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DETERMINATION DELIVERY DATE USING NETWORK ANALYSIS- A CASE STUDY OF FLOWSERVE MICROFINISH PUMPS

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Abstract
Operations research involves optimizing productivity by minimizing resource usage or maximizing utility. Two timeless techniques in operations research are PERT and CPM, which focus on efficient cost and time management for projects. Flowserve Microfinish Pumps, a prominent company located in Hubli, Karnataka, India, serves customers nationwide and even exports its products. While the company is well-known for providing high-quality pumps at competitive prices, customers frequently complain about delivery delays. The primary research revealed that delivery dates are determined informally, lacking a systematic method. To address this issue, the researcher utilized network diagram techniques to identify delivery dates that can be met with a 99% success rate.

Keywords:
Delivery commitments, PERT CPM, Normal Distribution, customer satisfaction, vendor rating

1.0 INTRODUCTION

The toughest task for a project manager is to coordinate numerous activities across the project. Planning, coordinating of various tasks, creating a realistic schedule, and then keeping track of the project's progress require careful consideration of many factors. The project's timeline adhering and the prioritization of tasks and resources within it are the two most crucial aspects of project management. To successfully manage a large-scale manufacturing project, one needs to keep track of number of moving parts. The planning and coordination of these endeavors necessitates careful attention from minute to detail. The project's progress and the efforts put into creating a reasonable timeline should be tracked. There are number of factors to be taken into account while mapping out the project's structure, coordinating its many moving parts, and keeping tabs on any pressing issues or developments.

The first thing to do while planning a project is to create a list on duration of each task or component is expected to take and then execute systematically the all the tasks within that timeline. Fortunately, operations research provides tools like the critical path method (CPM) and the programme evaluation and review technique (PERT) to assist the project manager in fulfilling these roles. In successful execution of projects, networks play a crucial role, both in terms of facilitating planning and displaying the synchronization of all operations.

1.1 Concept of Project Management

In order to minimize the time and money spent on the project as a whole, project managers must carefully plot out and oversee every step of the endeavor. In project analysis, the time it takes to complete a project is the unpredictable variable, while the men, materials, money, and machines involved in the project are the controllable ones (Bagshaw, K.B. 2011). Investment of limited resources is necessary for project implementation and completion. It is the responsibility of the project manager to break down the project's overall scope into smaller, more manageable pieces of work (sub-activities) and to ensure that each cycle of the project runs efficiently and on time (Singh, S. 2017). Tasks like launching, mapping out, carrying out, monitoring, and winding down projects for clients come under the umbrella of project management. It helps people and businesses stay on track to achieve their goals and stick to their budgets (Stuckenbruck, L.C. 1986).

Effectiveness, efficiency, and minimizing wasted time are the cornerstones of project management. All that's required of project managers is to round up and put to work a group of highly efficient workers who are fully invested in seeing the project through to its completion (Heagney, J. 2011). This group assists management in finishing projects on time and within budget. As a result, effective project management necessitates the management of trained personnel to ensure that project circles are carried out as planned (Tomomitsu, H.T.A., Carvalha, M.M.D. and Moraes, R.D.O. 2018). In today's knowledge-based economy, the value of products and services, as well as the value of regular workplace activities, is greatly enhanced by the involvement of project management (Kumar, V.K. and Ganesh, L.S. 1998)

Planning, executing, monitoring, and controlling in a project are carried out using scientific methods. It takes into account many factors in a project. Allotments of time, energy, money, and other assets are examples. Scope, Time, and Money are all part of it.

For this purpose, network planning strategies are employed. Both PERT and CPM are well-known methods of administration. Program Evaluation and Review Technique, or PERT for short, is a method for analysing and improving the effectiveness of a project's management. Critical Path Method focuses on the major activities (abbreviated as CPM).

1.2 Framework for PERT and CPM

The network analysis of any project involves the following steps

- Defining the project in terms of activities
- Identify starting, subsequent and finish node points
- Develop relationships among the tasks
- Draw the "network" connecting all the tasks
- Assign time and/or cost estimates to each task
- Compute the critical path
- Use the network to help plan, schedule, monitor and control the project

1.2.1 Basic terms in a Network:

The terminologies that are used in network analysis are as discussed below.

a. Task / Activity:

- **PERT activity**: Putting in the effort and using up the resources necessary to complete a task. It can symbolise the work, money, and time needed to get from one thing to another. In PERT, a task can't be done unless its forerunner has already happened or been finished.
- **PERT sub-activity**: It's possible to break down a PERT activity even further into smaller tasks. P1 can be broken down into subtasks P1.1, P1.2, and P1.3. A sub-activity is an activity in its own right, with all the characteristics of an activity, including the ability to have predecessor and successor events. It is possible to further break down an activity into even smaller tasks.

b. Event:

- **PERT event**: There is a beginning and an end to everything you do. It requires zero effort and no material investment. If the event is the culmination of several steps, it is not "reached" (does not occur) until those steps have all been taken.
- **Predecessor event**: This is an occurrence that comes right before another one, without any intervening occurrences in between. It is possible for an event to both precede and be preceded by other events.
- **Successor event**: This is something that happens right after something else does, without any time in between. A single event can be the successor of other events and have multiple successors.

1.3 Statement of the Problem

As technology has advanced and the requirement for projects to be completed efficiently has grown, it is imperative to meet deadlines. The project managers employ a variety of techniques based on their applicability and effectiveness in order complete the project within deadline. But in reality, the project completion deadlines are fixed by the marketing department using a thumb rule approach. A manufacturing organization can supply material within the delivery date promised only when the delivery dates are scientifically determined. CPM and PERT are the most popular and successful project management tools that help to decide the probable date completing the project. This study aims to support the process of determining the probable delivery date for supplying of products in the M/s Flowserve Micorfinish pumps private ltd., which otherwise employed a thumb rule approach. Though the company obtained a good vender rating for quality, price and customer service, the rating obtained for delivery is less.

Hence the company approached the researcher to help in determining systematically the delivery date to be quoted to the customer.

1.4 Scope of the Study

This study is conducted in Flowserve Microfinish pumps Pvt Ltd. Hubli. The study involved observing the process, and deciding different time estimates, and determining systematically the delivery dates. The technique employed can be used for other manufacturing industries as well. The study is conducted on OK standard pumps, Jacketed pumps, and central line mounted pumps. The same methodology can be employed for other products.

1.5 Objectives of the Study

This case study is conducted with the following objectives.

- To understand the operations methodology in manufacturing pump and breadown the work in to elements
- To identify the pessimistic, optimistic and most likely time for each activity
- To calculate the expected time for each activity and calculate the total time required to complete the project
- To compare actual time taken, time committed and time determined using PERT and CPM
- To suggest to the organization on promising the delivery dates

2.0 RESEARCH METHODOLOGY

The researcher has followed observational study method and discussion method to identify the various activities of the manufacturing process. A Delphi technique is employed to finalize the time estimates. After obtaining the data on the pessimistic, optimistic and most likely time for each activity, the expect time is calculated. Network analysis using PERT and CPM is employed to draw the network diagram.

3.0 ORGANIZATION PROFILE

Microfinish Pumps Pvt. Ltd was established in 1989 to manufacture Industrial chemical process pumps. Their clients include: Sugar, Distilleries, Beverages, oil and gas, petrochemical, refineries, power & co -generation, fertilizer, food, pharmaceutical, chemical process and allied industries. The company is recognized as a reputed quality, reliable pump & valves manufacturer for the process industry. The company manufactures quality pumps of various grades of steel, different sizes and shapes. The company was acquired by MNC company named Flowserve in the year 2000.

3.1 Manufacturing Activities At The Company

The various activities involved in manufacturing a pump is as below

1) Booking Department- Preparation of Work orders by comparing Purchase orders, offers and enquiry sheets received from customers.
2) Design Department-
a) Technical Analysis of orders as per required specifications.
b) Drawings preparation and issuing work orders to all departments
3) Stores Inventory- Checking of raw materials for issued work orders. If there is any shortage of materials then information is given to Purchase Department
4) Purchase Department- Purchase of castings, mechanical seals and brought out components. Order is placed to suppliers.
5) Suppliers supply the raw materials
6) Material Inward Stores- Raw materials received and stored.
7) Production Department- Castings are machined for required order.
a) Fabrication- If any fabrication required in particular order, then raw materials is sent to fabrication section.
b) Sub Contractors- For components that require lot of machining time sent to Sub contractors.
8) Material inward of Machined Components- From Sub contractors machined components are received.
9) Final Inspection of Machined Components- Machined components from machine shop, fabrication section and components received from Sub contractors are checked and inspected as per required dimensions and requirements as per work orders.
10) Assembly- From final inspection, components are sent to assembly.
11) Testing Section- Pump is assembled and sent to testing section. Pumps are tested for required duty conditions.
12) In-house Inspection- Pumps are inspected with respect to work orders.
13) Third party inspection- For the customers who specify TPI inspection, special arrangements are made and TPI is carried out by Inspectors.
14) Painting and Packing- Pumps are received from both TPI and In-house inspection section. They are painted as per required painting specifications and are packed.
15) Dispatch Department- Orders are invoiced and shipped to customers.

3.2 Work Observation By Researcher

The researcher visited the plant and studied the site conditions and observed the process of pump manufacturing. The process consisted of 16 phases. The order was given a specific number of pumps. Preparataion of drawings for particular order is done. Later approval of drawings is taken. Order is feeded into ERP Software (Enterprise Resource Planning Software) for storing the data related to work order. Enterprise Resource Planning Software consists of ll details from booking to dispatch of orders. Special comments can be inserted in the order entry process. For easy access to all the employees of company ERP is made available in the comapany server. Each department of company gets the access to software based upon their specific requirements such as the model of pump, Material of Consruction, quantity and type of pump . The main aim was to process complete order within expected time. Booking department registered the orders. Technical ananlysis of order is carried out. The stores department allots the raw material for production.Required raw material are procured by purchase department. Production is carried out for required orders. Manufacturing plan is prepared by Sales and marketing department based on urgency of orders. Based on given schedule, machining of pumps is carried out. Grouping is done in order to save the time. Inspection of machined components is carried out to avoid the defects and to avoid post dispatch problems. Pumps are assembled, inspected and made ready for dispatch. Dispatch documents are shared to customers. Later commissioning and service is carried out if there is any requirement.

Based on the observed information and the information collected during discussions, the researcher identified the nodes and activities as shown below.

Table 1: Node and Activity Detail

Node No	Node Details	Activity	Activity Details
1	Order received from customers for booking.	1-2	Booking of Order
2	Booked order for Design Analysis.	2-3	Technical analysis of Design
3	Technical clear order for checking raw materials at stores.	3-4	Checking inventory and preparing list of items to be procured
4	List of materials for procurement purpose.	3-7	Sending available material from store to production
5	Orders received at suppliers.	4-5	Preparing and sending purchase orders
6	Materials inward at Stores.	5-6	Material produced and supplied by Suppliers
7	Ready for Production.	6-7	Material inspection
8	Completion of fabrication for inspection.	7-8	Production of sub assembly
9	Completion of Machining at sub-contractors.	7-9	Sending material/drawing to sub-contractors
10	Materials inward at Stores.	8-10	Inspection of sub assembly
11	Completion of Final inspection for Assembling.	9-10	Production at sub-contractors and collect part
12	Completion of Assembling for Testing.	10-11	Final Assembly
13	Completion of Testing for final inspection.	11-12	Inspection of Finally Assembly
14	Completion of Inhouse /Third Party Inspection for painting.	12-13	Testing of Assembly
15	Completion of Painting for packing and dispatching.	13-14	Third party inspection
16	Completion of Dispatch.	14-15	Painting of final assembly

Further the researcher selected_O-K Standard Pumps, Jacketed Pumps and Centre Line Mounted Pumps for network analysis which were under production during the period of study

4.0 NETWORK ANALYSIS

The researcher conducted network analysis for the following pumps

4.1 O-K Standard Pumps

Figure 1: Construction of Network Diagram for 0-K Standard pumps

The network diagram for the project, along with E-values and L-values, is

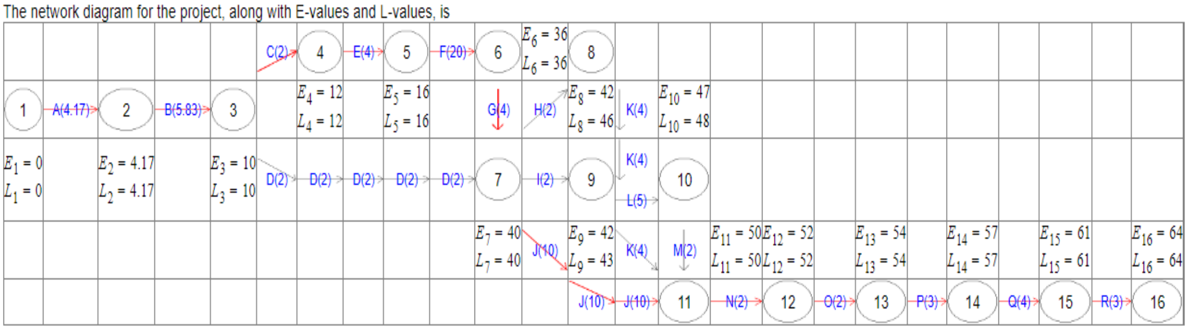

Table 2: Expected value and Variance of duration of each activity for 0-K Standard Pumps

Activity	Optimistic Time(To)	Most Likely Time Tm	Pessimistic Time (Tp)	Expected Time Te=(To+4tm+Tp/6)	Critical Activities	Σ2=((Tp-To)/6)2
1 - 2	3	4	6	4.2	1 - 2	0.25
2 - 3	3	6	8	5.8	2 - 3	0.69
3 -4	1	2	3	2.0	3 - 4	0.11
3 - 7	1	2	3	2.0		
4 - 5	2	4	6	4.0	4 - 5	0.44
5 - 6	19	20	21	20.0	5 - 6	0.11
6 - 7	2	4	6	4.0	6 - 7	0.44
7 - 8	1	2	3	2.0		
7 - 9	1	2	3	2.0		
7 - 11	8	10	12	10.0	7 - 11	0.44
8 -11	2	4	6	4.0		
9 - 10	3	5	7	5.0		
10 - 11	1	2	3	2.0		
11- 12	1	2	3	2.0	11 - 12	0.11
12 - 13	1	2	3	2.0	12 - 13	0.11
13 -14	2	3	4	3.0	13-14	0.11
14 -15	2	4	6	4.0	14 - 15	0.44
15 - 16	2	3	4	3.0	15 - 16	0.11
						∑σ2= 3.39

CRITICAL PATH =1-2-3-4-5-6-7-11-12-13-14-15-16
EXPECTED TIME= 64 DAYS
σ Network=√Sum of variances along the Critical Path
√3.39 = 1.84

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Probability of completing the project within a given date
Z=(TS-TE)/σ
where TS= scheduled time for project completion
TE= expected time for project completion
From the Normal distribution table, the table value for 99% probability of completing the project is 2.33
Hence, the duration the organization can commit to deliver products is
2.33 X 1.84 + 64 = 69 days

4. 2. Jacketed Pumps

Figure 2: Network Diagram for Jacketed Pumps

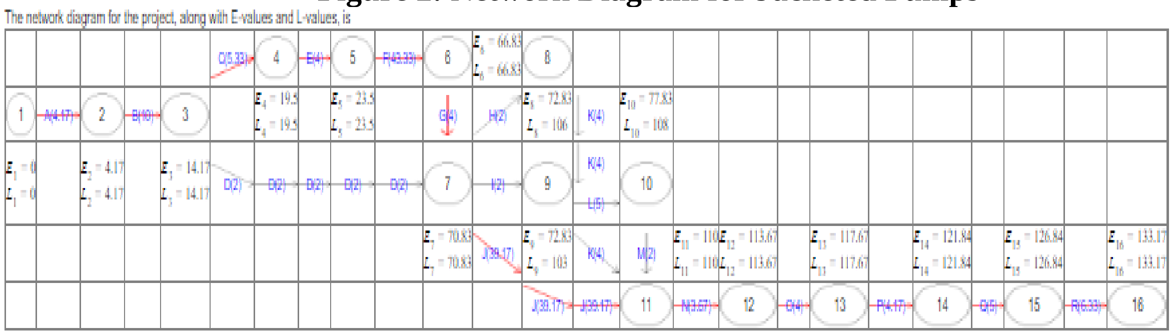

Table 3: Expected value and Variance of the duration of each activity for Jacketed Pumps

Activity	Optimistic Time(To)	Most Likely Time Tm	Pessimistic Time (Tp)	Expected Time Te=(To+4tm+Tp/6)	Critical Activities	Σ2=((Tp-To)/6)2
1 to 2	3	4	6	4.2	1 to 2	0.25
2 to 3	5	10	15	10.0	2 to 3	2.78
3 to 4	3	5	9	5.3	3 to 4	1.00
3 to 7	1	2	3	2.0		
4 to 5	2	4	6	4.0	4 to 5	0.44
5 to 6	35	45	55	45	5 to 6	11.11
6 to 7	2	4	6	4.0	6 to 7	0.44
7 to 8	1	2	3	2.0		
7 to 9	1	2	3	2.0		
7 to 11	30	40	55	40.8	7 to 11	17.36
8 to 11	2	4	6	4.0		
9 to 10	3	5	7	5.0		
10 to 11	1	2	3	2.0		
11 to 12	1	3	9	3.7	11 to 12	1.78
12 to 13	2	4	6	4.0	12 to 13	0.44
13 to 14	1	4	8	4.2	13 to 14	1.36
14 to 15	3	5	7	5.0	14 to 15	0.44
15 to 16	4	6	10	6.3	15 to 16	1.00
						∑σ2= 38.42

CRITICAL PATH =1-2-3-4-5-6-7-11-12-13-14-15-16
EXPECTED TIME= 133 DAYS
σ Network=√Sum of variances along the Critical Path
√38.42 = 6.18
Probability of completing the project within a given date
Z=(TS-TE)/σ
where TS= scheduled time for project completion
TE= expected time for project completion
σ= standard deviation for the network
The organization wanted to meet the committed delivery date to the accuracy of 99%, the corresponding value from normal distribution table is 2.33
Hence the Scheduled time for the Project is
2.33X6.18+133 =147 Days.

Activity	Optimistic Time(To)	Most Likely Time Tm	Pessimistic Time (Tp)	Expected Time Te=(To+4tm+Tp/6)	Critical Activities	Σ2=((Tp-To)/6)2
1 to 2	3	4	6	4.2	1 to 2	0.25
2 to 3	5	7	9	7.0	2 to 3	0.44
3 to 4	1	2	3	2.0	3 to 4	0.11
3 to 7	1	2	3	2.0		
4 to 5	2	4	6	4.0	4 to 5	0.44
5 to 6	30	35	45	35.8	5 to 6	6.25
6 to 7	2	4	6	4.0	6 to 7	0.44
7 to 8	1	2	3	2.0		
7 to 9	1	2	3	2.0		
7 to 11	25	40	50	39.2	7 to 11	17.36
8 to 11	2	4	6	4.0		
9 to 10	3	5	7	5.0		
10 to 11	1	2	3	2.0		
11 to 12	2	4	6	4.0	11 to 12	0.44
12 to 13	1	2	3	2.0	12 to 13	0.11
13 to 14	2	3	4	3.0	13 to 14	0.11
14 to 15	3	4	5	4.0	14 to 15	0.11
15 to 16	2	3	6	3.3	15 to 16	0.44
						∑σ2= 31.06

4.3 Centre Line Mounted Pumps -

Figure 3: Network Diagram for Centre Line Mounted Pump

The network diagram for the project, along with E-values and L-values, is

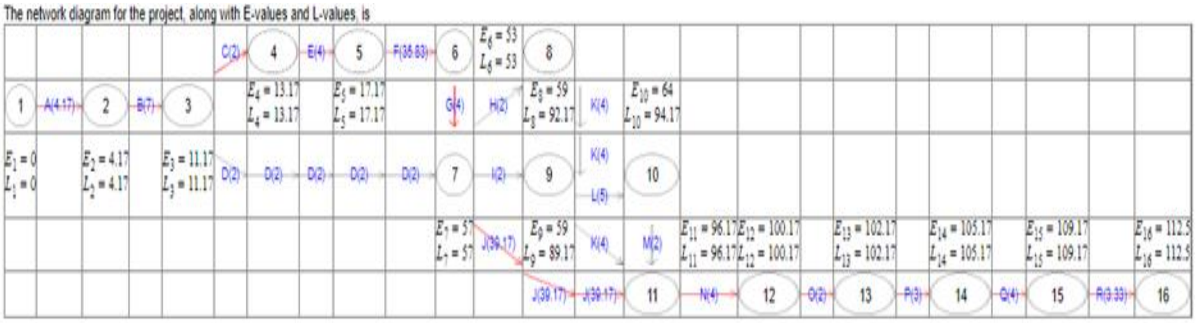

Table 5.3- Expected value and variance of duration of each activity for CLM Pumps

Critical Path =1-2-3-4-5-6-7-11-12-13-14-15-16
Expected Time= 112 DAYS
σ Network=√Sum of variances along the Critical Path
Probability of completing the project within a given date
Z=(TS-TE)/σ
where TS= scheduled time for project completion
TE= expected time for project completion
σ= standard deviation for the network
The organization wanted to meet the committed delivery date to the accuracy of 99%, the corresponding value from normal distribution table is 2.33
Hence the Scheduled time for the Project is
2.33X5.6+112 =125 Days

5.0 FINDING, SUGGESTION AND CONCLUSION

5.1 Findings

The researcher calculated the actual delivery date and the delivery date that can be committed to the customer at 99% success rate level.

Sl No	Type of Pump	Customer	Traditionally Promised delivery date	Actual Delivery Date	The new delivery date that can be committed
1	O-K Standard Pumps	Vapco Industries.	45 days	64	69 days
2	Jacketed Pumps	Mojj Industries	140 Days	133	147
3	Centre Line Mounted Pumps	Deccan Industries.	130	112	125

5.2 Suggestions

This paper proposes, based on research using PERT and CPM in project management, that:
1) Using scientific methods like CPM and PERT in project leads to systematic planning and scheduling
2) Meeting the deadline as committed is highly significant in the present day competitive market.
3) The company can get good vendor rating in all the aspects as they can now supply the products with the delivery date promised.
4) The company can now adopt the technology for all the products it is producing

5.3 Conclusion

PERT/CPM plays the prominent role in manufacturing the pumps as per requirement of customers. The research demonstrates that CPM and PERT are useful tools for project managers in many contexts, including but not limited to scheduling, monitoring, and control. The company has now started committed delivery dates considering the actual time required systematically.

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