Information Systems development: time network planning

G. Haramis¹ & Th. Fotiadis
¹University of Macedonia, Thessaloniki, Greece

Abstract

For a complete and foolproof control for the development of an Information System (IS) there arises a need for proper time planning of the relative activities, which is achieved by the "diagram" depiction of the "time arrangements" of these activities (Bar Charts, CPM, PERT). In this paper there are briefly presented, a Bar Chart and a model of the network CPM for the time scheduling of the IS's development. Furthermore, with the use of the Beta Distribution what is achieved, is the Theoretical Distribution of Frequency of the Time Development of the IS. Thus, the design of the equivalent network PERT is easy, and as a result with the contribution of PERT and of the Central Limit Theorem, the assessment of the possibility of development of IS within the planned time is attempted.

1 Introduction

Time planning was initially applied during the procedures for the construction of the Polaris rockets and it is estimated that it succeeded in reducing construction time by two years. It is generally reckoned that the time economized by this system fluctuates between 15% to 20%.

The purpose of time-planning is to create a program (diagram) by which it will be possible to estimate what jobs are to be carried out at any given time and during the entire duration of the project-development. The diagram constitutes a primary aid to the project leader for the following reasons:
- it assists him in the correct supervision of the total project,
- it enables him to check separately each job in the project,
- it makes it possible to coordinate these various jobs,
it gives him a timely warning when a change should become necessary in the
organization and finally,
it guides the project leader and indicates to him the various points that
require particular attention and also the likely "critical" steps on
which a well-planned execution of the entire project.

This "design" can be graphically represented with the well-known "Gantt"
diagrams, which enable the surveillance both of the overall execution of the
project and of each stage of its development.

However, very often the jobs of one section interfere with those of
another. In such cases, the "Gantt" diagrams are of little service, whereby
the-application of a different method becomes necessary, namely that of
"Network Analysis" (Program Evaluation and Review Technique or PERT,
Critical Path Method or CPM).

It is called Network Analysis because the series of works planned for
execution are graphically represented by a network.

Network is a conjunction of lines through which the flow of variables
"time", "cost", and "means" can be realized. The network consists of events
and activities.

Activity is any work which is necessary for the execution of a project
and which, therefore, requires time, cost and means. In the other hand,
event is called the beginning and the end of any activity.

The activity is represented with an arrow, while the events are
represented with a circle numbered with integral, positive numbers. The
numeration must be ,of such kind that the number of the ending event j is
bigger than the number of the beginning event i.

\[
\begin{array}{c}
\text{i} \\
\text{Activity x} \\
\text{j}
\end{array}
\]

where \( j > 1 \).

An activity cannot be embarked upon unless the event which precedes
this is not realized previously. An event, on the other hand, is not fulfilled
if all the activities, which lead to this are not executed.

An activity, which does not require time spending, costs etc., since it
does not represent real work and is simply set in the network for
clarification of relations among the network data, is called slack activity
and is represented with an interrupted arrow and has zero time.

2 Chronograms

The practice of Time-Planning insures a full and effortless surveillance of
the development of a system. Its use involves diagrams to illustrate the
"time-schedules" of the jobs concerned.

The oldest and simplest way to present the advance planning of time for the development of a system is the use of "time-measuring" or "milestone" charts. These provide each member of the team with a plan of the tasks that he must fulfill. The estimated length of time for the realization of each task is filled in the relevant column of the charts. These charts are graphically represented by the known chronodiagrams "Bar Charts" or "Gantt Charts" by Harry L. Gantt, who was the first to use them. They contain the graphic outline of the total jobs of the members of the team.

It’s easy to read and bring, the chronodiagrams up to date, but a full picture of the interferences and connections between the various tasks are not obtained. It can be said with certainty, that when faced with a complex project, where there is definitely an interference between the tasks, the diagram "Gantt" is not suitable because it requires that the analysis, the supervision and the coordination of the tasks concerned are made by a different method before the diagram can be applied.

The purpose of this procedure is to obtain perfect results and at the same time, to break the interference between activities, facilitating hereby the design of the diagram considerably.

In Figure 1 a model - chronodiagram is proposed for the development of one IS

Here the months are of the year "x" and apart from Sunday, all the days of the week are counted as working days. In the second line of the model's title, beneath the months, are marked the weeks (date for each Monday) and in the third line is indicated (in man-days) the duration of each activity that leads to the development of the system.

Each phase requires the following:

1st Phase \( (30 \times 4) + (2) + (5) + (20) + (15) = 76 \)

2nd Phase \( (2) + (22) + (5) + (10) \)

3rd Phase \( (2) + (2) + (1) + (2) + (1) + (2) \)

\[ \text{total} = 125 \text{ man days} \]

The particular advantages of the diagram are as follows:

- it can effectively supervise the progress of the jobs for the development of the system,
- it can point out any areas in the project, where there is under or overproductivity, and
- it can determine the time that is needed for the completion of the system.

3 Critical path method network

3.1 Uses and advantages

The method "CPM" (Critical Path Method) was developed in 1958 by Morgan R. Walker and James E. Kelly. It appeared almost simultaneously with PERT (Program Evaluation Review Technique), which had been used for the first time in 1958.
These two methods share a similar technical analysis of the problem with the difference that each was developed on its own and independently from the other. Their essential distinction lies in the fact that CPM studies events can be estimated with logical precision, whereas PERT concerns itself with
cases that have not been calculated (predicted) in advance. In short, the first method relies on facts, where as the second on probabilities: CPM is chiefly used for the purpose of minimizing the following:
total time needed for the development of a system,
- the correspondent total cost,
- the time for each given cost,
- the cost for each given length of time, and
- the number of analysts-programmers engaged in the development of the system.
It has been proven that both CPM and PERT are suitable methods require a definite objective aim during a definite length of time. During this period the corresponding network (within which certain independent activities will be promoted in a given order) must be completed.
The particular advantages of CPM can be considered as follows:
- planning the activities for the development of the system,
- improving the communication between the members of the development team and the user departments. This communication is established by appropriate plans and estimates of time and cost,
- specifying the requirements in men and equipment,
- supervising and evaluating the progress of the system,
- pinpointing the "critical" activities, and
- reducing the overall time required, in case the time that is available is not sufficient for the promotion of the project.
Furthermore, CPM is useful in informing, instructing and facilitating the "contact" between new members (analysts, programmers) of the project team.

3.2 Design of the CPM Network
The significance of the CPM method is based on the "diagram" representation of the activities, which leads to the fulfillment of the system. Prior to the design of the network, the subject of each activity (should be studied and the activities should be searched for, which they are possible to be confronted simultaneously (in parallel) with the examined one fill those, which are going to follow.
The size of the activities (IS's phases, steps) it depends on the nature of the IS. Generally, the method of the "critical path", of the longest path to the network, is mainly used for the time planning of the large systems development, however this is not always the rule.
The steps that have to be taken in a given order for the design of the CPM Network are the following:
- Specify the self sufficient and complete parts of the project (sub-projects), provided that there are such, and provided that it is desirable to construct for them particular networks (CPM Networks). Also specify the method and the necessary resources for the realisation of each of these sub-projects.
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- Specify all the activities of the project that exceed the minimum, which was defined as such (i.e. 1 man-day).
- Specify the order in which the various tasks will be carried out and annotate the cases activities), that can be completed simultaneously. The job is made much easier by the fact that by the end of each stage of the project, it can be distinguished the tasks as critical or non-critical.
- Design the CPM diagram. It determines that the leader must have in mind, in addition to the above points, all the activities (both critical and non-critical), which cannot be carried out unless a number of other activities have been completed before.
- Complete the (CPM) diagram with the scheduled time (needed) for each activity (in man-days), relying on the estimated man-hours and the number of analysts-programmers of the team. This scale of time is based on the supposition that the network begins at zero time, that each activity continues without breaks until its completion, and that no activity can begin if all preceding activities have not been completed.
- Layout the "critical path" in the whole diagram (network) by specifying those (critical) activities, which take for their completion, the maximum of-the-time estimated for the development of the project.

As soon as the network has been designed, it becomes evident that there are many paths that lead to the completion of the project. The path that requires the maximum time (the longest path) is the critical and preferable one. If this length of time lies within the desired limits, then the development of the project is defined chronologically, otherwise the entire network has to be planned again from the start, after one has examined which activities can be carried out in a shorter time than before.

The design of the CPM network is realized by the project leader, nevertheless, some points of the network require, for the design, the relative collaboration of the leader with the members of the project team, for instance in the case of the works for the project, which are possible to be executed in parallel.

Figure 2 proposes a model "CPM" Network for the development of a system in the same example (project) of the model-chronodigram of Figure 1.
The Critical Path is indicated by the heavy lines.
Numbers in parentheses indicate man-days.

Duration:
Phase I = 30 + 4 + 2 + 5 + 2 + 1 + 5 = 76
Phase II = 2 + 22 + 3 + 10 = 37
Phase III = 2 + 2 + 1 + 2 + 12 = 19

Figure 2: Critical Path Network Model for IS’s development
4 PERT (Program Evaluation and Review Technique)

4.1 Development of the Network

The development of the PERT Network takes place in stages. The members of the project team design some first drafts of networks either for the entire project or (usually) for a part or parts of it. These first networks are gradually linked together and they then produce the final form of the complete network. During this procedure, the various possible differences between the output of one network-part and the input of another must be located and worked out. In conclusion, the project leader and the team members must examine the complete (final) network for its reasonability.

The network will illustrate the program and the time that is required for the development of the system. Furthermore, it will illustrate the critical path (the longest path) and all the other paths that can influence the (final) length of time needed for the system to be implemented.

Such is the nature of the PERT-method, that the longer and more complex the project, the more profitable it becomes to use it. If, at the planning of the program (network), a scheme is applied that had pre-existed and then the method represents simply a means of reporting the project's activities. If, however, this is not the case, then the method PERT serves both as a means of reporting as well as of scheduling.

During the development of a network and each activity, the following points have to be studied in particular:
- the earliest starting time,
- the earliest ending time,
- the latest starting time, with no need to revise the diagram,
- the latest ending time, and
- the maximum time available for the accomplishment of the activity.

This is obtained by subtracting the earliest starting time from the latest ending time.

The design of the diagram PERT is similar to that of the CPM diagram but, as it has been mentioned, PERT concerns itself with cases that have not been estimated in advance. Because of this uncertainty, three estimates of time are necessary so that each activity can be materialized:
- the shortest possible time (optimistic time), that is obtainable if the activity is accomplished under ideal conditions.
- the most likely time that is usually derived with an average experience and on the hypothesis that the activity will be carried out under normal conditions, and
- the longest time (pessimistic time) that shall be needed if the activity is carried out under the worse conditions.

Relying on these three estimates of each activity, three equal estimates will be put forward for the development of the entire IS and the project leader, who must be familiar with the object of the project in development, will study the three final (total) estimates and will decide either for the design
of a new network and for the reallocation of the Analysts-Programmers in the phases of the system development or for a new priorities determination.

4.2 Estimates of the network

The importance of PFRT lies in that it can be used as an information-source for the management. It advises the management of the progress a project makes in terms of time, more specifically, in terms of when the project is developing smoothly or when it lies before or after the estimated limit of time. This can be achieved by specifying the slack time that shall indicate the duration of any delay, which can occur during certain activities, without deferring the whole project. It also indicates the time difference between the latest expected time and the earliest expected time and the earliest expected time for each activity.

The events in which this difference is zero are called "critical events" in that any delay can cause an increase in the expected likely time for the promotion of the whole project.

The slack time can be a positive or negative number or a zero. The zero indicates a situation that fits into our estimates; the negative number a development that is slower than estimated, while a positive number indicates a development that is faster than what it is predicted.

For the calculation of the slack time, apart from defining the slower and earlier expected time, it is also needed to work out the "mean time" and the "time deviation" of each activity. The "mean" and "deviation" time are obtained from the three estimates of the time needed for IS development.

The use of three estimates instead of one shows the time for the realization of the IS as a probability rather than a certainty. The probability, as it is known, can be shown by one probability distribution. In the case, given the fact that the time of one action cannot be reduced beyond a certain point, (whereas its delay can be of any duration), the most frequently used distribution of probability is the "Beta Distribution". An approximate estimate of its parameters is given by the following formula:

\[ t_e = \frac{\alpha + 4m + b}{6} \]
\[ \sigma T = \frac{\beta - \alpha}{6} \]

where  
\( t_e \) = the meantime,
\( \sigma T \) = the deviation, and
\( \alpha \) = the optimistic estimate of the time needed for the realization of the activity (optimistic time),
\( b \) = the pessimistic time, and
\( m \) = the most likely time.

The above sizes are shown in Figure 3.
Figure 3: Beta distribution of IS’s development times

Furthermore, for the mathematics expression of the calculations, it is to be considered as the time necessary for the fulfillment of an activity, the referred time for it. Afterwards, the earliest expected time of each event is found, \( (t_j) \). This time is given by the longest path from the initial event of the network to the event \( j \). Accepting that the earliest expected time for the initial event is zero, then for the remaining events is given by the relation:

\[
t_j = \text{Max}(t_i + \Delta_{ij})
\]

for \( t_i = 0 \) and \( 2 \leq j \leq v \),

Where \( v \) = the last event of the project, and where \( j \) receives the prices of all the previous events, for which there are activities \((i, j)\).

The earliest expected time for the final event of the network gives the least possible time of development of the whole system.

Then the latest expected time \( (t_j) \) can be calculated during which the event \( j \) should be realized, so that there will be no delay at the systems development. It is given through the longest path between the event \( j \) and the final event of the network and, if it is not determined in advance, it is regarded as equal to the earliest expected time \( (\tau_j = t_v) \) and for the rest of the events is given by the following relation:

\[
t_j = \text{Min}(\tau_{\lambda_{j}} - \Delta_{p_j})
\]

for \( j < \lambda \) and \( 1 < j < v - L \),

where \( v \) = the last event of the project, and where \( j \) receives the values of all following events for which activities exist \((ij)\).

5 Likelyhood for the system to begin at the scheduled date

Deviations between the schedule of an event and its realization occur almost always. PERT’s role in defining a deviation is significant. In this method the calculations rely on the estimated values, which is why it makes sense to also consider the probability of their realization. So, it is necessary to find the probability for the realization of each event in relation to the program and relying on the deviation from the scheduled time and on the error-during its calculation.
It has been observed that the hypothesis involving the time for carrying through an event follows the normal distribution, has brought satisfactory results in practice. So, it is adopted the normal distribution and accepted the fact that the times \((a, m, b)\) for the realization of an event are random variables and that they are ruled by the central limit theorem.

According to it if a random variable \(y\) is the total of independent variables \(x_1, x_2, \ldots, x_v\), which follow any probability function, then the distribution of \(y\) approaching the normal distribution with:

\[
\mu_y = \sum_{i=1}^{v} \mu_{x_i} \quad \text{and} \quad \sigma_y^2 = \sum_{i=1}^{v} \sigma_{x_i}^2
\]

as \(v\) is maximized.

It can thus to proceed by calculating the probability for the realization of one stage or of the entire project at a scheduled date \(x\).

The shaded area presented in the diagram (Figure 4) shows the probability that time \(r\), that will be actually required (actual time) is equal to the scheduled time \(x\). This probability is easily worked out by the relevant tables of the areas of the normal curve and on the basis of the formula:

\[
Z = \frac{T_s - T_e}{\sigma T_e}
\]

in which  
- \(T_s\) = the scheduled time,
- \(T_e\) = the expected time, and
- \(\sigma T_e\) = the deviation (square root of the sum of the fluctuations in the activities that had been used in order to find \(T_e\)).

![Figure 4: Probability of IS's development within the schedule time.](image)

It must be mentioned that if time \(\chi\) lies before \(T_e\), then \(Z\) will be negative and the probability that is sought will be very small in relation to that derived from the positive \(Z\).
6 Conclusion

It is recommended that before starting the development of the IS the project leader must schedule the IS development Bar Chart and/or the CPM Network according to the proposed models. Afterwards and during the evolution of the IS development the project leader has to follow up all the proposed suggestions and as soon as a deviation has appeared in the scheduled times, he has to proceed to find its cause. Immediately after he has notified the users, he must discuss with them the effects of the deviation on the work, as well as the way of changing or rescheduling the time plan finally, he must try to minimize the cost of the additional work required for amending the plan.

References


