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RESEARCH ARTICLE

**An ethical committee approval and/or legal/special permission has not been required within the scope of this study.*

PROJECT PLANNING WITH CPM AND PERT METHODS: EXAMPLE OF DEFENCE INDUSTRY*

Beste DESTİCİOĞLU TAŞDEMİR

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ABSTRACT

Project management is the process of planning activities in the project, estimating time and cost, assigning resources, making schedules, and performing controls. Project planning methods are used in project management to make time estimations. CPM, PERT, Gantt Charts, Fuzzy CPM, Fuzzy PERT are project planning methods. The CPM method is used when the activity durations are known certainly. However, in a project implemented for the first time, the duration of activity cannot be estimated certainly. In order to take this variability into account, the PERT method, which calculates the optimistic, probable and pessimistic durations of the activities, is used. Defence industry projects are of great importance as they are related to the defence of the country. In order for defence industry projects to be successful, the projects must be planned effectively. In this study, the planning process of a project realized for the first time by a company serving in the defence industry was examined. In the study, first of all, the activities of the project, their previous activities and duration are defined. In the study, the completion time of the project was calculated using CPM and PERT methods and the results were compared. In the last part of the study, the completion time of the project was calculated under different probabilities by using the PERT method.

Keywords: *Defence Industry, Project Management, CPM, PERT, Project Planning.*

Beste DESTİCİOĞLU TAŞDEMİR

CPM VE PERT YÖNTEMLERİYLE PROJE PLANLAMA: SAVUNMA SANAYİ ÖRNEĞİ

ÖZ

Proje yönetimi, projedeki faaliyetlerin planlanması, zaman ve maliyet tahmininin yapılması, kaynakların atanması, programların yapılması ve kontrollerin gerçekleştirilmesi sürecidir. Proje yönetiminde zaman tahminlerinin yapılabilmesi için proje planlama yöntemlerinden faydalanılmaktadır. CPM, PERT, Gantt Şemaları, Bulanık CPM, Bulanık PERT proje planlama yöntemlerindendir. CPM yöntemi faaliyet süreleri kesin olarak bilindiğinde kullanılmaktadır. Ancak ilk kez uygulanan bir projede faaliyet süreleri kesin olarak tahmin edilememektedir. Bu değişkenliği dikkate alabilmek için ise, faaliyetlerin iyimser, olası ve kötümser süreleri hesaplama yapan PERT yöntemi kullanılmaktadır. Savunma sanayi projeleri, ülke savunması ile ilgili olduğundan büyük önem taşımaktadır. Savunma sanayi projelerinin başarıya ulaşabilmesi için, projelerin etkin bir şekilde planlanması gerekmektedir. Bu çalışmada da savunma sanayinde hizmet veren bir firmanın ilk kez gerçekleştirdiği bir projenin planlanma süreci incelenmiştir. Çalışmada ilk olarak, projenin faaliyetleri, öncüllük ilişkileri ve süreleri tanımlanmıştır. Çalışmada projenin tamamlanma zamanı CPM ve PERT yöntemleri kullanılarak hesaplanmış ve elde edilen sonuçlar karşılaştırılmıştır. Çalışmanın son bölümünde ise PERT yöntemi kullanılarak farklı olasılıklar altında projenin tamamlanma zamanı hesaplanmıştır.

Anahtar Kelimeler: *Savunma Sanayi, Proje Yönetimi, CPM, PERT, Proje Planlama.*

1. INTRODUCTION

The project is the set of activities created to achieve the determined targets within the specified time frame. The most confusing concept of the project concept is the operation. Although the project and the operation have many common aspects, there are points where these two concepts differ. While the project is defined as original and temporary activities; operation is defined as ongoing and repetitive activities. In this case, project can be defined as a unique service, product or a temporary attempt to achieve a specified goal. The project is the process where resources or employees come together with an organization within a certain time interval and these resources are transferred to other units after the project is completed in order to reach the determined goal (Abdel-Basset et al., 2021). Since projects consist of many activities, they must be carefully planned and completed within the specified time by acting in a coordinated manner at each stage (Gül et al., 2017).

In order for a project to be successful, it is necessary to make a good planning, to determine the relationships between the activities correctly, to predict the completion time and cost of the project, and to allocate resources accordingly. The success of the project is only possible with a successful project management. Project management can be defined as the process that ensures the effective management of the machinery, workforce, tools, information, software and other resources needed for the high quality of the project, in the shortest time possible, with minimum cost. Project management includes all stages of planning, management, organization and control of project activities in order for the project to be carried out in any sector to achieve its determined goals (Aksoy et al., 2019). Project management includes the stages of planning activities to achieve the determined goal, estimating the completion time and cost of the project, assigning resources and realizing project control (Temiz and Dursun, 2016).

Project management, considering the project as a whole, allows examining all components, making systematic arrangements within the project and carrying out activities suitable for the project. Project management enables the company to see ahead even in a project implemented for the first time (Sanchez et al., 2019). With the realization of an effective project

management, companies can estimate the completion time and cost of the project at the beginning of the project.

Planning is the first stage of project management and also forms the basis of the project. Therefore, the planning must be carried out effectively in order for the project to be successful. The planning stage is the stage in which what, when and how to do is determined, and at the same time resource allocation is carried out. Estimating the completion time of the project is the most important part of the planning phase. For the estimation of the completion time, it is first necessary to determine the priority relationships between the activities and these activities. When we look at the studies in the literature, it is seen that the Critical Path Method (CPM) and Program Evaluation and Review Method (PERT) are mostly used in estimating the durations.

Defence industry projects are among the most important factors that will increase the success of countries in the field of defence. Countries are investing heavily in defence industry projects in order to be a deterrent against their enemies by increasing their defence power. It is seen that a large share is allocated to defence industry projects within defence expenses. In order for defence industry projects to be successful and to reduce costs by using resources effectively, proper planning is required. In the creation of these plans, it is very important to define the activities, to determine the antecedent relations, and to estimate the completion time of the project by considering these relations.

As a result of the literature review, it has been determined that the researchers have been working on project planning for different sectors, and it has been seen that there is no study on project planning in the field of defence industry. Therefore, in this study, project activities were defined for a product to be produced for the first time by a company serving in the defence industry, and the project completion time was estimated. In the literature, it has been seen that CPM and PERT methods are widely used in determining the completion times of projects. However, in the projects implemented for the first time, this uncertainty should be reflected in the durations as the durations are not known clearly. For this reason, in the study, PERT method was used to determine the critical path by taking into account the optimistic, probable and pessimistic duration in order to define

the uncertainty in question in the duration of the activities. In addition, critical paths were determined for both CPM and PERT; Project completion times were calculated with both methods.

In the study, firstly, the literature research on project planning is included. In the following, CPM and PERT methods are discussed. In the next section, the network of the project was drawn by considering the priority relations of the activities in the project. In the study, the probable completion times of the project were calculated using CPM and PERT methods and the results were interpreted. In the last part of the study, the completion time of the project was calculated for different possibilities with the PERT method.

2. LITERATURE REVIEW

It is seen that there are many studies on project planning and project scheduling in the literature. In the studies in the literature, it has been determined that CPM, PERT, Fuzzy CPM and Fuzzy PERT methods are generally used in project planning. In this section, information is given about the studies carried out in recent years.

In their study, Turan and Güner (2013) used the CPM method to calculate the completion time of the green platform supply vessel project to be built for the first time in Turkey. In the study, the critical activities and critical path that took place during the project and directly affected the completion time of the project were determined. With the calculated slack, they stated how long the project could be delayed without changing the completion time.

Mazlum and Güneri (2015) used CPM and PERT methods in the scheduling of the online internet branch project. Researchers stated that there may be uncertainty in activity durations and defined activity durations using fuzzy triangle numbers. Fuzzy CPM and fuzzy PERT methods were used to calculate the completion time of the project with fuzzy activity times. In the last part of the study, they compared the results obtained with CPM, PERT, fuzzy CPM and fuzzy PERT methods.

Agyei (2015) examined the scheduling of a construction project in Ghana. In the study, the completion time of the project and the cost to be incurred were estimated by using CPM and PERT methods. At the same time, the changes that will occur on the project costs when the project is accelerated are also discussed in the study.

Temiz and Dursun (2016) used the PERT method to calculate the completion time in the port marine services automation project in their study. In the study, they also calculated the probability of completion of the project in different time periods by finding the variance values of each activity.

Gül et al. (2017) used fuzzy CPM and fuzzy PERT methods to evaluate the patient flow of the emergency department in a university hospital. Since the services provided in the emergency department contain uncertainty, they determined the duration of their activity with fuzzy numbers. In the study, factors affecting patient flow were determined. Researchers created the project network by considering the priority relations and calculated the completion time of the project.

Kholil et al. (2018) calculated the completion time of 36 house types (defined as 36 m2 houses) projects with CPM and PERT methods. In the study, the results obtained by using both methods were compared and interpreted and the project was planned more efficiently.

Maulana and Kurniawan (2019) used CPM, PERT and PDM (Preecedence Diagram Method) methods to determine the completion time of the social service construction project in their studies. As a result of the calculations, the shortest completion time was obtained with the PDM method. In the study, they stated that the fact that the completion of the predecessor activity was not taken into account in the beginning of an activity was effective in the fact that the PDM method was lower than the others.

In their study, Tümtürk and Tümtürk (2020) examined the planning of urban transformation building projects in İzmir Karşıyaka. In the study, they used the CPM method to calculate the completion time of the project and made cost estimation. The study also includes how much the project can be accelerated and the additional costs that this acceleration will bring.

Gasparikova and Leitner (2021), in their study, created the evacuation planning process of people using the network analysis method. In the study, networks of processes related to crisis management and evacuation of people were created, and the completion time of the evacuation was calculated with the PERT method. In the last part of the study, the results obtained are interpreted.

Abdel-Basset et al. (2022) studied the scheduling of high-risk projects under uncertain environmental conditions. Since the activity durations are uncertain, they used fuzzy numbers to determine the durations. In the study, they calculated the completion time of the project using fuzzy CPM and fuzzy PERT methods.

In the literature review, it was seen that the researchers conducted studies on the planning and scheduling of projects in different sectors. However, it has been determined that no study has been done on the planning of the projects carried out in the defence industry before. Therefore, in this study, the planning phase of a plate project to be developed by an enterprise serving in the defence industry has been examined. In the literature review, it was determined that researchers generally use CPM and PERT methods in calculating the required completion time in the planning process of projects. Therefore, in this study, CPM and PERT methods were used to calculate the completion time of the project. In the next part of the study, CPM and PERT methods are explained.

3. CPM AND PERT METHODS

The first study on project planning techniques was made by Gantt in the 1950s. Gantt developed the Gantt chart for estimating project durations. In the creation of this scheme, the completion time of the project was calculated by taking into account the antecedent relationships between the activities (Anderson et al., 2000). Although the Gantt chart shows the relationship between successive activities of the same activity, it falls short of showing the relationship between different activities. Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) were developed to show the relationship between different activities (Temiz and Dursun, 2016).

CPM and PERT are network-based methods developed for project planning, coordination and control. Both methods require the creation of the project network, taking into account the priority relations between the activities. The purpose of these methods is to create tools for planning the project. The network is the diagram in which the activities in the project and the antecedent relationships are shown by arrows and nodes. Drawing the network of the project by considering the priority relations of the activities helps in calculating the completion time of the project (Gül et al., 2017).

If the duration of the activities involved in the project is known certainly, the critical path method (CPM) can be used to determine the completion time of the project. CPM was developed by Kelly and Walker in order to calculate the downtimes caused by maintenance activities in chemical plants and to complete the project as soon as possible (Kelly and Walker, 1957). In the CPM method, the project's completion time is calculated by determining the critical activities and critical paths of the project. The critical path is the longest path between the start and end points in the project network. The activities on the critical path are called critical activities (Gül et al., 2017). In order to control the deficiencies in the project, it is of great importance to determine the critical path and critical activities of the project. Since the sum of the durations of critical activities is equal to the completion time of the project. The slightest delay that may occur in critical activities will cause disruption of the project and the amount of delay will affect the completion time of the project. If the project manager wants to make flexibility in terms of the duration of the activities, he/she can only do so through non-critical activities.

In the CPM method, it is assumed that the activity periods involved in the project are known certainly. The critical path is determined by calculating the earliest start and earliest completion times, and the latest start and latest completion times of the activities. Here first, the earliest start and earliest completion time of each activity is found. Afterwards, the earliest completion time of the last activity is equal to the latest completion time of the last activity, and the backward calculation is made. Let ES_j represent the earliest start time of activity j, EF_j the earliest completion time of activity j, and t_j the duration of activity j. Accordingly, ESj, earliest start time of

activity j and EFj, earliest completion time of activity j are calculated using Eq. 1 and Eq. 2:

$$ES_j = \max_{i<j}[EF_i] \quad (1)$$

$$EF_j = ES_i + t_j \quad (2)$$

If there are n activities in the project, the ESn value of the nth activity gives the completion time of the project. In order to determine the critical path of the project, it is necessary to calculate the latest start and latest completion time of each activity. In order to make this calculation, first of all, the earliest completion time of the last activity, n, must be equal to the latest completion time. Afterwards, the calculation must be done backwards to the first activity. In order to make this calculation, it is necessary to calculate the latest start and latest completion times for each activity. Let LS_i represent the latest start time of activity i, and LF_i the latest completion time of activity i. Accordingly, the latest completion time of activity i is calculated by Eq. 3, and the latest start time of activity i is calculated using Eq. 4:

$$LF_i = \min_{i<j}\left[LF_j\right] \quad (3)$$

$$LS_i = LF_i - t_i \quad (4)$$

In order to determine the completion time of the project and the critical path, it is necessary to calculate the earliest start and completion times and the latest start and completion times for each activity. The path combining activities with equal earliest and latest completion times is called the critical path, and the activities in this path are called critical activities. Project completion time can be calculated by adding up the durations of critical activities on the critical path.

Project Evaluation and Review Technique (PERT) is a method used in project scheduling. The PERT method emerged as a result of the work of the United States Navy in 1958. The PERT method was used for the first time in the development process of a rocket (Çetmeli, 1982). This method is used to determine the start and end times of the activities in the project and the completion time of the project. In the PERT method, the completion time of the project is calculated by using the network diagram created

according to the priority relations between the activities. In the project planning, the first time the workers do that job, the disruptions in the supply of materials, unexpected machine downtimes, malfunctions, etc. Due to various reasons, there may be changes in the activity periods (Gencer and Türkbey, 2001). In general, PERT method is used in the planning of projects that are implemented for the first time or where the duration of the activity cannot be determined certainly. In the PERT method, the activity times are not known certainly. In this method, triple time estimation is made as optimistic time, probable time and pessimistic time. In addition, the average duration and standard deviation of each activity are calculated in the PERT method, and the probability of completion of the project in different times can be determined by using the normal distribution (Temiz and Dursun, 2016). In the PERT method, the duration of the activities conforms to the Beta distribution, and the completion time of the project conforms to the normal distribution. In the PERT method, the critical path and critical activities are calculated with the formulas used in the CPM method.

In the PERT method, the standard deviations calculated for the activities show how much deviation can occur in the activity times and these deviations enable it to be determined how much longer the project will be completed than the planned time. In the duration estimation, a is the optimistic duration, b is the pessimistic duration, and m is the probable duration, and the probable duration of the activity is calculated with the following formulation:

$$\mu = \frac{a + 4m + b}{6} \tag{5}$$

The variance and standard deviation of each activity are calculated with the Eq. 6 and Eq. 7 given below:

$$\sigma^2 = \left[\frac{b - a}{6}\right]^2 \tag{6}$$

$$\sigma = \frac{b - a}{6} \tag{7}$$

In the PERT method, mean times and variances are calculated for all activities. After calculating the activity times, the critical path and critical activities in the project network are determined. The completion time of the project with 50% probability is equal to the sum of the durations of the critical activities. In order to calculate the deviation in the completion time of the project, the variances of the critical activities are added and then the square root of the total is taken (Temiz and Dursun, 2016). The completion time of the project follows a normal distribution.

When there is more than one critical path in the project, the path with the largest variance is determined as the critical path. In the PERT method, Eq. 8 is used to calculate the probability of completion of the project in the specified time:

$$Z = \frac{X - \mu}{\sigma} \tag{8}$$

X= Time required to complete the project

μ= Average completion time of the project

σ= Standard deviation of the project

The probability of completion of the project within the specified time is calculated by determining the value that the value found as a result of the calculations corresponds to from the standard distribution table.

4. METHODOLOGY

CPM and PERT methods are used in scheduling projects in many sectors, from construction sector projects to production sector projects, from service sector projects to logistics sector projects. In the literature review, it has been seen that CPM and PERT methods are used in many different areas such as port project, construction project, organization of emergency services of hospitals, creation of a website. However, it has been determined that there is no study on the scheduling of defence industry projects in the literature. Therefore, in this study, CPM and PERT methods were used to calculate the completion time of the plate project to be produced by an enterprise serving in the defence industry.

The development of the defence industry is seen as an indicator of the military, economic and political power of the countries. The defence industry not only involves more risk and uncertainty than other industries, but also requires a large investment and capital (Uçakcıoğlu and Eren, 2017). Therefore, time and cost management should be done carefully in the planning of defence industry projects. In this study, the scheduling and time estimation of the plate project that will be produced for the first time by an enterprise serving in the defence industry has been made. In the study, firstly, the network of the project was drawn by considering the priority relations of the activities. Afterwards, the probable completion time of the project was calculated with CPM and PERT methods. At the end of the application part, the completion time of the project is calculated for different possibilities.

Gantt Chart is widely used in calculating the completion time of projects. However, the Gantt diagram is insufficient in determining the priority relationships in the project and the critical activities of the project. Critical activities are activities that directly affect the calculation of the completion time of the project. The completion time of the project is obtained by summing the durations of the critical activities. Therefore, it is of great importance to identify the critical activities of the project. Critical activities that are so important for the project can be determined as a result of calculations made with CPM and PERT methods. In this study, considering this situation, CPM and PERT methods were used to calculate the completion time of the project.

The activities of the plate to be produced, the priority relations between the activities and the duration of the activities are given in Table 1.

Table 1. Activities, priority relations and durations in the project.

Activities	**Predecessor**	**Durations**	**PERT Durations**		
			a	**m**	**b**
A- Creation of prescriptions	-	120	100	120	132
B- Preparation of the mixture	A	8	7	8	10
C- Waiting for the mixing sand to dry	B	10	9	10	14
D- Sifting the mix sand	C	5	4	5	6
E- Placing the press mold	A	2,5	2	2,5	4
F- Pressing	D, E	3	2	3	5
G- Quality control of the pressed product	F	2	2	2	3
H- Preparation of the pre-sinter mold	G	6	5	6	7
I- Pre-sintering	H	18	17	18	22
J- Emptying the pre-sinter furnace	I	2	1	2	3
K- Quality control of pre-sintered products	J	5	4	5	7
L- Preparation of the sinter mold	K	6	5	6	8
M- Sintering of products	L	32	30	32	40
N- Emptying the sinter furnace	M	6	5	6	7
O- Quality control of sintered products	N	7	6	7	8
P- Preparation of composite fabrics	A	8	6	8	9
R- Arrangement of products to be autoclaved	O, P	1	0,5	1	2
S- Processing of products in autoclave	R	6	5	6	7
T- Emptying the autoclave	S	2	1	2	3
U- Quality control of products	T	8	6	8	10
V- Packaging of products	U	3	2	3	5

In order to calculate the completion time of the project with CPM and PERT methods, first of all, the activities, the duration of the activities and the antecedent relationships between the activities should be defined. Afterwards, the network of the project should be created by taking into account the priority relations of the activities. In order to be able to calculate in CPM and PERT methods, the network of the project must be created. Therefore, the network diagram of the project given in Figure 1 was created

by considering the priority relationships between the activities given in Table 1.

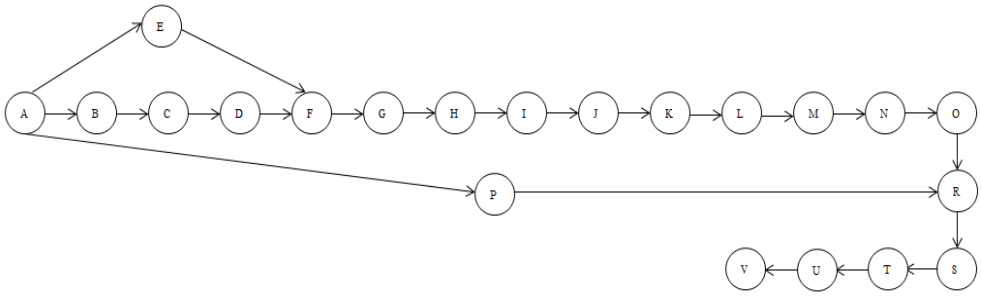

Figure 1. Network of the project.

4.1. Calculations of CPM Method

When the activity periods of the project are deterministic, the completion time of the project can be calculated with CPM. In this calculation, firstly, the earliest start and completion times of each node and the latest start and completion times are calculated using the equations given in Eq. 1, Eq. 2, Eq. 3 and Eq. 4.

In Table 2, the earliest start and completion times and the latest start and completion times and completion times for each activity in the project are given. Critical activities in the project are also indicated in the Table 2.

As a result of the calculations, it was found that the project could be completed in 250 hours. Activities other than E and P are critical activities in the project. In other words, the duration of these activities directly affects the completion time of the project.

Table 2. Results from the calculation with CPM.

Activity	Predecessor	Durations	Earliest		Latest		Note
			ES	EF	LS	LF	
A	-	120	0	120	0	120	Critical*
B	A	8	120	128	120	128	Critical*
C	B	10	128	138	128	138	Critical*
D	C	5	138	143	138	143	Critical*
E	A	2.5	120	122.5	140.5	143	
F	D; E	3	143	146	143	146	Critical*
G	F	2	146	148	146	148	Critical*
H	G	6	148	154	148	154	Critical*
I	H	18	154	172	154	172	Critical*
J	I	2	172	174	172	174	Critical*
K	J	5	174	179	174	179	Critical*
L	K	6	179	185	179	185	Critical*
M	L	32	185	217	185	217	Critical*
N	M	6	217	223	217	223	Critical*
O	N	7	223	230	223	230	Critical*
P	A	8	120	128	222	230	
R	O; P	1	230	231	230	231	Critical*
S	R	6	231	237	231	237	Critical*
T	S	2	237	239	237	239	Critical*
U	T	8	239	247	239	247	Critical*
V	U	3	247	250	247	250	Critical*

4.2. Calculations of PERT Method

In real life problems, variables such as demand and time cannot be known precisely in advance, and these values change over time. For example, for a project made for the first time, the duration of a machine to be used for the first time cannot be predicted. In this case, an average processing time for the machine is determined using the information from previous projects. In the PERT method, besides the possible duration, the optimistic and pessimistic duration for the activity is also determined. PERT method is

used to calculate the completion time of the project by considering these three different periods. In this study, since the project will be implemented for the first time, it is thought that there are uncertainties in the activity durations and optimistic duration, probable duration and pessimistic duration are defined for each activity. Afterwards, the calculations were made with the PERT method. Table 3 was created by using the results obtained in the calculations. The table also includes the average durations and variances of the activities.

Table 3. Results from the calculation with PERT.

Activity	**Durations**			**μ**	**σ^2**	**Earliest**		**Latest**		**Note**
	a	**m**	**b**			**ES**	**EF**	**LS**	**LF**	
A	100	120	132	118.7	28.41	0	118.7	0	118.7	Critical*
B	7	8	10	8.2	0.25	118.7	126.9	118.7	126.9	Critical*
C	9	10	14	10.5	0.69	126.9	137.4	126.9	137.4	Critical*
D	4	5	6	5	0.11	137.4	142.4	137.4	142.4	Critical*
E	2	2,5	4	2.7	0.11	118.7	121.4	139.7	142.4	
F	2	3	5	3.2	0.25	142.4	145.6	142.4	145.6	Critical*
G	2	2	3	2.2	0	145.6	147.8	145.6	147.8	Critical*
H	5	6	7	6	0.11	147.8	153.8	147.8	153.8	Critical*
I	17	18	22	18.5	0.69	153.8	172.3	153.8	172.3	Critical*
J	1	2	3	2	0.11	172.3	174.3	172.3	174.3	Critical*
K	4	5	7	5.2	0.25	174.3	179.5	174.3	179.5	Critical*
L	5	6	8	6.2	0.25	179.5	185.7	179.5	185.7	Critical*
M	30	32	40	33	2.78	185.7	218.7	185.7	218.7	Critical*
N	5	6	7	6	0.11	218.7	224.7	218.7	224.7	Critical*
O	6	7	8	7	0.11	224.7	231.7	224.7	231.7	Critical*
P	6	8	9	7.8	0.06	118.7	126.5	223.9	231.7	
R	0,5	1	2	1.1	0.33	231.7	232.8	231.7	232.8	Critical*
S	5	6	7	6	0.11	232.8	238.8	232.8	238.8	Critical*
T	1	2	3	2	0.11	238.8	240.8	238.8	240.8	Critical*
U	6	8	10	8	0.44	240.8	248.8	240.8	248.8	Critical*
V	2	3	5	3.2	0.25	248.8	252	248.8	252	Critical*

In order to find the completion time of the project, the earliest start and latest finish times, and the latest start and latest finish times were calculated for each activity, as in the CPM method. As a result of the calculations, it was found that activities other than E and P activities are critical activities. In this case, the sum of the durations of the activities other than the E and P activities gives the completion time of the project. The time calculated by the PERT method shows the completion time of the project with 50% probability. Accordingly, the completion time of the project with 50% probability was calculated as 252 hours.

The same problem is solved using both CPM and PERT method. When the calculations for both methods are examined, it is seen that the completion times of the activities are close to each other. Table 4 was created to compare the times calculated with CPM and PERT.

Table 4. Comparison of results obtained with CPM and PERT.

Completion Time	**CPM**	**PERT**	**Difference**
Time (hour)	250	252	2

When Table 4 is examined, it is seen that the CPM method is more effective than the PERT method. While it is predicted that the project will be completed in 250 hours with the calculations made with the CPM method, it is predicted that the project will be completed within 252 hours as a result of the calculations made with the PERT. When the completion time calculated by the PERT method is compared with the completion time calculated by the CPM method, it is seen that there is a 2-hour deviation. This difference is due to the fact that three different situations are taken into account in the PERT method, as optimistic, probable and pessimistic duration for each activity. Considering the pessimistic time for activities negatively affects the results obtained by calculating the completion time of the project.

The time obtained by the PERT method gives the project completion time with 50% probability. However, no manager can carry out project planning by taking into account estimation made with 50% probability. Therefore, it is necessary to calculate the completion time of the project with higher probabilities. In the literature, it is seen that the completion time of the project is calculated with high probabilities such as 90%, 95%, 97.5% and

99%. Therefore, in this section, the completion time of the project is calculated with 90%, 95%, 97.5% and 99% probabilities.

In order to find the completion time of the project for different probabilities, it is first necessary to calculate the sum of the variances of the critical activities.

$$\sum \sigma^2 = 35.09 \tag{9}$$

In order to be able to calculate with Eq. 9, the sum of the standard deviations of the critical activities is needed. By taking the square root of the calculated variance, the standard deviation of critical activities was found to be 5.92. Table 5 was created by calculating the completion times of the project for different possibilities.

Table 5. Project completion time for different possibilities.

Probability	**Completion Time**
%50	252
%90	259.6
%95	261.7
%97.5	263.6
%99	265.8

When Table 5 is examined, it is seen that the completion time of the project increases as the probability value increases. The reason for this increase is taking into account the fact that all activities were carried out in the pessimistic period. As a result, the project will be completed in 265.8 hours with 99% probability. In this case, it is seen that there is a 15.8 hour deviation between the completion time found by the CPM method and the 99% probability completion time found by the PERT method. However, in the project planning applied for the first time, the workers doing that job for the first time, the disruptions in the supply of materials, unexpected machine downtimes, malfunctions, etc. Due to reasons, there may be changes in the operating times. With the calculations made with the PERT method, more realistic results are obtained for real life problems. Therefore, it would be

more appropriate to plan the project according to the times obtained in the PERT method.

5. CONCLUSION

Project management is the process of managing time, cost, resources, etc., in order to achieve the targeted goal in the project. The use of resources and costs at the right time and in the right place is possible by establishing an effective project management. In order for the projects to be concluded successfully and to reach the determined targets, the project must be managed successfully. Defence industry projects are of great importance for both Turkey and the whole world.

Defence industry projects are among the most important factors that will increase the success of countries in the field of defence. Countries are investing heavily in defence industry projects in order to be a deterrent against their enemies by increasing their defence power. The success of defence industry projects is of great importance for the defence of the country. Therefore, defence industry projects need to be planned and managed effectively. In the literature review, it has been determined that there are studies on the planning and scheduling of projects in different sectors, but there has been no study on the planning of projects in the defence industry sector before. Therefore, in this study, the project planning process for a newly developed project of a company working in the defence industry sector was examined.

In the study, first of all, the activities, predecessor relations and activity durations of the project were defined. The network of the project was created by taking into account the precedence relations between the activities. Afterwards, the completion times of the project were calculated using CPM and PERT methods. As a result of the calculations made with the CPM method, it was found that the project could be completed within 250 hours. As a result of the calculations made with the PERT method, it was found that the project could be completed in 252 hours with 50% probability. Afterwards, the completion times of the project were calculated under different probabilities using the PERT method. As a result of the calculations, it has been determined that the completion time of the project increases as the probability values increase.

When the calculations made with CPM and PERT methods are compared, it is seen that there is a 2-hour deviation between them. This is due to the fact that calculations are made in the CPM method under the assumption that the activity durations are deterministic, while in the PERT method, the calculations are made by considering 3 different activity periods of the activities: optimistic, pessimistic and probable duration. When the studies in the literature are examined, it is seen that better results are achieved with the calculations made with the CPM method. However, since the projects made for the first time contain uncertainty, there may be variability in the activity periods. The estimations made according to the results obtained by the PERT method, which takes into account the variability in the activity periods, are more consistent for the completion times of the projects encountered in real life. Therefore, using the PERT method in scheduling the projects for the first time and planning the project accordingly will be effective in the success of the project.

In this study, CPM and PERT methods were used to calculate the completion time of a project developed for the defence industry and the results were compared. The variability in the activity period of the project, which was carried out for the first time in the study, was taken into account with the PERT method and calculations were made. In the literature, it is seen that fuzzy CPM and fuzzy PERT methods are also used in calculating the completion time of the project in order to take into account the variability in the activity times. In future studies, the completion times of the projects can be calculated and compared between them by using fuzzy CPM and fuzzy PERT methods. Also, taking into account the assumption that the activity times are stochastic, the completion times of the project can be calculated.

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

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