. The main objective of the project is to eliminate unusual time loss and optimize the process plan. To overcome these problems an application is developed which gives the pictorial details of the production plan. Data's such as machines, parts, operations for these parts, cycle time, load/unload time, setting time are previously entered into the system using LEAN works software.*

Keywords- Production Planning, Scheduling, Gantt Chart

I. INTRODUCTION

Worldwide competition and rapidly fluctuating customer requirements are making major changes in the production styles and configuration of manufacturing organizations. The idea of using computers for managing manufacturing activities is not a new concept. The objective of production plan is simply to maintain flow. The word production planning or production scheduling covers all the aspects from start to end of the product.

Production planning consists of two wings Process Planning and Production Scheduling. Process planning efforts on the selection of the machines and setup of machine parameters for job operations, while production scheduling deals with the assignments of machines and also manufacturing time to process the job operations [1].

The current system is LEANworks software, which1is the productivity monitoring system. This monitors the activity in the firm. In this the displaying of the production1plan and schedule is not included and hence one cannot get the exact time of process start and end time with1respect to predecessor relationship and resource availability. If one needs to know the completion time, then one has to compute manually and this process is time consuming and tiresome job. So these problems have shown that there is a need for study of production planning1and scheduling for optimizes the process plan.

II. LITERATURE SURVEY

Manufacturing and1logistic service provision enterprises are trying to establish and increase the efficiency of their cooperation, by means of software that supports negotiations at different levels of automation.

Haldung et.al, [2] defines that the well organized and wisely performed work routing, scheduling, and dispatching are necessary to bring production through in the required quantity, of the required quality, at the required time, and at the most reasonable cost. Production control is the job of forecasting, planning and scheduling work, taking manpower into account, materials availability and further capacity restrictions, and cost so as to achieve appropriate quality and quantity at the time it is needed and then following up the schedule to see that the plan is carried out, using whatever systems have proven appropriate for the purpose. Cox et.al, [3] define detailed scheduling as the actual task of start and/or end date to operations or groups of operations to show when these need to be completed if the manufacturing order is to be done on time. This is also known as operations scheduling, order scheduling, and shop scheduling. Gantt [4] first described a version of his charts in an article published along with Frederick W. Taylor's Shop Management paper (Taylor). The two were to be considered jointly as an integrated production planning1and control system. Truscott and Cho [5] apply Gantt charts to scheduling batch production through multiple work centers. Although they focus only on lot-splitting, this is the sort of difficult for which Gantt developed his charts.

Gantt charts are appropriate for displaying schedules, whether produced manually or through some empirical or optimizing algorithm. In these cases the benefits follow from their effectiveness in offering a great1deal of information. The method is highly flexible and can readily focus on issues that concern managers. Gantt charts are not key techniques but they helps communication between the analyst and operator, and deliver a powerful method for implementing interactive tactics to scheduling.

III. TOOLS TO BE CONSIDERED IN PRODUCTION PLANNING

While considering Production planning, one should consider the following points,

- Deciding which product is to be made, in what quantity and when it should be completed.
- Schedule the delivery and /or production of the products and parts.
- Planning the manpower and equipment required to complete the production plan.

Capacity planning is the maximum quantity of work that an organization is capable of concluding in a given period [6]. Effective capacity is the maximum quantity of work that an organization is proficient of finishing in a given period due to limitations such as quality problems, delays, material handling, etc. It is given by,

$$\text{Capacity}(number\ of\ machines) * (number\ of\ shifts) * (utilization) * (efficiency) \quad \ldots \textit{Equation (i)}$$

Production Scheduling

The production schedule is derived from the production plan; it is a plan that approved the operations function to produce a certain amount of an item within a definite time frame. In a large company, the production schedule is drawn in the production planning department, whereas, within a small company, a production schedule could initiate with a lone production scheduler or even a line supervisor [7].

Production Scheduling has three primary goals.

1. Involves due dates and avoiding late completion of jobs.
2. Involves throughput times; the firm wants to reduce the time a job spends in the system, from the opening of a shop order until it is closed or completed.
3. Concerns the exploitation of work centers. Firms usually want to fully utilize costly equipment and personnel.

Scheduling Tools and Techniques

Project Managers can use a range of tools and techniques to develop, monitor and control production schedules. Many of these can be applied digitally.

1) GANTT Chart: This is a horizontal bar graph plotted over time. Each activity is shown as a bar (its length based on a time estimate). Depending on job dependencies and resource availability, these bars may be sequential, or run in parallel as shown in Figure 1. Gantt charts are beneficial tools for planning and scheduling projects [8].

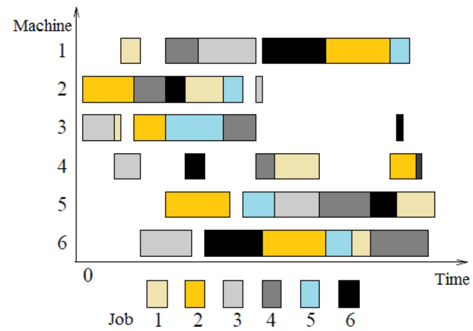


Figure 1 Gantt chart

2) Schedule Network Analysis: The schedule network is a graphical display (from left to right across a page) of all logical interrelationships between elements of work in sequential order, from initial planning through to project ending. As a project progress, regular analysis of this network diagram is a checked to ensure the project is proceeding on track [9].

3) Critical Path Method: The critica1 path of a project is the sequential string of activities that takes the longest time to complete, identifying any dependencies between tasks in this sequence (e.g. one cannot start till another finishes). Arrowed lines denote activities with circles at each end representing milestones (start and finish) [9].

4) PERT (Program Evaluation and Review Technique): PERT charts differ from CPM charts in the way times are calculated for activities [16]. For each activity, three estimates of time are obtained: the shortest time (SP), the longest time (LT) and the most likely time (MT). The estimate assigned for the activity is a weighted average of these three estimates. The formula is,

Expected time = (SP + 4(MT) + LT) /6.… *Equation (ii)*

Performance Measures

There are two important performance measures in Planning and Scheduling. Flow time is the period a job spends in the manufacturing system, and Tardiness is the amount of time by which a job lost its due date. These two performance measures can be insufficient, depending on the competitive priorities of a process [16]. Additional performance measures follow:

- **Makespan:** The total amount of time required to complete a set of jobs is called makespan. Minimizing makespan supports the competitive priorities of cost (lower inventory) and time (delivery speed).

$$\text{Makespan} = \text{Time of completion of last job} - \text{Starting time of the job}$$
… Equation (iii)

- **Total Inventory:** This performance measure is used to measure the usefulness of schedules for manufacturing processes. The sum of scheduled receipts and on-hand inventories is the total inventory.

Total Inventory = Scheduled receipts for all items + On hand inventories of all items… *Equation (iv)*

- **Utilization:** The degree to which equipment, space, or the workforce is currently being used, measured as the ratio of the average output rate to maximum capacity. Maximizing the utilization of a process supports the competitive priority of cost (slack capacity).

Scheduling Rules

While scheduling, one has to follow some of the sequencing rules which are described below,

- The First-come, First-served (FCFS) rule gives the job arriving at the workstation first the highest priority and so on.
- The earliest due date (EDD) rule gives the job with the earliest due date highest priority and arranged based on earliest due dates.
- Critical Ratio. The critical ratio (CR) is calculated by dividing the time remaining until a job's due date by the total shop time remaining for the job, which is defined as the setup, processing, move, and expected waiting times of all remaining operations, including the operation being scheduled. The formula is

$$CR = \frac{Due\ date - Today's\ date}{Total\ shop\ time\ remaining}$$
… Equation (v)

The difference between the due date and today's date must be in the same time units as the total shop time remaining. A ratio less than 1.0 implies that the job is behind schedule, and a ratio greater than 1.0 implies that the job is ahead of schedule. The job with the lowest CR is scheduled next.

- Shortest Processing Time. The job requiring the shortest processing time (SPT) at the workstation is processed next.
- Slack per Remaining Operations. Slack is the difference between the time remaining until a job's due date and the total shop time remaining, including that of the operation being scheduled. A job's priority is determined by dividing the slack by the number of operations that remain, including the one being scheduled, to arrive at the slack per remaining operations (S/RO).

$$S/RO = \frac{(Due\ date - Today's\ date) - Total\ shop\ time\ remaining}{Number\ of\ operations\ remaining}$$
... Equation (vi)

The job with the lowest S/RO is scheduled next. Ties are broken in a variety of ways if two or more jobs have the same priority. One way is to arbitrarily choose one of the tied jobs for processing next.

Existing Process Flow in System

To operate any production industry efficiently, the company must organize equipment, processes, plan and control the production to satisfy quality requirement. Discussion on existing process flow from manufacturer to the customer is illustrated in the Figure 2.

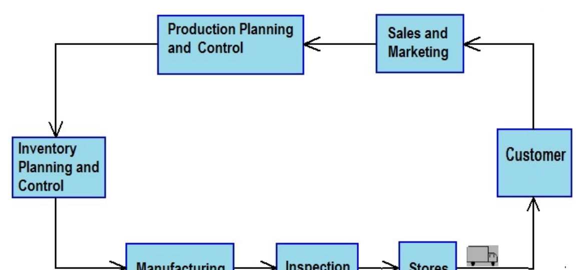


Figure 2 Existing Production Process flow in system.

In the present system orders from the customers are received by the sales and marketing department. This order consists of the description of the part, quantity and the due date. Based upon the details of received order quantity and due date an capacity planning is done that details the time, shifts and/or sub-contractors required to manufacture those parts. Then plan is prepared to complete ordered parts, generally the plan is prepared for every three days since manual calculations are done. The table for capacity planning and 3 day production plan is shown in TABLE I and II. Once the plan is prepared manufacturing of the parts are carried on respective machines. After manufacturing parts are checked for accuracy, and then stored in storage space provided. Packing and transport is made to the customers.

TABLE I
Example of Capacity Planning Table for Given Parts.

Parts	Operation	Setting time	Cycle Time	Load/ Unload Time	Total time	Qty
Plate Assembly	M	4:00:00	0:28:00	0:03:00	4:31:00	60
	M	1:30:00	0:04:00	0:02:00	1:36:00	60
Stopper	T	2:00:00	0:04:30	0:00:30	2:05:00	110
	T	2:00:00	0:03:30	0:00:30	2:04:00	110
	D	0:20:00	0:03:00	0:00:30	0:23:30	110
	T	1:30:00	0:04:00	0:00:30	1:34:30	110
Bearing Housing	T	1:30:00	0:01:30	0:01:00	1:32:30	55
	T	2:00:00	0:06:00	0:01:00	2:07:00	55
	T	2:15:00	0:04:00	0:00:30	2:19:30	55
	M	2:30:00	0:15:00	0:02:00	2:47:00	55
Total Hours Required				115:20:00		
Total Machining Hours Available(for 5 days and 3 shifts)				112:30:00		
Total Machining Shortage				02:50:00		
Shortage Hours per Machine				00:34:00		

Where, M – Machining, T– Turning, D– Drilling

TABLE II
Example of three day Production Plan

Shift 1			Shift 2		
Machine Name	Plan	Job	Machine name	Plan	Job
VMC-1	P	Plate Assembly	VMC-2	A	Plate Assembly
VMC-2	P	Plate Assembly	CNC Turning-1	A	Pin
CNC Turning-1	A	Stopper	VMC-1	P	Bearing Housing
CNC Turning-2	A	Bearing Housing	Drilling	S	Stopper
CNC Turning-1	S	Pin	CNC Turning-1	P	S
VMC-2	P	Intermediate Arm	VMC-1	P	Intermediate Arm
VMC-1	S	Plate Assembly	Drilling	A	Pin
CNC Turning-2	S	Pin	VMC-2	S	Plate Assembly
Drilling	P	Stopper	CNC Turning-2	A	Bearing Housing

TABLE I shows the parts that are considered for tabulation with two Milling machine, two Turning machine and one drilling machine.

TABLE II show the three days plan of production in the firm, but this chart do not give the detailed description of the parts completion date, process and operations performed to compete the part.

Time and Persons Involved in Generating the Production Plan in Existing System

The present system currently involves minimum of 5 personnel for generating the production plan. The people involved here are operator, sales and marketing engineer, supervisor, planning engineer, and maintenance engineer and information management system.

The data is procured manually by the planning engineer regarding new requirements by sales and marketing engineering. The requirements are entered in the standard template of company. Based upon these collected data, capacity planning is prepared in the standard template and according to the capacity of the firm and due date, production plans are prepared. Since the plan prepared is manually, only three days plan are generally prepared. Traditionally, production data is collected manually from the machines and fed into computers. It depends on the operator/ work person and hence it is inaccurate and error prone.

In 6 working days, 2 days is spent on recording, documenting and preparing the production plan.

Stages of Application Development

Application Development is the term often used to discuss the activity of computer programming, which is the process of writing and maintaining the source code. This also includes all that is involved between the conceptualization of the desired application to the final appearance of that application. The application development comprises research, new development, modification, reuse, re-engineering, maintenance or any other activities that affect the finished application.

The different stages of application development are given in Figure 3. Here one has used C# asp.net programing language to develop the application.

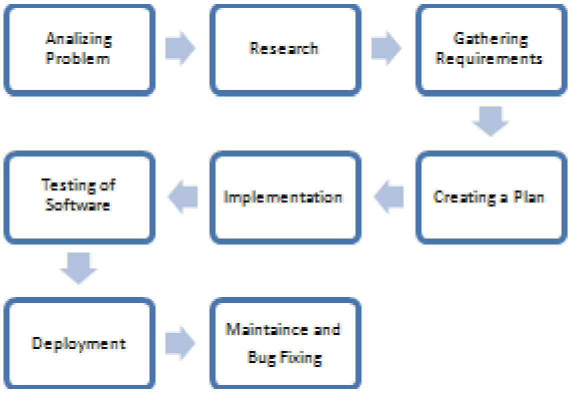


Figure 3 Stages of Application Development.

The TABLE III below gives the details of the products, quantity and due date as received by the sales and marketing department.

TABLE III
Product Details

Sl No	Product Name	Quantity	Due Date
1	Plate assembly	500	19/06/2016
2	Stopper	475	12/06/2016
3	Plate	85	02/07/2016
4	Bearing Housing	700	28/06/2016
5	Bearing Retainer	710	17/07/2016
6	Intermediate arm	260	16/07/2016
7	Guide	205	14/07/2016
8	Plate	680	14/07/2016

Data Feeding

Cadem provides a Productivity monitoring system called LEANworks. It consists of Manager Module in which various details are entered such as Machine details, part details, part material, operations required to complete the part, start date and end date etc. The actual time is compared with the standard time to measure the deflection. The data entered is stored in the SQL server database. One can retrieve the data from the database to generate the chart. For generating the scheduling module, one should write the query as given below

SELECT *
FROM [tblLWWorkOrders]
Select
[tblLWWorkOrders].dtPlannedstartdate,[tblLWWorkOrders].dtPlannedenddate,
[tblLWWorkOrders].nPartId,[tblLWParts].[strPartName]
From [tblLWParts] inner join [tblLWWorkOrders] on [tblLWParts].nPartId = [tblLWWorkOrders].nPartId

This will generate a table according to the data fed in the database as shown TABLE IV

TABLE IV
Part Schedule Table

Part Id	Part Name	Work Order	Planned Start Date	Planned End Date
BB 23055	Stopper	WON_ BB23055	02/06/2016	10/06/2016
81007096	Plate assembly	WON_ 81007096	02/06/2016	18/06/2016
KG31304	Bearing Housing	WON_ KG31304	04/06/2016	26/06/2016
21245614 01	Plate	WON_ 2124561401	04/06/2016	01/07/2016
BB 24378 A	Guide	WON_ BB24378A	30/06/2016	12/07/2016
KG00237	Plate	WON_ KG00237	27/06/2016	13/07/2016
20374825	Intermediate arm	WON_ 20374825	26/06/2016	15/07/2016
KGV191 2 A	Bearing Retainer	WON_ KGV1912A	11/06/2016	16/07/2016

Most of the manufacturing companies require the schedule based on due dates so that the priority is given to due date while preparing schedule table.

Logic Used for the Development of the Module

Assumption,

There are 5 jobs with different operations as shown in the TABLE V below,

TABLE V
Table of Jobs with respective operations

Operation / Job	O1	O2	O3	O4	O5
J1	Y	Y	-	-	-
J2	Y	Y	Y	-	-
J3	Y	-	-	-	-
J4	Y	Y	Y	Y	Y
J5	Y	Y	Y	Y	-

J1,J2,J3,J4,J5 are Jobs and O1, O2,O3,O4,O5 are operations. The job should be in the due date order Job 1, Job 2, Job 3, Job 4, Job 5 and the sequence of the operations are in the same order.

For performing these jobs, the different operations are given in the TABLE VI below,

TABLE VI
Jobs with different operations

Job 1	Milling	Turning	-	-	-
Job 2	Turning	Milling	Drilling	-	-
Job 3	Milling	-	-	-	-
Job 4	Milling	Turning	Milling	Drilling	Tapping
Job 5	Turning	Drilling	Tapping	Grinding	-

There are 5 machines to perform different operations in the described sequence as shown below. For Job 1, first milling is performed and then turning is performed, similarly Job 2, Job 3… so on are carried out.

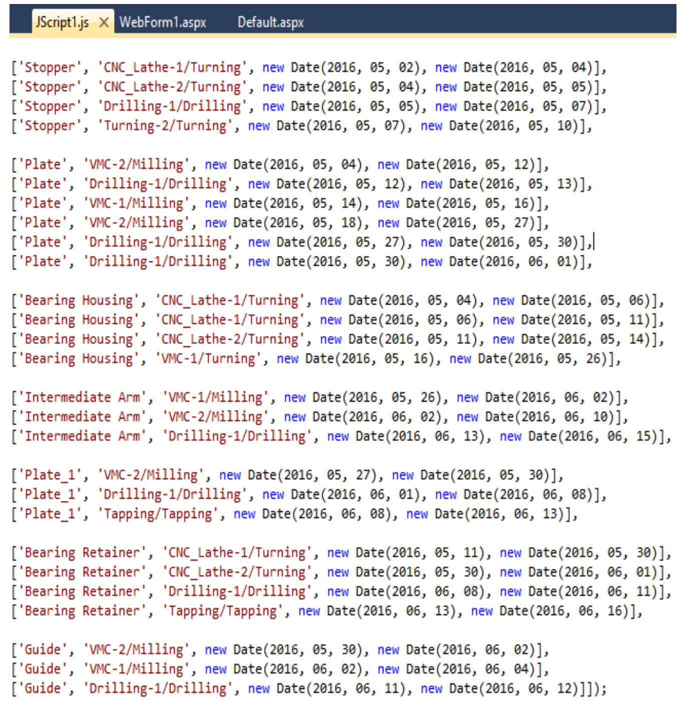
TABLE VII
Operation/Jobs Performed on Different Machines

Machine 1 (VMC)	Machine 2 (Turning)	Machine 3 (Drilling)	Machine 4 (Tapping)	Machine 5 (Grinding)
J1(OP1)	J2(OP1)	Idle	Idle	Idle
J2(OP2)	J1(OP2)	J2(OP3)	Idle	Idle
J3(OP1)	J5(OP1)	J5(OP2)	J5(OP3)	J5(OP4)
J4(OP1)	J4(OP2)	Idle	Idle	Idle
J4(OP3)	Idle	J4(OP4)	J4(OP5)	Idle

Schedule generated should be based on above shown logic. One should minimize the number of machines which are idle so as to decrease machine lead time and increase the productivity of the firm.

Coding for Generating the Charts

Code used for generating Work order chart is shown below in Figure 4.



```
JScript1.js  WebForm1.aspx  Default.aspx

['Stopper', 'CNC_Lathe-1/Turning', new Date(2016, 05, 02), new Date(2016, 05, 04)],
['Stopper', 'CNC_Lathe-2/Turning', new Date(2016, 05, 04), new Date(2016, 05, 05)],
['Stopper', 'Drilling-1/Drilling', new Date(2016, 05, 05), new Date(2016, 05, 07)],
['Stopper', 'Turning-2/Turning', new Date(2016, 05, 07), new Date(2016, 05, 10)],

['Plate', 'VMC-2/Milling', new Date(2016, 05, 04), new Date(2016, 05, 12)],
['Plate', 'Drilling-1/Drilling', new Date(2016, 05, 12), new Date(2016, 05, 13)],
['Plate', 'VMC-1/Milling', new Date(2016, 05, 14), new Date(2016, 05, 16)],
['Plate', 'VMC-2/Milling', new Date(2016, 05, 18), new Date(2016, 05, 27)],
['Plate', 'Drilling-1/Drilling', new Date(2016, 05, 27), new Date(2016, 05, 30)],
['Plate', 'Drilling-1/Drilling', new Date(2016, 05, 30), new Date(2016, 06, 01)],

['Bearing Housing', 'CNC_Lathe-1/Turning', new Date(2016, 05, 04), new Date(2016, 05, 06)],
['Bearing Housing', 'CNC_Lathe-1/Turning', new Date(2016, 05, 06), new Date(2016, 05, 11)],
['Bearing Housing', 'CNC_Lathe-2/Turning', new Date(2016, 05, 11), new Date(2016, 05, 14)],
['Bearing Housing', 'VMC-1/Turning', new Date(2016, 05, 16), new Date(2016, 05, 26)],

['Intermediate Arm', 'VMC-1/Milling', new Date(2016, 05, 26), new Date(2016, 06, 02)],
['Intermediate Arm', 'VMC-2/Milling', new Date(2016, 06, 02), new Date(2016, 06, 10)],
['Intermediate Arm', 'Drilling-1/Drilling', new Date(2016, 06, 13), new Date(2016, 06, 15)],

['Plate_1', 'VMC-2/Milling', new Date(2016, 05, 27), new Date(2016, 05, 30)],
['Plate_1', 'Drilling-1/Drilling', new Date(2016, 06, 01), new Date(2016, 06, 08)],
['Plate_1', 'Tapping/Tapping', new Date(2016, 06, 08), new Date(2016, 06, 13)],

['Bearing Retainer', 'CNC_Lathe-1/Turning', new Date(2016, 05, 11), new Date(2016, 05, 30)],
['Bearing Retainer', 'CNC_Lathe-2/Turning', new Date(2016, 05, 30), new Date(2016, 06, 01)],
['Bearing Retainer', 'Drilling-1/Drilling', new Date(2016, 06, 08), new Date(2016, 06, 11)],
['Bearing Retainer', 'Tapping/Tapping', new Date(2016, 06, 13), new Date(2016, 06, 16)],

['Guide', 'VMC-2/Milling', new Date(2016, 05, 30), new Date(2016, 06, 02)],
['Guide', 'VMC-1/Milling', new Date(2016, 06, 02), new Date(2016, 06, 04)],
['Guide', 'Drilling-1/Drilling', new Date(2016, 06, 11), new Date(2016, 06, 12)]]);
```

Figure 4 Screen shot of codes

Above codes are used to generate work order chart and similar codes are written for generating job order and machine vs Time chart. These codes are used to generate chart manually. This can be integrated with the SQL database in which all the data is fed by writing query. It is given below:

IV. RESULTS AND DISCUSSION

This chapter discusses the result obtained by development of the production1planning module in terms of Job order, Work order and machine vs time chart. The results are presented below.

- Production planning time was certainly reduced. Manual planning is replaced by automatic computer system which helps in eliminating data loss during data transfer. It also eliminates manual errors.
- Job order chart helps in visualizing part start date, end date, duration
- Work order chart will help in visualizing start and end date of the various operations performed on the part, machine on which the operations are performed and duration of that operation.
- Machine vs Time chart will help in visualizing machine working and idle date. It also shows the parts produced in that duration.
- These charts together help in planning of the future parts to be produced. This can be done by assigning idle machines to perform different operation which in turn reduce lead time.

Comparison of time and labor in present system and proposed system for a week is given in Table VIII.

TABLE VIII
Time Comparison of Present and Proposed System

Human resource Involved	Time invested (hrs)		Difference in %
	Present system	Proposed system	
Sales and Marketing	8	4	50
Supervisor	9	0	100
Maintenance Engineer	3.5	1	71.4
Information Management System	12	10	16.6
Operator	6	2	33.3
Total	38.5	17	55.85

The chart for Job order, Work order and machine vs Time is shown in below Figure 5, Figure 6, Figure 7 respectively.

Job Order Chart

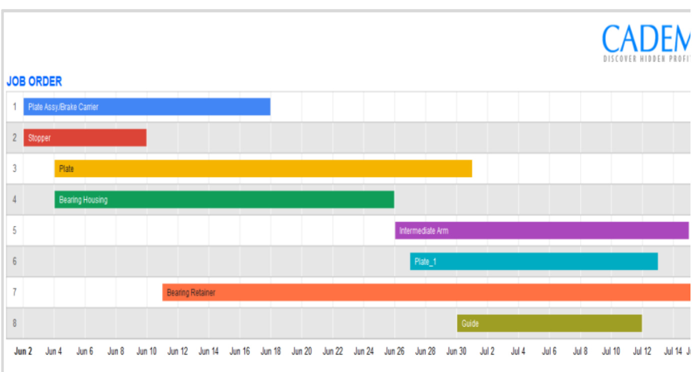


Figure 5 Job Order Chart.

Work Order Chart

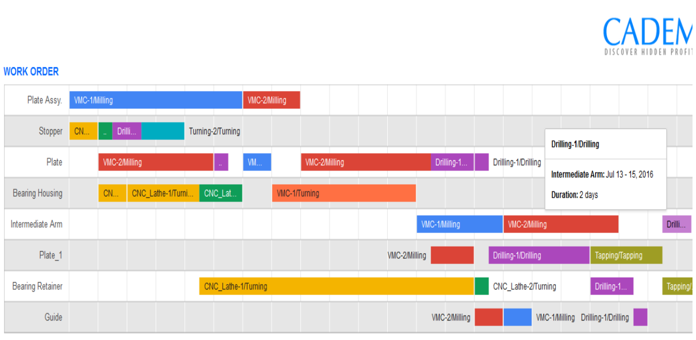


Figure 6Work Order chart.

Machine Vs Time Chart

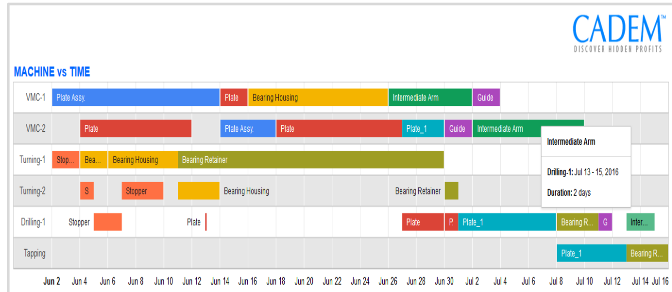


Figure 7 Machinevs Time chart.

V. CONCLUSIONS

Here one has presented an overview of the main concepts and solution methods of a production planner and scheduler system.

- The main feature of this project is to help in production planning and reducing the planning time by 55%.
- The manual errors such as human errors, data entry etc. are eliminated by using computer system. Effective data transfer can be made without any data loss.
- Decisions on the time of making the customer orders are shared with decisions concerning the load on resources. This approach results in superior due-date observation and executable production plans.
- One has also analyzed the role of these charts in production planning and scheduling in manufacturing system. Since charts are easy to understand and provide better view of the job and machine condition.
- The proposed application helps in generating the charts based on the data which is previously fed into the SQL database with the LEANworks manager. The data such as parts, machines, operations are fed into the manager.

The production planning management system is effective and satisfactory. However, it can certainly be further refined.

VI. FUTURE SCOPE

As a part of future scope the following aspects may be considered,

- It can be integrated with the database system so that the graphs can be generated automatically.
- The application which is developed is to be integrated with the productivity monitoring system LEANworks. So that both planning and monitoring can be done with same interface.

An automated material planning and handling system has to be developed and integrated so that manual interference can be reduced or eliminated.

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REFERENCES

[1] Vollmann, Thomas E., William L. Berry, Clay D. Whybark, and F. Robert Jacobs. Manufacturing Planning and Control for Supply Chain Management. 5th ed. New York: Irwin McGraw-Hill,2005

[2] Haldunaytung, Mark A Lawley et al, Executing production schedules in the face of uncertainties: A review and some future directions, 1930

[3] Jeffrey W Herrmann, Cox et , How to improve production Scheduling, ISR Technical report, university of Maryland, 2007

[4] Cortex, Manual on Gantt, VEX, Video Trainer using ROBOTC, Carnegie Mellon Robotics Academy, 2010

[5] Truscott, W.G., Cho, D.I., Scheduling batch production with character graphics. Industrial Engineering 19 (2), 1987

[6] M. P. Groover, Automation, Production Systems and Computer Integrated Manufacturing, 3rd edition, 2001

[7] Hamdy A Taha, Operation Research, 8th edition, university of Arkansas, Fayetteville, Pearson- 2007

[8] James M. Wilson, Wennink and Salvelsbergh, Gantt charts: A centenary appreciation, Department of Business and Management, Glasgow University, University Avenue, Scotland, 1996

[9] Suppliment J, Operations Scheduling , Pearsons Publication, 2008