Measuring Process Effectiveness Using Cpm/Pert

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Abstract

Most organizations around the world have discovered that the strategy of customer satisfaction translates very rapidly to higher profit and productivity. We show here how some simple Operations Research methods can be used to achieve better customer satisfaction. The methods of CPM and PERT were used to analyze a process that delivers service to customers in an organization faced with the problem of providing additional parking space for its customers' trucks. By reducing and stabilizing the process cycle time, the problem was solved, saving the company the cost of leasing more parking lots for the customers' trucks. In addition, the customers were happy with less time spent in the company's premises.

Keywords: Customer satisfaction, Process cycle time, Process effectiveness critical activities, Critical path

1. Introduction

Service quality has taken the center stage in most organizations with the focus on customer satisfaction. This comes from the realization that no organization can be truly successful without paying due attention to the needs of their customers.

The modern theory of total quality management classifies customers into two: Internal customers and external customers. Internal customers are people in the same organization who receive the output of a process as input into their own processes. External customers, however, are the end users of the products of the organization. Both customers are important if the organization is to attain its quality goals. There is no way the final products of the organization can meet customers' satisfaction if workers within the organization are busy passing defective items from one process to another.

Having satisfied external customers is fundamental to the growth of the organization. It is not only the products of the company that must meet their requirements; the level of services they receive at the organization as they come to transact businesses with the organization, must also be satisfactory. Defining the right quality standards at this product-market interface is crucial to customer satisfaction. Organizations should be able to determine what will make customers feel good about them.

Usually customers' definition of quality is sometimes amorphous and the company should find a way to fine-tune customers' requirements in line with the quality goals and strategy of the organization. According to Box and Platts (2005), the company's strategy must be made explicit and diffused throughout the organization to allow people to plan and create needed change. The strategy should be simple and comprehensible, based on an identifiable core concept, with clear priorities and resource allocation. Companies that have high contacts with customers stand a risk of customer disaffection unless they can distill customer requirements into their global quality objectives. In the broadest sense quality exists to the degree that customers are satisfied with, or excited by, a company's services (Lawton, 1991). Majority of unhappy customers do not express their unhappiness to the hearing of the organization. Usually the marketing departments in most organizations shoulder the responsibility of managing the customer contact interface of the company. The nature of service provided at this level determines the impression customers create about the company.

Customers coming to receive services at the organization will pose a number of problems, which will concern both the customers themselves and the organization. How the organization help customers to tackle the problems they face in the cause of transacting businesses with them contributes significantly to the level of service quality offered by the organization. The process that delivers services to the customers is therefore significant and should be defined in such a way that customers enjoy the best service quality the company can offer. To achieve this will sometimes require changes at a micro (process) level. An underlying culture of change acceptance will ease alignment of purpose for the team involved as they will be less distracted by the process of making the change and more able to concentrate on delivering the right change. A culture of change requires employees trained in change techniques and processes, trust, the acceptance of mistakes and organizational learning (Box and Platts, 2005).

Fundamental process characteristics that have some impact on customer service quality include process efficiency and process effectiveness. Chase et al. (1983) define operating efficiency as follows:

Potential operating Efficiency =

f(1 – {(customer contact time)/(service creation time)})

and stated that service facilities characterized by high customer contact are perceived as being inherently limited in their production efficiency because of the uncertainty that the customers introduce into the service creation process. Service processes can be designed to reduce effects of variation due to customers contact problems. As a matter of fact most customers will come with common problems.

Effectiveness is the level to which a process attains its objectives. Usually such objectives are numerical and measurable. One of the Lawton's six steps in creating customer-centered culture in an organization is to define service quality as a tangible product (Lawton, 1991). That way it can be measured and assessed objectively. Processes that deliver services to customers must be objectively measured to ensure that customer satisfaction is maintained at all times. This accounts for the importance organizations place on Business Process Management (BPM) in recent times. BPM has become a buzzword with many organizations (Muehlen, 2005). Zairi and Sinclair (1995) defined BPM as a structured approach to analyze and continually improve fundamental activities such as manufacturing, marketing, communications and other major elements of a company's operation. Elzinga et al (1995) characterize BPM as a systematic, structured approach to analyze, improve, control and manage processes with the aim of improving the quality of products and services. Harmon (2004) sees BPM as aligning processes with the organization's strategic goals.

In this work, the focus is process effectiveness and how it is measured. Process effectiveness measure is very central to a successful BPM implementation in any organization. Section 2 deals with effectiveness measure, section 3 discusses the application of CPM/PERT to process effectiveness measure and section 4 is on application of the method.

2. Process Effectiveness

Process effectiveness is the extent to which the goals and objectives of the process is met. Harrington (1991) defines effectiveness as the extent to which the outputs of the process or sub process meet the needs and expectations of its customers. He takes effectiveness to be synonymous with quality. In other words, a measure of effectiveness is a measure of the level of quality in the process.

To ensure a process is effective, customer's expectations and needs must be recognized and built into the process. This will ensure that the process produces the desired output. Such needs and expectations must be defined in a measurable term and observed through regular data collection.

Inputs for effectiveness measure must come from both internal and external customers. All processes have internal customers, and for those that deal with external customers, the chain of transactions among the internal customers provides the output for the external customers. To satisfy the external customer, the needs of internal customers must be met.

Flowcharting is a common tool used to describe how the various tasks of a process are connected together. Flowcharting provides a pictorial view of the process and reveals the interconnectivities among the various tasks. Harrington (1991) defines flowcharting as a method of graphically describing an existing process or a proposed new process by using simple symbols, lines and words to display pictorially the activities and sequences in the process. Flowcharting an entire process down to the task level is the basis for analyzing and improving the process.

A measurable effectiveness characteristic, which indicates how well a process is performing, can be set at a level determined by management after working with all parties involved in the process. Sometimes it can be a level already agreed upon and documented in company chatter. Everybody involved works to achieve the specified level of effectiveness.

An effectiveness characteristic can be cycle time of the process or any other quality characteristic defining the final output of the process. A delayed activity, or finding a better way to perform an activity affect the process cycle time. The former will increase the cycle time while the latter will shrink it. In most cases an excellent way to reduce cycle time is to find tasks that can be performed together. In such a situation, a considerable gain can be recorded in cycle time, which translates to better customer satisfaction and better quality. The CPM/PERT can provide a tool for analyzing such processes.

3. CPM-PERT

CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) were developed as techniques of project management for the basic managerial functions of planning, scheduling and control (Rao (1992)). A project is a one time effort such as construction of a highway, construction of a bridge or an airport. Hosting a major sports tournament such as the Olympic or the world cup can also be regarded as a project. These examples have definite beginning and end times, which is a requirement of a project. Atkinson (1999) provides some fine definitions of project and project management. Oakland and Tanner (2006) identified project management as one of the successful business change strategies. This is also supported by Martin and Cheung, Y (2002) and Smith (2003).

The Critical Path Method was first used by E. I. Du Pont de Nemours and co. in the 1950s, while PERT was developed in 1958 by the US Navy special project office as part of the Polaris Missile system (Rao (1992), Winston (1993)). Both are central tools of project management. The two methods are basically time-oriented methods, which lead to the determination of time schedules for a project. The difference between them lies in their time estimates. CPM assumes that the time estimates for different activities (or tasks) are deterministic while in PERT they are regarded as probabilistic. PERT assumes that the duration of each activity has a probability distribution, which is approximated by the beta distribution. The beta distribution has a density function given by:

$$f(t) = \begin{cases} kt^{p-1}(1-t)^{q-1}, 0 \le t \le 1 \\ 0, elsewhere \end{cases} \tag{1}$$

where $p \ge 0; q \ge 0$, k a constant selected so that the area under the density function is 1:

$$k = \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} \tag{2}$$

where $\Gamma(.)$ is the gamma function. The mean and variance are approximated by

$$\bar{t} = \frac{t_0 + 4t_m + t_p}{6} \tag{3}$$

$$\sigma_t^2 = \left(\frac{t_p - t_0}{6}\right)^2 \tag{4}$$

where t_0, t_m and t_p are 3 given numbers.

CPM assumes that activity durations can be represented by a single value. It is mainly used in projects where there is background experience, which can aid the estimates of the activity durations. Such projects include construction works. PERT employs statistically estimated activity durations and is used mainly in projects where background experience may be lacking. Such projects include research and development works, hosting major sports tournament, etc.

The two methods can be applied to process management to determine effectiveness of processes where the effectiveness characteristic is process cycle time. The major difference between a project and a process is that a project is a one-time effort while a process is repeated over and over again. The repetitive nature of a process will not invalidate the assumptions of the two methods. For example, CPM assumes that activity durations are deterministic. In a process, the activities may be repeated infinite number of time. We can assume that the activity durations are deterministic and represent them by a single number for the purpose of determining the effectiveness of the process. As for PERT, the assumption that activity durations are probabilistic cannot possibly be violated by the repetitive nature of a process. Rather by repeating the process over time, the correct probability distribution can be determined for the activity durations through data collection. The assumption of a beta distribution is just an assumption to approximate the distribution of activity durations, which can be dispensed with if necessary or validated through empirical study. For the purpose of this work, we shall assume that the activity durations have the beta distribution.

3.1 Network Representation

Both CPM and PERT require the construction of a network of the project. In a network, arrows are used to represent activities, and the completion of an activity (which may also be the beginning of another activity) is represented by a circle called a node. Activities are denoted by a pair of number (i, j), while nodes are denoted by a number (i). To apply this method to process management, a network is used in place of a flowchart. To construct a network, the following conditions must be observed:

1) Identify the precedence relationships between the various activities. This will reveal activities that must be completed before a particular activity can commence.
2) Each activity is represented by only one arrow in the network.
3) No two activities can have the same end nodes. This may arise whenever two activities can be performed simultaneously. In that case, a dummy activity is used to separate their beginning nodes.
4) The arrows should not form close loop.
5) The network should have unique starting and end nodes.
6) For more details on how to construct networks, the reader is referred to Rao (), Winston (1993), or Taha (1987).

3.2 Determination of the Critical Path

The critical path is a chain of activities through the network and contains activities that cannot be delayed. It has the smallest possible cycle-time for the process. The critical path will provide an estimate of the process cycle-time.

Definition of Terms:

Earliest Event Time (ET_i) is the earliest time at which the event corresponding to node (i) can occur.

Latest Event Time (LT_i) is the latest time at which the event corresponding to node (i) can occur without delaying the completion of the project.

Total Float (TF_{ij}) of activity (i, j), $(i < j)$ is the amount by which the starting time of activity (i, j) can be delayed beyond its possible starting time without delaying the completion of the project.

The critical path is computed in two parts:

Part 1: Forward Pass through the Network:

For the starting event, we set the time at zero, ie. $ES_0 = 0$. Let the duration of activity (i, j) be denoted by d_{ij} $(i < j)$.

$$ET_j = \max_i \{ES_i + d_{ij}\}, (i, j) \tag{5}$$

for all activities (i, j) which terminate at node j.

Part Two: Backward Pass Through the Network:

For the terminal node we set the latest event time equal to the earliest event time, i.e. $LT_T = ET_T$, and compute

$$LT_i = \min_j \{LT_j - d_{ij}\}, (i < j) \tag{6}$$

for all activities (i, j) originating from node j.

The final calculation is the total float (TF_{ij}) for activity (i, j), $(i < j)$.

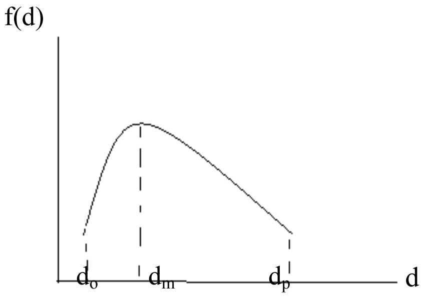
$$TF_{ij} = LT_j - ET_i - d_{ij}, \forall (i, j), (i < i) \tag{7}$$

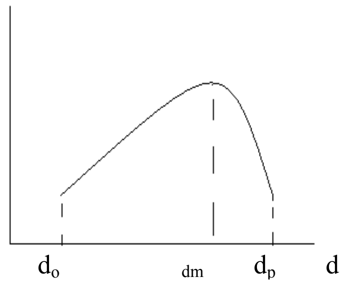
Critical activities are activities with total float equal to zero. A path from node 1 to node T consisting entirely of critical activities, is called the critical path.

4. The Pert Method

The PERT method utilizes 3 time estimates for each activity and assumes that the duration of each activity has a density function approximated by the beta distribution.

The beta distribution is unimodal and takes the shape of the form





The three values can be used to estimate the parameters of the model.

To determine the critical path in PERT, $\overline{d}_{ij}$ is used as the duration of activity $(i, j), (i < j)$ and the variance of each activity is also calculated using the (4). All other calculations remain the same.

The process cycle time is given by

$$\overline{D} = \sum \overline{d}_{ij} \tag{8}$$

which is the expected length of the critical path, and has a variance given by

$$\sigma_{\overline{D}} = \sum \sigma_{ij} \tag{9}$$

for all activity (i, j) on the critical path.

Probability statements can be made concerning the process cycle time. We assume normal distribution for the expected cycle time and the probability that the process cycle time will not last beyond a specified value A is given by

$$p(D \leq A) = p\left(\frac{D - \overline{D}}{\sigma_{\overline{D}}} \leq \frac{A - \overline{D}}{\sigma_{\overline{D}}}\right)$$

$$= p\left(z \leq \frac{A - \overline{D}}{\sigma_{\overline{D}}}\right) \tag{10}$$

where z is the standard normal variate with mean 0 and variance 1. The probability is read off from the table of the standard normal distribution.

5. Application

A manufacturing company (name withheld) in the commercial city of Lagos, Nigeria that produces household utilities was faced with the problem of parking space for its customers after the government of Lagos state came with a new law prohibiting trucks and other vehicles from parking by the road sides of major highways. The company has a parking lot for its customers, but because of limited space, some were compelled to park by the roadside outside the fence of the company. This means they will have to pay fines to the government, which can be quite substantial, in case their trucks are impounded. This will add to the cost of transacting business with the company. This development is certainly not good for the company's image and quality objectives. Though the additional cost is on the part of the customers, the company feels sufficiently concerned because such an additional costs could affect customer satisfaction negatively. The marketing department decided to look inward to see what could be done about it. The author was consulted and he suggested that the process that delivers services to the customers be examined. The company's record shows that the trucks spend only a few hours at the premises of the company before they are loaded. If the process is effective it is possible to eliminate congestion at the parking lot.

The company operates with a charter time for customer service, which was 90 minutes. This means services must be completed within 90 minutes for every customer. We looked at past data, which were poorly recorded, and found that in the last one year, the daily average time spent on loading a truck range from as low as 70 minutes to as high as 140 minutes. While the true effectiveness of the process could not be determined from the poor data record, one could almost certainly claim that the performance of the process could be improved upon significantly.

The process activities, together with their durations, were identified and listed in table 1. People involved in carrying out the activities were asked to provide the estimated time for each activity. A study was then carried out and the data on table 2 were collected. We then proceeded to a brainstorming session to identify the right operational relationship between the various activities. This led us to the result on table 3:

Insert table 1, 2, 3 here

Before the session ended we came up with the network given below:

Insert figure 1 here

It is now obvious that some activities can take place at the same time. For example, activities B and C can take place at the same time. Also G and H. While vehicle is being weighed out, delivery note can be validated at the credit control, and the auditor can check and sign necessary papers. These changes, we found out, would be at no extra cost to the department.

The CPM and PERT were applied to obtain the smallest process completion time.

CPM CALCULATIONS

Table 4 shows the result of CPM calculations. The critical activities are indicated with a star.

Insert table 4 here

PERT CALCULATIONS

To carry out the PERT calculations, three values of activity durations are needed; the optimistic time, the pessimistic time and the most likely time. Three values were taken from the ten observed for each activity and used to calculate the mean activity duration and the standard deviation of the durations. The results are shown in table 5.

Insert table 5 here

The mean duration times were used to obtain the earliest event time, the latest event time and the total float. The results were shown in table 6. Critical activities are indicated with a *. We found that both approaches gave the same critical activities but with slightly different minimum cycle time for the process. CPM gave 73 minutes while PERT gave us 71.86 minutes with a standard deviation of 3.36 minutes.

Insert table 6 here

The critical path is indicated with bold arrows in the network below.

Insert figure 2 here

The probability that the process can be completed within 73 minutes can be determined and is given by

$$P\left(z \leq \frac{73 - 71.86}{3.36}\right) = P(z \leq 0.3393) = 0.6293$$

The chance is well above 60% that the process duration will not exceed 73 minutes.

The marketing department adopted this model and within a few weeks of its use, the effect became visible. Congestion at the parking lot was completely eliminated and the fear that trucks may park on the highway was totally removed. In addition the company had no need to lease or acquire bigger parking space for its customers' trucks.

6. Conclusion

This work has shown that CPM/PERT can be applied to solve quality problems in an organization. By focusing on the process that delivers a product, a lot can be achieved in improving the quality of the product. CPM/PERT can also be used to measure process effectiveness and improve on it as we have shown here.

Areas of Further Research

Since processes are repetitive, there may be no need to make the beta distribution assumption concerning the distribution of the duration of each activity. An empirical distribution can be constructed for each activity in the process and by appealing to the central limit theorem; the normal distribution can be used to carry out necessary tests concerning the duration of the process.

Cost can also be included in the analysis to achieve better control over the process.

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Table 1. List of activities and their durations

NO	ACTIVITIES	DURATION
1	Customers bring authority to collect (ATC) to customer service manager and the manager works on it.	8 minutes
2	Customer service executives prepare the invoice and delivery note.	5 minutes
3	Delivery note is taken to commercial store and stamped with authority to load after confirmation of document.	3 minutes
4	Vehicle enters into the premises and proceeds to weigh bridge to be weighed in.	10 minutes.
5	Delivery note is given to loaders contractors and vehicle is loaded and checked by security checkers.	28 minutes
6	Driver proceeds to commercial store and signs out.	4 minutes
7	Delivery note is taken to weigh bridge and the vehicle is weighed out.	15 minutes
8	Delivery note is taken to credit control for validation	4 minutes
9	Auditors check and sign necessary papers.	5 minutes
10	Security at gate check and the vehicle leaves the premises	8 minutes

Table 2. Result of data collected on the duration for each activity. 10 observations were made on each activity

ACTIVITIES	OBSERVED DURATIONS
Customers bring authority to collect (ATC) to customer service manager and the manager works on it.	8.0, 7.5, 6.0, 8.5, 10.1, 9.1, 9.0, 7.1, 7.3, 6.5.
Customer service executives prepare the invoice and delivery note.	4.4, 4.9, 5.2, 5.7, 3.9, 3.7, 4.2, 3.6, 6.2, 6.5
Delivery note is taken to commercial store and stamped with authority to load after confirmation of document.	9.2, 9.7, 10.1, 11, 10, 10.3, 8.9, 9.1, 8.5, 8.6
Vehicle enters into the premises and proceeds to weigh bridge to be weighed in.	1.5, 1.7, 2.5, 3.0, 2.0, 3.5, 4.5, 2.0, 3.0, 2.7.
Delivery note is given to loaders contractors and vehicle is loaded and checked by security checkers.	30.0, 28.0, 29.0, 26.0, 27.9, 30.7, 25.0, 25.6, 27.7, 29.0
Driver proceeds to commercial store and signs out.	2.3, 3.7, 4.0, 4.5, 2.0, 4.9, 5.1, 5.7, 2.1, 3.4
Delivery note is taken to weigh bridge and the vehicle is weighed out.	16.4, 14.2, 16.0, 17.0, 15.0, 14.5, 13.5, 14.8, 13.0, 15.2
Delivery note is taken to credit control for validation	2.1, 3.5, 4.2, 3.7, 3.3, 5.0, 3.9, 4.4, 2.8, 2.4
Auditors check and sign necessary papers.	5.5, 4.3, 4.8, 4.9, 3.8, 3.5, 2.0, 3.4, 5.8, 4.0
Security at gate check and the vehicle leaves the premises	8.0, 10.1, 9.2, 7.0, 6.5, 7.5, 6.9, 8.2, 6.7, 7.2

Table 3. Precedence relationship between activities

ACTIVITY	DESCRIPTION	PRECEDENCE ACTIVITY
A	Customers bring authority to collect (ATC) to customer service manager and the manager works on it.	-
B	Customer service executives prepare the invoice and delivery note.	A
C	Delivery note is taken to commercial store and stamped with authority to load after confirmation of document.	A
D	Vehicle enters into the premises and proceeds to weigh bridge to be weighed in.	B
E	Vehicle enters into the premises and proceeds to weigh bridge to be weighed in.	C,D
F	Driver proceeds to commercial store and signs out.	E
G	Delivery note is taken to weigh bridge and the vehicle is weighed out.	F
H	Delivery note is taken to credit control for validation	F
I	Auditors check and sign necessary papers.	H
J	Security at gate check and the vehicle leaves the premises	G,I

Table 4. Summary calculations for CPM Method

ACTIVITY	DURATION (MIN)	TOTAL FLOAT	EVENT	EARLIEST EVENT TIME	LATEST EVENTS TIME
A	8	0*	1	0	0
B	5	2	2	8	8
C	10	0*	3	13	15
D	3	2	4	18	18
E	28	0*	5	46	46
F	4	0*	6	50	50
G	15	6	7	54	60
H	4	0*	8	65	65
I	5	7	9	73	73
J	8	0*			

* indicates critical activities

Table 5. The Optimistic time, The Pessimistic time, The Most-Likely time, the Mean and The Standard Deviation of each activity

ACTIVITY	OPTIMISTIC TIME (d_o)	MOST LIKELY TIME (d_m)	PESSIMISTIC TIME (d_p)	MEAN TIME $\bar{d}$	STANDARD DEVIATION σ_d
A	6.0	8.0	10.1	8.0	0.68
B	3.6	5.0	6.5	5.0	0.48
C	8.5	9.5	10.3	9.46	0.3
D	1.5	3.0	4.5	3.0	0.5
E	25	28	30.7	27.8	0.95
F	2.1	4	5.7	4	0.6
G	13.0	15	17.0	14.9	0.66
H	2.1	3.5	4.4	3.4	0.38
I	2.0	4.0	5.8	4.0	0.68
J	6.5	7.5	10.1	7.7	0.6

Table 6. Summary Calculations for the PERT Method

EVENT	EARLIEST EVENT TIME	LATEST EVENT TIME	ACTIVITY	DURATION (MIN)	TOTAL FLOAT
1	0	0	A (1,2)	8.0	0*
2	8	8	B (2,3)	5.0	1.46
3	13	14.46	C (2,4)	9.46	0*
4	17.46	17.46	D (3,4)	3.0	1.46
5	45.26	45.26	E (4,5)	27.8	0*
6	49.26	49.26	F (5,6)	4	0*
7	52.66	60.16	G (6,7)	14.9	7.5
8	64.16	64.16	H (6,8)	3.4	0*
9	71.86	71.86	I (7,8)	4.0	7.5
			J (8,9)	7.7	0*

* indicates critical activity

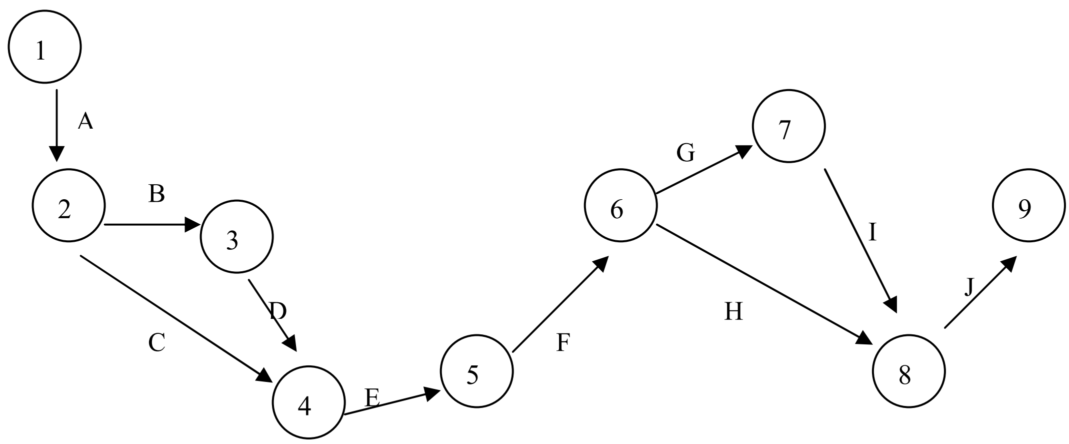

Figure 1. Network of the activities in table 3

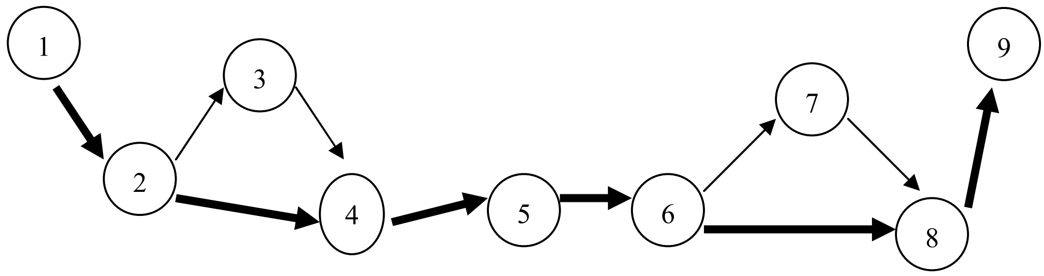

Figure 2. Network showing the critical path