ISTANBUL BILGI UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
BANKING AND FINANCE MASTER PROGRAM

PROJECT MANAGEMENT AND A CASE STUDY FOR A START-UP COMPANY

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ISTANBUL
2017

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PROJE YÖNETİMİ VE BİR START-UP İÇİN ÖRNEK UYGULAMA

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Approval Date: 03.07.2017

Total Number of Pages: 97

Key Words (English)	**Key Words (Turkish)**
1) Project Management	1) Proje Yönetimi
2) Gantt Chart	2) Gantt Şeması
3) CPM	3) CPM
4) PERT	4) PERT
5) Start-up Companies	5) Start-up Şirketler

PREFACE

I would like to express my sincere gratitude to my supervisor Yrd. Doç. Dr. Genco Fas. Without his advice and unique support this thesis would never had become a reality. I wish to express my greatest thanks to Deniz Güney Akkor and Gözde Kurusoy for their support, patience and understanding.

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LIST OF ABBREVIATIONS

PMI	: Project Management Institute
PMBOK	: Project Management Body of Knowledge
US	: United States
AACE	: American Association of Cost Engineers
CPM	: Critical Path Management
PERT	: Program Evaluation Review Technique
WBS	: Work Breakdown Structure
IPMA	: International Project Management Association
CAPM	: Certified Associate in Project Management
PMP	: Project Management Professional
CCTA	: Central Computing and Telecommunications Agency
TOC	: Theory of Constraints
EVM	: Earned Value Management
PRINCE	: Published Projects in Controlled Environment
IT	: Information Technology
ANSI	: American National Standards Institute
IEEE	: Institute of Electrical Electronics Engineers
OGC	: Office of Government Commerce

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ABSTRACT

This thesis aims to analyze the essentials of project management and present more feasible and more useful techniques to reach specific goals and objectives for a project. A project is a chain of organized activities to reach pre-determined results. Project management is the function of planning, managing and controlling resources such as people, tools and materials so that the project can be realized in the most efficient way considering the limited time, cost and technical situations.

Today, project management techniques are essential so that the strategic goals and objectives of the projects can be realized at optimum time and optimum cost. Therefore, project management techniques such as PERT and CPM are frequently used in project management. Project management is substantial for both active companies and newly established companies. Large-scale enterprises with complex problems and complicated processes can achieve their goals with project management more clearly and easily. On the other hand, for newly established companies or companies that are in establishment phase, a well-planned project management will annihilate the uncertainties in the projects because it can see the problems that can occur before they start to the project and they can take precautions accordingly.

ÖZET

Bu tez, bir proje için belirli hedeflere ulaşmak için proje yönetiminin temellerini analiz etmeyi ve daha uygulanabilir ve kullanışlı teknikler sunmayı amaçlamaktadır. Proje, önceden belirlenmiş sonuçlara ulaşmak için yapılandırılmış bir faaliyet zinciridir. Proje yönetimi, sınırlı zaman, maliyet ve teknik durumlar göz önünde bulundurularak projenin en etkin şekilde gerçekleştirilebilmesi için, insanlar, araçlar ve malzemeler gibi kaynakların planlanması, yönetilmesi ve denetlenmesi yöntemidir.

Günümüzde oldukça gerekli olan proje yönetimi teknikleri projelerin stratejik hedefleri ve hedefleri, optimum zaman ve optimum maliyetle gerçekleştirilmesini mümkün kılar. Bu nedenle, PERT ve CPM gibi proje yönetim teknikleri, proje yönetiminde sıklıkla kullanılmaktadır. Proje yönetimi hem aktif şirketler hem de yeni kurulan şirketler için oldukça önemlidir. Karmaşık problemlere ve karmaşık süreçlere sahip büyük ölçekli işletmeler hedeflerine proje yönetimi ile daha açık ve kolay bir şekilde ulaşabilirler. Öte yandan, yeni kurulan şirketler veya kuruluş aşamasındaki şirketler için iyi planlanmış bir proje yönetimi, projelere başlamadan önce oluşabilecek sorunları ön görebildiğinden projedeki belirsizliklerin ortadan kaldırılmasını ve buna göre önlemlerin alınabilmesini olanaklı kılar.

INTRODUCTION

Along with globalization, there are greater challenges and needs more than ever. Managing more and more complex projects has become increasingly tough. The projects now involve more partners, interaction and team members, and are carried out across the intercontinental range as they become available. The world is changing and accordingly the techniques and methodologies used in project management have to be changed with minor refinements. Undoubtedly, as we face new challenges that push our boundaries, new techniques and better practices will emerge to solve these problems.

People can have the capacity of foreseeing the future, determining alternatives per possible developments and creating the future. The increase in reachability and accessibility has brought competition to an unprecedented level in human history. In these times of rapid transformation, we need to align project-oriented thinking, behavior and business forms with project expectations to direct the process we are in and to shape the future in the direction of our own will.

Businesses should be able to manage and use their resources effectively and efficiently to achieve their goals and objectives. In projects that have limited activities in terms of time and cost can be achieved only with efficient planning, use and management of resources. From past to present, people have always carried out their activities within a plan to achieve their goals and have succeeded in this way. It can be said that similar implementations also apply to businesses. Project management is a management system that reduces uncertainties to minimum and analyses all the outputs of project down to the last detail. Project management will also help businesses make decisions for the unexpected situations. Project management techniques will shed light on large-scale projects with these features, as well as uncertainty over the initial stages of new investments.

This thesis which covers project management techniques and model consists three main parts. In the first part, general information and historical development of the project management concept including classification of projects and stages of project management will be given. The second part will cover project management techniques with details. The last chapter will cover a case study for a start-up company.

CHAPTER I

PROJECT MANAGEMENT

1.1. CONCEPT OF PROJECT

The project is the transformation of an idea into a life. It is the series of activities that are directly related to each other and can be realized independently of others by specific resources in a certain time and plan direction.

Projects carry out within a specific plan that has certain characteristics. It is an initiative to create a unique product or service. With a certain purpose, a project must have start and end times; otherwise it can be considered as an operation. At this point it is important to make the distinction between project and operation.

Project	**Operation**
Performed by limited number of sources (man, machine, software, etc.)	Performed by limited number of sources (man, machine, software, etc.)
One-off event	Permanency
Not specified or defined activity	Specified or defined activity
Not done before	May have been done before and the possibility of repeating
Cannot be done in same way, later	
Develops over time	Repeated by changing a little or never changes
Totally new	

Table 1: Difference between Project and Operation

There are ongoing operations and projects in every organization. A project is the whole set of methods which are created for a purpose and aims to reach the targeted result in a certain time. However, operation is the implementation of a project into the field or business.

Activities	Immediate Prerequisites	Activity Duration (Days)
A	-	5
B	-	4
C	-	2
D	B,C	2
E	A	4
F	-	5
G	E,F	3
H	D	6
I	F,H	4

Table 2: Sample Project

According to Table 2, the activities are assigned with short labels to make it simple the referring. As seen on the table, some activities such as (A), (B), (C) and (F) do not have any prerequisite activities.

The characteristics of the project can be listed as follows:

- Projects are the result of a need and aim to meet this need. In projects, problems are transformed into goals, goals are transformed into activities.
- In the projects; the environment in which the project is located, the mass of the product / service offered, the public authority, financing institutions and environmental conditions are elaborated.
- Project must be unique.
- Specific time frame. There must be certain start and end time.

- Project contains limited resources.
- The project must be planned in advance.
- Certain resources and budget are needed.
- It should be assessable and evaluation criteria should be determined at the beginning of the project.
- The results obtained from the project should be obvious to a user or customer.
- A project should contain people and manpower. (Heytworth, 2002)

1.2. CLASSIFICATION OF PROJECTS

In general projects can be classified by their size, executive bodies, purpose, by their contribution to their production, the sector and qualifications of the goods and services they produce. In this scope, the projects can be classified as follows;

- In terms of size: Projects can be classified as large, medium and small-scale projects.
- In terms of executing: Projects are divided into public and private sector projects and mixed projects.
- In terms of purpose: Projects are reviewed under three headings; profit-oriented, non-profit-oriented and research projects.
- In terms of contribution to production: Projects can be classified as infrastructure projects and reproductive projects. The infrastructure projects include economic based projects such as highways, railways, airports and port projects; and social infrastructure projects such as education, health, housing projects.

- In terms of sector: Projects can be categorized as sector-based such as agricultural projects, manufacturing industry, transportation-communication, mining, education, health projects or sub-sector based such as food, textile, roadway, railway and airway.
- In terms of quality: Projects can be classified under 7 headings; survey projects, new investment projects, renewal projects, capacity building projects, completion projects, improvement projects and research and development projects. (Spinner, 1997)

1.3. CONCEPT OF PROJECT MANAGEMENT

The project is the transformation of an idea into the life and starts with the willingness of people to design and apply a certain idea in their minds, and ends with the realization of this idea but each idea cannot be positioned as a project. A project has certain characteristics including start and end points and a certain purpose.

Project management is the implementation of knowledge, skills, tools and techniques in the planning and management of project activities to meet partners' needs and expectations. It enables planning, management and coordination of available resources throughout project life to meet specified objectives, scope, time, and quality and partner satisfaction. Project management consists of inception, planning, execution, monitoring, control and concluding conclude processes and means completing a job at the optimum time and cost and at the targeted quality.

"Project management is a set of principles, methods and techniques for effective planning of objective-oriented work, thereby establishing a sound basis for effective scheduling, controlling and re-planning in the management of programs and projects." (Bakouros and Kelessidis, 2000)

Project management provides an ingenuity plan, organization, implementation and control of activities by using people and resources with necessary tools for an organization.

1.4.HISTORY OF PROJECT MANAGEMENT

Project management has been implemented since the first civilizations of history. According to researches, the Great Pyramid of Giza and the Great Wall of China were the earliest examples of project management. On the other hand, some researchers state that the Manhattan Project which was designed in 1941 to develop the atomic bomb by the United States (US) military forces is another early example of project management.

Modern project management techniques were acquired in the late 19^{th} century with the need of arising complex business forms and vital management principles. Henry Gantt who is the forerunner of project management improved a scheduling diagram in 1917 called Gantt Chart which is still in use today.

In 1956, The American Association of Cost Engineers (AACE) was established by the associated specialties for planning, scheduling, cost estimation, cost and schedule control. This organization was the pioneer for cost estimators, cost engineers, schedulers, project managers and project control specialists. The first integrated processes for portfolio, program total quality management and project management was successfully done.

In 1957, the Critical Path Management (CPM) was invented by the Dupont Corporation. CPM is a technique to estimate the project duration by analyzing which activity sequence has the least amount of flexibility. This method was designed to overcome the complexities of the chemical plants' closure process for maintenance and after solving the problem, to restart the plant.

In 1985, the Program Evaluation Review Technique (PERT) was invented by the United States Department of Defense's US Navy Special Projects Office to develop a mobile underwater submarine ballistic missile project in Cold War Era. The PERT is a method to analyze the relevant tasks to complete the project, in particular to determine how much time is required for each task and the minimum time required completing the whole project.

In 1962, United States Department of Defense built the Work Breakdown Structure (WBS) as a part of ballistic missile project of Polaris mobile submarine. After completion of the project, the structure of business breakdown was published and this structure was enforced to use in similar future projects. WBS which has hierarchical tree structure of deliverables and tasks especially was most widely used by the private sector.

The International Project Management Association (IPMA) was found in 1965 by a group to encourage the use of project management processes and lead the development of the profession. The federation which was formed by approximately 50 local and global project management associations was found in Vienna, Switzerland. After IPMA, five volunteers whose aim was to support science and profession of project management established Project Management Institute (PMI) as a non-profit organization and Articles of Incorporation for PMI was issued. PMI offers two levels of project management certification; Certified Associate in Project Management (CAPM) and Project Management Professional (PMP).

In 1975, PROMTII has been developed as a solution to overcome the usual project budget and time limit, which is the result of the feasibility studies of computer projects. Although having more than one factor is normal, PROMPTII was created to reduce the guesses of computer programs to normal levels. Starting by 1979, United Kingdom Government's Central Computing and Telecommunications Agency (CCTA) used this program for its all information systems.

Frederick Phillips who is an American computer architect, software engineer, and computer scientist wrote a book called The Mythical Man-Month: Essays on Software Engineering. The main idea of the book, known as the Brooks Law "Adding manpower to a late software project makes it later." (Haughey, 2010) According to Brooks Law, adding an extra member to the team creates more need for communication than everyone expects because the level of experience of the team's member is different from each other. However, no matter how experienced they may be, adding an extra team member means extra time, discussing the results for a longer time, and dealing with technical details.

In 1984, a business guru Dr Eliyahu M. Goldratt wrote a book called Theory of Constraints (TOC) which has the main idea of the philosophy on general management that organizations continuously reach the goal. According to this theory, in a manageable project, there are few constraints for success but there will be always constraints in every project. TOC uses "Five Focusing Steps" to define the constraints and tries to analyze them. The method and algorithm used by TOC form the basis of Critical Chain Project Management.

The researchers, Mr. Takeuchi who is an associate professor and Mr. Nonaka, a professor at Hitotsubashi University in Japan introduced Scrum as a new way of project management style. In their study, they created a software development model based on many small teams working intensively and interdependently. Although Scrum was built for the management of software development projects, it is also preferred to manage general projects and programs. (Takeuchi and Nonaka, 1986)

In 1987, the Project Management Body of Knowledge (PMBOK Guide) Published by PMI to standardize the information and practices of project management. PMBOK Guide analyses 42 project operations under 5 categories including initiation, planning, execution, close-out and control processes. The book is the essential tool of project management and became a global standard. (A Guide to the Project Management Body of Knowledge: (PMBOK® guide))

Earned Value Management (EVM) started to be used in the late 1980s and early 1990s by the Undersecretary of Defense for Acquisition and had become an indispensable part of program and supply management. EVM has been using for measuring the project performance and progress by combining scope, time and costs to get accurate estimates of project performance problems.

In 1989, CCTA is a United Kingdom Government Agency, providing computer and telecoms to support the government departments; developed Published Projects in Controlled Environment (PRINCE) to create standard format for all government projects. (Guidelines for Managing Projects) The PRINCE Method came up with a new idea on "assuring progress" by combining the three-different separate but somehow linked perspectives. Due to its hard structure and applicability to only large projects PRINCE was revised in 1996.

The CHAOS report, which has been issuing every 2 years, started to be published in 1994, aim to provide information on project failures in Information Technology (IT) sector with the goal of guiding to increase the success rates and the value of investments in IT by creating more successful projects in the sector.

Originally developed to reduce cost and time overrides in Information System and Information Technology projects, PRINCE has been revised in 1996 to provide a more general and applicable understanding as PRINCE2.

The Critical Chain Project Management, developed by Eliyahu M. Goldratt, is based on the theory of constraints that he described in his 1984 novel "The Goal". The Critical Chain will keep the identified resources in the project network by keeping the resources flexible at the start-up time and making it possible to switch between work packages in the continuation of the project. Thus, the project will be completed in the specified program and date.

PMBOK was accepted as the standard in project management by the American National Standards Institute (ANSI) in 1998 and the following year, the Institute of Electrical Electronics Engineers (IEEE) also accepted it as a standard.

AACE International first introduced the idea of "Total Cost Management Framework" in 1990. Total cost management is the name given by AACE International as long as they apply the knowledge and skills that cost engineering contains. Also, total cost management is the first integrated process and method for portfolio, program and project management.

PMBOK's 4th edition in 2008 maintains a PMI tradition of excellence in project management, providing a practical way to understand and implement the methodology with the coherence and well-explained nature of the areas of knowledge.

Office of Government Commerce (OGC) has made major changes to PRINCE2 in 2009 because the need for easy understanding and internalization in people using PRINCE2 made it difficult to complete the project. In the updated version, there were seven basic principles that were not available in previous versions and would contribute to the success of the project.

The fifth edition of PMBOK, published in December 2012, contains the methodology and roadmap that should be used for project management. In the updated version, 'Project Stakeholder Management' introduces 10 areas of knowledge with the new addition of the information field by including four new planning processes.

1.5. PHASES OF PROJECT MANAGEMENT

Project management process starts with the project preliminary design; continues with planning, execution and control phases; ends with the close-out phase. Project management is a race that takes place over time in response to changing conditions. The process should be supported by correct and effective decisions since it is not a return and rehearsal and this is only possible with a project management that is correctly and effectively designed. According to PMBOK, project management is structured in 5 phases:

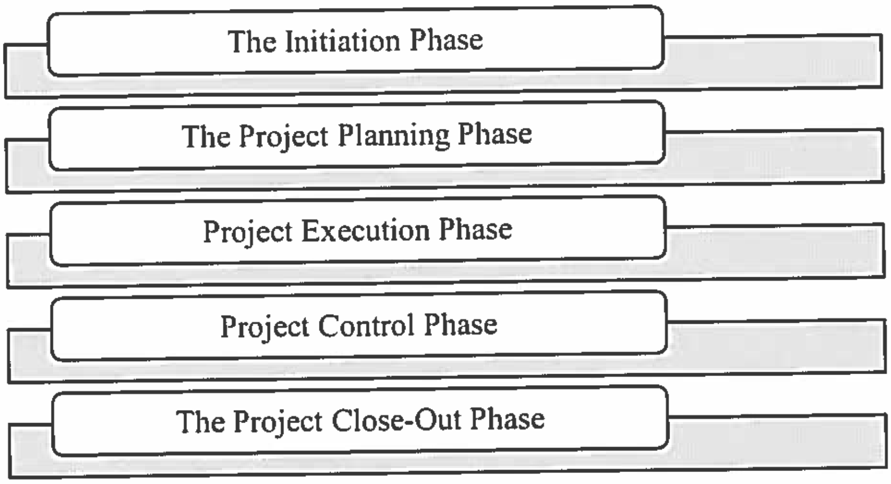


Table 3: Phases of Project Management

1.5.1. The Initiation Phase

The goal is to develop a high-level plan and risk assessment for the project. If the initiation phase is not properly carried out, the project will be less likely to meet the needs of the organization. It is very important to understand the business environment in the beginning and add the necessary controls to the project. Any deficiencies in project design at this stage should be immediately identified and corrected. The emphasis is placed on analysing the urgent needs of the project sponsor in addition to the strategic needs. The initialization phase should include a plan covering the following areas:

- Analyses the organization's needs and requirements according to measurable goals.
- Analyses of current operations.
- Financial analysis of benefits and costs including budget.
- Shareholder analysis including users and support staff.
- A project contract including cost, duties, products and timeline.

Defining the project in an accurate and systematic manner has great importance for a successful project management process. The start-up phase is the first step in getting started in the other phases of the project, including the start and operation of the project. Project initiation phase can also be defined as all of the processes carried out to define this project or phase, with approval to start a new project or a new phase of an existing project (PMI 2008). This stage is the one where the need and the idea are revealed and expressed. The need or idea that emerges can be a new product or service.

There are two important issues that need to be addressed at this phase:

1- To define the project objectives clearly,

2- To organize all necessary resources within the framework of these objectives.

Managers should be very careful when decisions are taken at this stage. The reason for this is that the effects of decisions in the initial phase on time and costs are much important than those in subsequent phases.

1.5.2. The Project Planning Phase

After the initialization phase, the project must be planned to the required level. The planning determines the nature and extent of the project. It helps to understand the necessary work to be done to complete the project, and then to plan the activities to be done in a logical order through graphical representations such as diagrams. These activities include individual activities and the necessary resources.

The main purpose of planning is to estimate the costs and resources required for the project and effectively manage the risks involved during the project implementation.

Errors in the planning phase can cause major obstacles to the success of the project as well as to the initiation phase. The planning phase must be dynamic to guide the work to be done, and avoid detracting from the guidance unless it is absolutely necessary for the project to resist environmental changes. Project plans are as unique as projects; but all plans have some common feature.

- Description: Includes concepts such as project name, description, client / sponsor name, project manager name, output, archive information and terminology.
- Managerial and Technical Approach: Includes concepts such as managerial objectives, controls, risk management, staffing and technical processes.
- Outputs: Includes main task packages, main output and other information.
- Time: This element includes summary calendar, detailed calendar and other information.
- Cost: Includes summary budget, detailed budget and other information.

The planning phase generally includes:

- Determine how to make project planning.
- Improve the scope of the project.
- Form the planning team.
- Define the products to be formed and generate the work breakdown structure.
- Estimate resource requirements for activities.
- Estimate the required time and cost for activities.
- Prepare the timeline.
- Prepare the budget.
- Risk planning.

- Get official approval to start the job.

In addition to these steps; communication planning, identification of roles and responsibilities, identification of purchases for the project and making a commencement meeting can also be included in this phase.

1.5.3. Project Execution Phase

The implementation phase consists of processes intended to meet the project requirements specified in the project management plan. The goal in this phase is to monitor the progress of the project, analyze its performance and find solutions to its problems when the project is over. The execution phase involves coordinating people and resources and at the same time making efforts to bring their activities in line with the project management plan.

An important part of the implementation phase is the drawing of the network, taking into account the priorities and interrelationships of the activities and the creation of the advanced project programming or scheduling in which all necessary activities related to the project are represented by the time graphic. It sets the time parameters of the project and assists the project managers throughout the project in coordination of the entire project team and the efforts made.

Cleland and Lewis list the important points as follows:

- The project should be understandable by the team,
- The project must have the ability to define the critical tasks,
- The necessary innovations and adaptations must be flexible in practice,
- It should provide a basis for managing and evaluating the use of project resources,

- Based on the right time, the appropriateness of resources should be estimated,
- It should be able to comply with other organizational plans that share common resources. (Cleland and Ireland, 2002)

The basic approach throughout implementation techniques is to establish activity networks and relate to graphs that show sequential relationships between tasks in projects. Definitions of the tasks required to be in front of or behind each other should be made explicitly. Such a moment is a powerful tool for project planning and control, and it has these benefits:

- The project provides a solid framework for planning, programming, monitoring and control.
- Demonstrates the commitment of all tasks, workloads and staff.
- Helps ensure proper communication between departments and functions.
- Identifies the expected project identification period, defines critical activities.
- It also identifies heavy walking activities and avoids damages that may arise for delays that may occur at significant times.
- Determine when tasks can start or specify when to start if the project is eligible for the schedule.
- Indicates which tasks need to be coordinated at the source or time conflict.
- It also shows which tasks are to be carried out and the success of the project completion period determined accordingly.
- Clearly avoids some personal conflicts with defined business ties.

1.5.4. The Project Close-Out Phase

All the processes carried out to conclude all the activities in the project are defined as the closing phase of the project (PMI 2008). Closing phase is one of the most overlooked stages in project management. If the point at which the project arrives is acknowledged by the authorities and the controls are decided not to take additional action, the project can now be switched to the closing phase. In the case of the closure of the project, it is also verified that the project is completed properly.

When this stage is completed, it is confirmed that all phases defined for the project have been completed and the project or project phase has been appropriately closed and the project has been officially completed. With the closure of the project or the respective phase, the subsequent flow of the project will now become the sequence of operations. With the completion of the closing phase, the project will put into practice.

1.5.5. The Project Control Phase

In project management, project control can be described as a stand-alone function. The control function is very important in order to support the determined performance and the intended targets. According to the PMBOK, project controls are defined as the following:

"Project controls are the data gathering, management and analytical processes used to predict, understand and constructively influence the time and cost outcomes of a project or program; through the communication of information in formats that assist effective management and decision making."

Project control is data collection, management and analytical processes used to predict, understand and constructively manage the time and cost outcomes of a project. This definition covers all phases of the life cycle of a project analyses the necessities to develop the requirements by understanding the reasons for reflective learning and failures and the initial estimation needed to 'resize' a proposed project.

The project control system consists of the following phases;

Establishment of standards: Including minimum expectations for projects; project plan, determination of the objectives of the project, determination of the targets and strategies, cost of the project, timing, technical features and strategy adaptation. According to Cleland, the key standards are working area, project properties, business review plans, workloads, cost estimates and budgets, main and supporting timing, financial forecasting and monetary plans, quality, the estimation of project owner, the prediction of project team, estimation of supervisors, estimation of foreign investors, reliability, physical properties of work, performance of contractor / subcontractor, project management, innovation, usage or resources and productivity.

Performance Observation: It is necessary to make a good observation to measure the performance of the project which is already expected with the projected performance and to obtain sufficient information. The information needed for project performance can come from different formal or non-formal sources. Formal resources can be listed as reports, briefings, interviews, letters and audit reports; non-formal resources can be listed as rumours circulating within the project team about dialogues, observations and operations. In order to protect the situation of the project, both formal and informal sources of information are needed.

Comparison of Scheduled and Actual Performance: Desired project standards are concerned with answering two fundamental questions about the project: ‘How is the project going?’ and ‘If there is deviation from the project plan, what is the reason of it?' Project case evaluation for project team and senior management is a continuous ongoing responsibility. The information is obtained after the performance of the projects is determined according to the expected performance standards and when it is passed to the final stage of the project control by comparing with the expected performance standards required improvements are made.

Corrective Actions: Re-planning, creating new programs, redistributing resources or managing and organizing the change of the project path.

CHAPTER II

PROJECT MANAGEMENT OVERVIEW

Today, all businesses are involved in many projects. The projects have an important place in change and are in need of modern business life. A large part of the projects involve information technologies and therefore enterprises have to stay close to the latest technology.

Businesses are constantly producing projects as a means of growing up and they try to accomplish these projects. These projects can be categorized as small diameter and large diameter (dam, bridge etc.) projects. Small-scale projects are often projects that do not require expertise and can be easily designed and implemented; but it is not possible to say the same for big projects. Large-scale projects are complex and require high-level expertise, and these projects are difficult to prepare, manage and implement. At the same time, project management and planning are about the project size. It is difficult to manage large projects especially their businesses planning.

At this point, various methods and programs for businesses have been developed such as Gantt chart, CPM and PERT. By means of these methods, the enterprises can have preliminary knowledge about the project by performing source; cost and time analysis before starting the project and thanks to the data to prepare in advance, the project could made and finished in the best way.

In 1917, Henry Gantt (1816-1919) developed the Gantt chart, which was greatly facilitated the creation of the project calendar. This method has been used effectively without much change. Over time, the business world became more complex, making some changes necessary and CPM and PERT methods are improved. These project techniques, which were first used in military field weapon development, have become indispensable tools for industrial projects.

2.1. GANTT CHART

The Gantt chart which is of the oldest project planning and control technique was designed in 1915 by American Henry Gantt to give information about the general appearance and course of a project. It is widely used in the preparation of work programs with its advantage of lean usage. Gantt Charts are also referred to as timeline or milestone diagrams.

The Gantt chart appeals to everyone on a common ground, expressing a popular understanding of project management. The value of this method derives from its ability to manifest important information in an open and concise manner with its simple structure.

The Gantt chart is constructed by determining the start and end dates of the planned and actual periods of each step or process of the project along a time line. In the Gantt chart, the steps are from top to bottom or from left to right. These steps or processes are showed as boxes, lines or symbols. The duration of the process is proportional to the size of the boxes or lines. All of this shows when transactions will start and end and how transactions will be done.

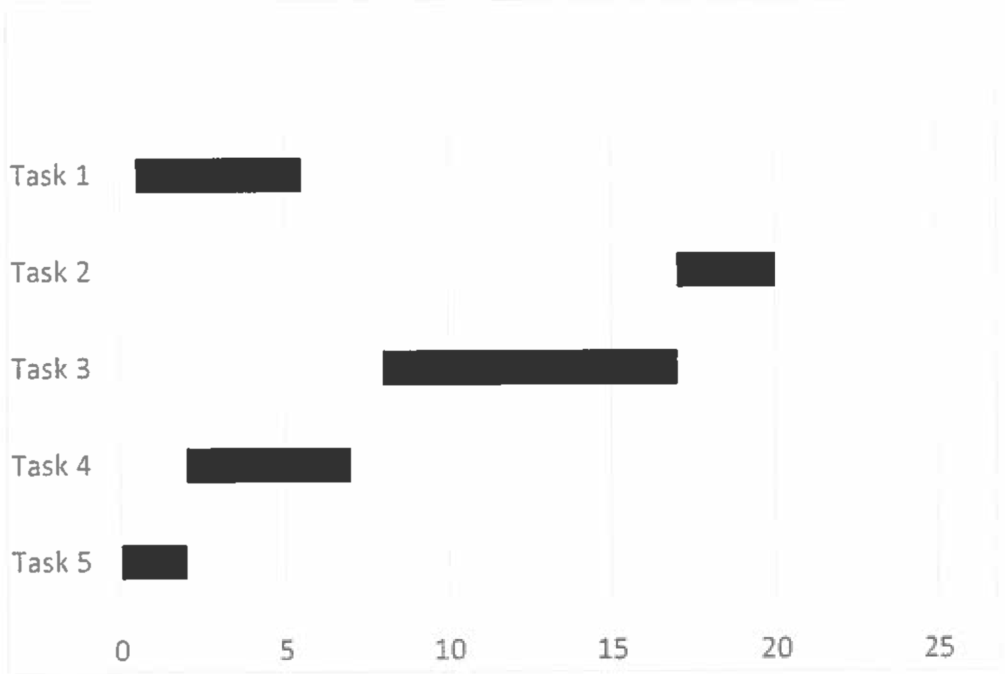


Table 4: Gantt chart Example

Gantt chart has a visual structure showing the activities to be performed. The elements of this structure, while giving the beginning and ending stages of the activity, revealed the relationship between stages and stages of activity. In this way, when the project is considered, it becomes clear that an activity has come to many stages and sub-activities. However, when each activity shows the relationship between its own ranks, the inability to establish inter-activity relations make the Gantt chart inadequate.

For example, a project from three different activities is shown in Table 5. These are (A), (B) and (C) activities. It is clear that the completion of each of the activities (A), (B) and (C) means completion of the project. Also, completion of activity (A) is possible by completion of activities 1 and 2, which are two sub-phases of this activity. Completion of activity (B) in the same manner; 3, 4, 5 activities and completion of (C) activities is possible with the completion of 6, 7, 8 activities.

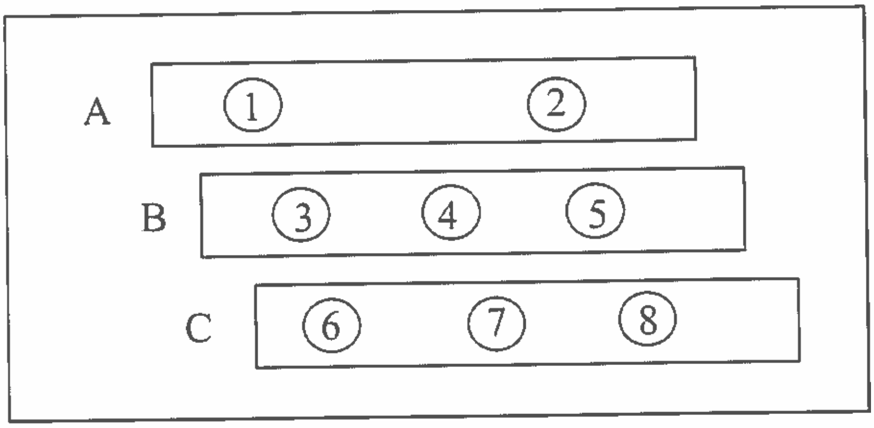


Table 5: Gantt chart Example – 2

As shown in Table 5, activity 2 cannot be started until activity 1 is completed in activity (A). It seems that there is a link between these two activities, as a logical sequence. However, Gantt chart do not provide any information on whether this logical and actual sequence is between (A) – (B) and (B) – (C) activities. This is a major drawback of the Gantt chart.

2.1.1. Methods Used in Creating the Gantt Charts

It is possible to prepare the Gantt diagram in three different ways: the filling method, the block method and the symbol method.

2.1.1.1. Filling Method

In this method, each step of the project is divided into sub processes as it is stated in the first step. In the blocks shown, the letters representing the sub-activity are written according to the end of each sub-activity. In this way, a more detailed monitoring is possible.

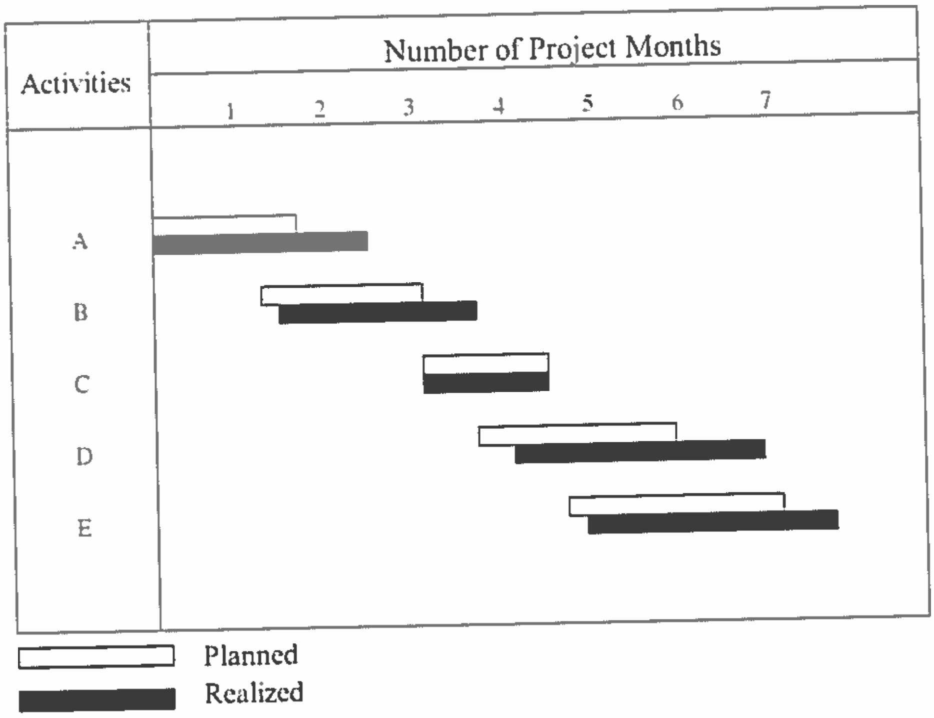


Table 6: Filling Method of Gantt chart

2.1.1.2. Block Method

In this method, the project phases are shown in blocks. Each stage refers to a work schedule that shows planned and actual dates. The Gantt chart is usually used in this format.

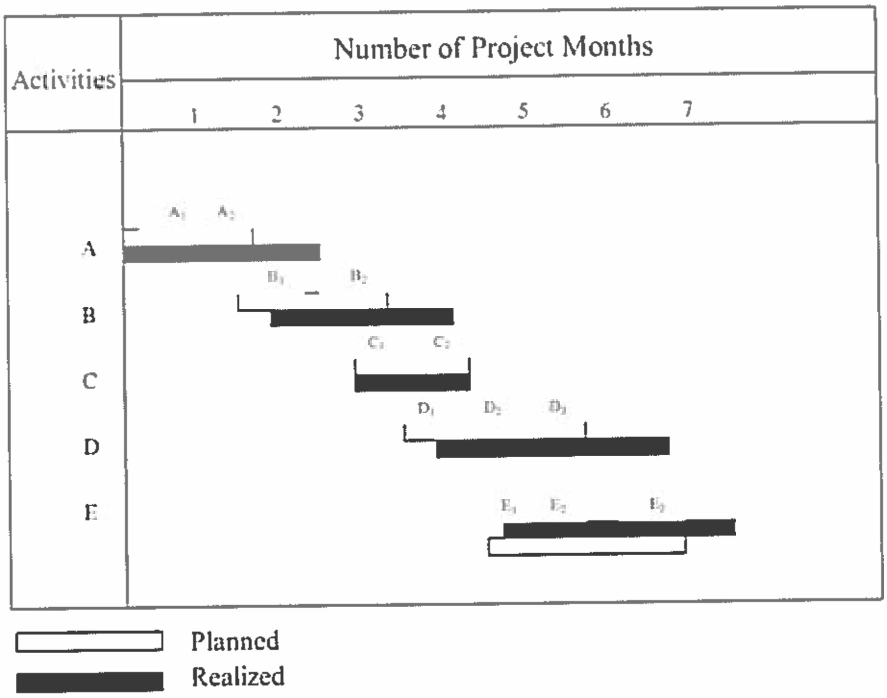


Table 7: Block Method of Gantt chart

2.1.1.3. Symbol Method

In this method, when the Gantt diagram is created, the start and end dates are usually represented by the triangle symbol. The hollow triangles are planned, while the filled triangles are used to show the actual dates.

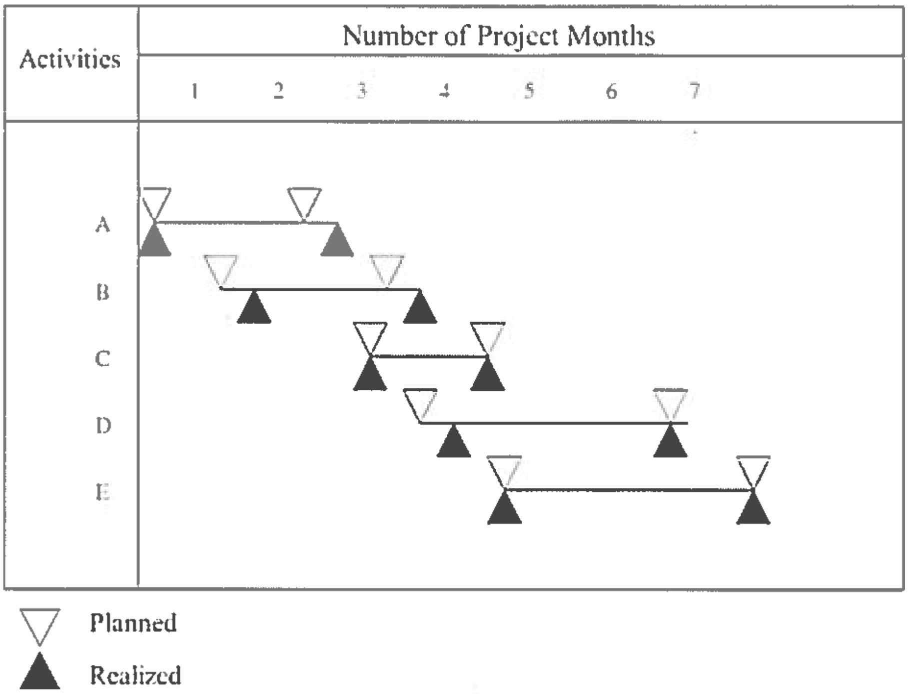


Table 8: Symbol Method of Gantt chart

2.1.2. Advantages and Disadvantages of the Gantt Chart

The Gantt chart is the most appropriate tool to use to describe, track and report small-scale projects involving a small number of employees. However, this vehicle has very limited control mechanism. When it uses properly, it maintains an important advantage which is easily managing time and finding problems and also it can be prepared quickly and easily. However, besides this feature, the Gantt chart is insufficient for extensive projects requiring extensive information and technical skills.

Albayrak listed the inadequacies of the Gantt chart as follows;

- It does not identify weak associations between possible problems and activity steps.

-The activity does not specify how a delay in one of the stages will affect the subsequent stages.

-It does not contain information about critical points.

-It does not coordinate the necessary resources and requirements.

Despite its simplicity and usability, the shortcomings of the Gantt chart are a negative impact for project management. One of the biggest shortcomings of this method is that all logical connections between activities cannot be shown. These diagrams, therefore, do not show how a delay in one phase will affect the other. Besides this, only limited amount of control activities can be carried out the planning. This is just the percentage of completion of the activities in the project. Apart from this, it is not possible to reach the report information such as which activities should be completed on time, the weight of each activity during the project period. In the event of any change in the application of any work, the entire fiction must be drawn from the beginning again.

As a result, bar diagrams are nevertheless extremely simple to use for projects consisting of a limited number of activities with an effective planning, programming, control and reporting tool.

In the historical development of the Gantt diagram, the network method, which forms the basis of the CPM and PERT techniques, had reached.

2.2. NETWORK DIAGRAMS

Network diagrams are events and activities that have underlying relationships. Events occur during streaming so each process starts with an event and ends with an event again. Activities form parts of the project flow. There are also a few non-flow processes. Transactions usually refer to the work to be done.

Figure 1: Graphic Display of Two Activities

The general characteristics of network diagrams can be listed as follows;

- Network diagrams are an overview of the project. The network diagrams show the events and operations, their duration and the sequence and the relationships between them. It consists of flows and transactions where there are many connections between them. It is especially necessary to use it in large-scale projects.
- Network diagrams provide information on how events and processes can be completed by presenting the logic and time of the project flow. They indicate the times and the critical points. They show the planned and actual results of events and transactions. Network diagrams that provide great ease in project planning and management are an important guide for effective project management.
- Network diagrams reveal business relationships between team members. In large-scale projects where two or more processes are executed at the same time, team members' business relationships are rather complex. In such situations, the network diagram is prepared in a more detailed and understandable manner, helping to finish the project on its run.

- Network diagrams are a mathematical model of the project. Describe the length of events and transactions and the need for labour. It reveals what kind of work needs to be done to finish the job and plays a significant role in improving the work flow between the teams. It can also be used in budgeting and scheduling resources and costs.
- Network diagrams have the ability to provide information. It is constantly informed about the changing conditions and the progressive processes and assists in various problems. It acts as a key for changes that need to be made and indicates precautions to be taken.
- Network diagrams are an important tool for project implementation. With this tool, it is possible to monitor the project application in terms of quantity, quality and cost. However, an effective network diagram implementation is required for all these to be monitored. There are also a number of questions that need to be addressed in an effective network diagram application.

The questions can be listed as;

- What are the activities of the project and how should they be ranked among these activities?
- Which of the activities in the project can be carried out simultaneously?
- How long is the time required for each activity in the project?
- What are the constraints in the project?

2.2.1. Main Concepts Used in Network Diagram-Based Methods

- **Project Network:** A graphical representation of the interrelated activities of the project. The activities are organized with respect to the order of arrival before and after each other.

- **Activity (Process):** The smallest unit of the project task that constitutes the project and must be completed within a certain time frame by consuming a certain amount of resources. The activities are represented by arrows in the drawing of the project network. The duration, cost and number of the activity will be indicated by the notes written on the arrow.
- **Node:** A circle or box representation of the operations.
- **Arrow:** A line connects two nodes. Indicates the relationships and priorities between processes. Every arrow has a starting point.
- **Predictive Activity:** Represents the processes or operations that must be completed before a process starts, when the order of the processes in the network diagram is considered.
- **Sequence:** A process or processes that follow an operation in the network diagram.
- **Event:** Activities in the project have points that they need to reach at specified time intervals. This particular point is called the event. Events do not require time and resources like activities. They symbolize a moment that has taken place in a certain period of time as a result of the resource use of the activities. The beginning and end moments of an action is an event. As an event is shown in a circular or elliptical form, the code or significant properties of the event are specified in this mark.

Activities and events on any cellular network diagram is the subject of the formula given below:

$$\text{Number of activity} > (\text{Number of event} - 1) \quad (2.1)$$

Activities on the network diagram are indicated by arrows and events are represented by circles.

- **Dummy Activity:** A process that does not consume time and resources and has a special character in the planning and project process. For example, the beginning and ending processes of the project, or the processes that indicate the beginning or completion of certain stages, are dummy processes that provide the integrity of the project, but have a zero duration, which do not require resource consumption.
- **Continuous Dummy Activity:** Activities that do not require resources but are time consuming. Continuous dummy activities can be shown with normal or dashed lines.
- **Explosion Point:** If several operations have the same priority, this is called the explosion point and subsequent operations cannot start until this operation is completed.
- **Aggregation Point:** If several operations have the same successor (subsequent processing), this is called the aggregation point.
- **Optimistic Time (a):** Indicates when an activity can be performed under the best conditions.
- **Pessimistic Time (b):** Indicates when an activity can be completed under the most adverse conditions.
- **Possible Time (m):** Indicates when an activity can be performed within the delays that may occur under normal operating conditions.

- **Expected Time (te or T_E):** Expresses the expected completion time calculated based on the optimistic, pessimistic and possible time estimation of an activity.
- **Most Early Start Time (T_{ES}):** Specifies the earliest time an activity can start, provided that the activities that occurred before it are completed.
- **Earliest End Time (T_{EF}):** Time value with the earliest start time plus the duration of the activity (or expected time).
- **Latest Start Time (T_{LS}):** It refers to the latest time an activity can start, ensuring that all subsequent activities take place and does not change the project completion time.
- **Last End Time (T_{LF}):** The time value found by adding the duration of activity (or expected time) to the latest start time.
- **Space (S):** The difference between the earliest and latest start times of an activity. The project refers to the period in which an activity can be delayed without delay in project time.

  $$S = T_{LS} - T_{ES} = T_{LF} - T_{EF} \qquad (2.2)$$

- **Critical Path:** The project network has the longest completion period, which is the sequence of activities that determine the project duration.
- **Milestone:** When an activity network is drawn up, various activities and events will be shown linked to one another in a graphic representation. Some of the events are more important than others, and the project shows significant improvements over the various phases. Such events are called milestones or key events. (Heizer and Render, 2001)

Various networking methods have been developed for planning and monitoring the projects. Among these methods, CPM and PERT methods are the most common applications. Both methods are based on the plotting of the programmed task-related tasks on a network or graph and these methods are developed to program long-term projects, both of which will be implemented at different amounts or only once. In PERT, certain durations of activity are assumed while in the CPM, periods of activity are probabilistically defined.

2.2.2. Creating Network Diagrams

A network diagram is a graphical representation of the planned relationships of the activities required to complete the project, using arrows and circles. According to Hamdy A. Taha, it is a demonstration of premise relations and interdependencies among the activities of the project. (Taha, 20017)

The two applications used in establishing the network diagram are as follows;

1) Activity-on-Arrow (A-o-A): It is a method in which activities are shown with arrows and premise and successive activities are shown with circles. In this application, the circles or nodes show the events in symbols and indicate which activity started and finished.

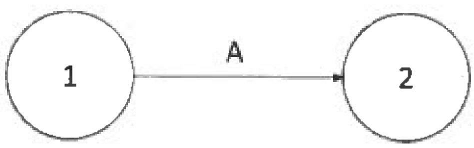


Figure 2: Activity-on-Arrow Display

Characteristics of A-o-A as listed below;

- It is easy to prepare and apply.
- It is generally used in manual operations, but it is also used in some computer software programs.
- Those outside the field of expertise will make the network better understand.
- Milestone events can be easily seen.
- Multiple primitives and subsequent associations can be easily expressed on the network.

2) Activity-on-Node (A-o-N): It is the method in which the project activities are shown with nodes and thus the sequence is specified during the application. Also called Priority Diagram Method.

Most Early Start Time ←	T_{ES}	T_{LS}	→ Latcst Start Time
	Definition of Activity		
	Time	S	→ Most Early Start Timc

Table 9: Activity-on-Node Display

Characteristics of A-o-N as listed below;

- It is easy to show complex activity relationships.
- It is mainly used in computer software programs, including Microsoft Project.
- No puppet activity. There are only those activities on the network, no matter how much activity you have. (Except milestones)
- All information about the activities is found in the node.

Process Display	Time (t)	Work	Name
	+	+	Activity
	+	-	Activity duration
	-	-	Dummy activity

Table 10: Operation in network diagrams

According to Table 10, the "+" sign indicates an increase in the duration or the work done, and the "-" sign indicates no change in the duration or work done.

In order to be able to draw the network diagram, all activities in the project must be defined and the priorities and interrelationships between the activities must be defined. (PMI, 2008)

Points to consider when drawing a network diagram are as follows;

- In the operation of arrows, activities are shown with arrows, events are shown in circle, and arrows indicate the course of action. The length of the arrow does not give any information about the process of the formation of the activities and only shows the relation between the activities. In the action nodes application, the activities arranged according to the priority order are written in the circles or boxes and these circles showing the activities are connected with the arrow. Periods are also written on the activities.
- Each event is indicated by a number, and each activity is usually indicated by a code (such as A, TH1500) or the start and end event numbers of the activity are specified. For easy monitoring of the project, for every activity; it is more useful that the start event number is smaller than the end event number.
- An event can be found in more than one activity's start or end point.

- The start and end events of any two activities cannot be the same. That is, two consecutive events can be directly connected by at least one activity. Dummy activity is required to connect two activities with the same start and end events.
- Critical and non-critical activities are identified.
- Before the drawing of the network diagram, it is necessary to determine what activities are affecting each other in a timely manner, what activities cannot be started without one end, and what activities can be carried out simultaneously in order to be able to determine relations between activities.
- After defining the network diagram, it is important to know how long the project will last, what activities will have a full effect on the project duration, which activities should start at a specific time and again at a certain time, which activities can be started and end at a desired time and it is necessary to determine how much time intervals are allowed to occur.

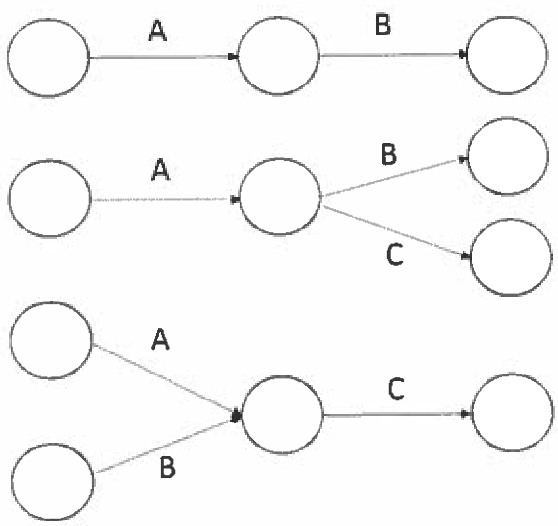


Figure 3: Example of various activities

According to figure 4, wrong situation is shown in the network diagrams. According to right diagram, after figure B completes, and then D starts. After A and B are complete, C operation can start.

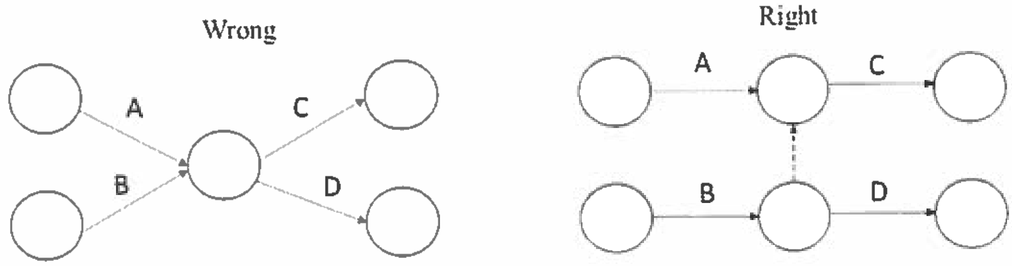


Figure 4: Wrong and right situations in network diagrams

In the projects, this process is a logical network diagram which consists of logical and technical monitoring of each other. The rules that must be obeyed in the preparation of the series can be summarized as follows:

1. Only one operation can be defined between two nodes.

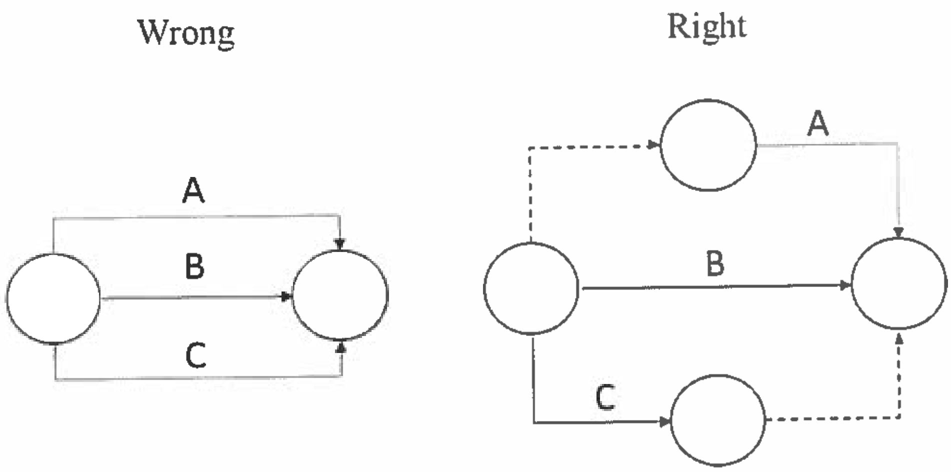


Figure 5: Rule 1 Demonstration

2. Transactions cannot be organized to form a circle.

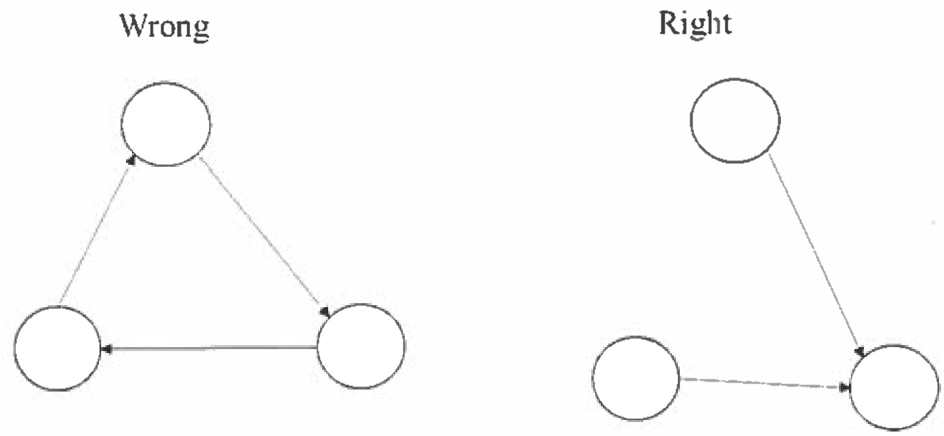


Figure 6: Rule 2 Demonstration

3. There must be only one start node and one end node in the series.

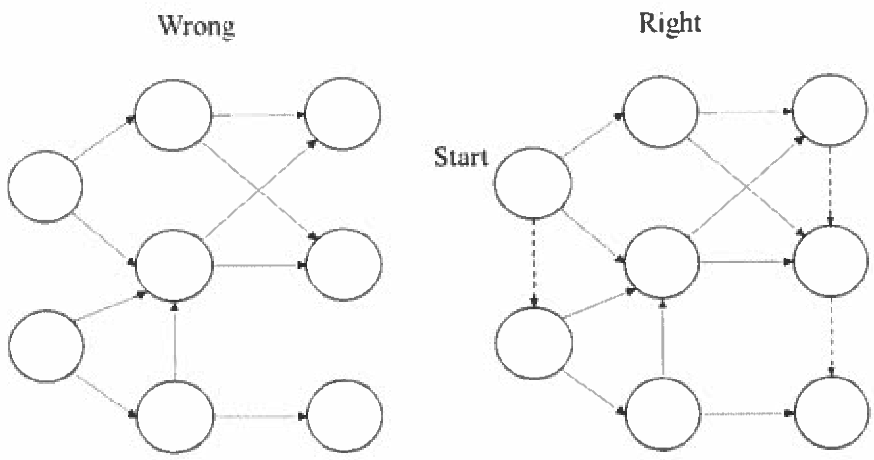


Figure 7: Rule 3 Demonstration

4. When a process from the main stream is converted into a detail stream or sub-stream, the start and end nodes must not conflict with the process end nodes of the main stream.

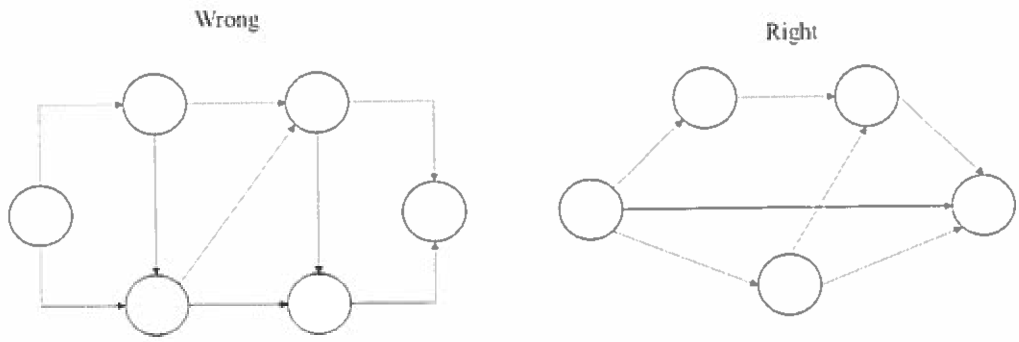


Figure 8: Rule 4 Demonstration

5. Logical mistakes should not be made when relationships are established between processes.

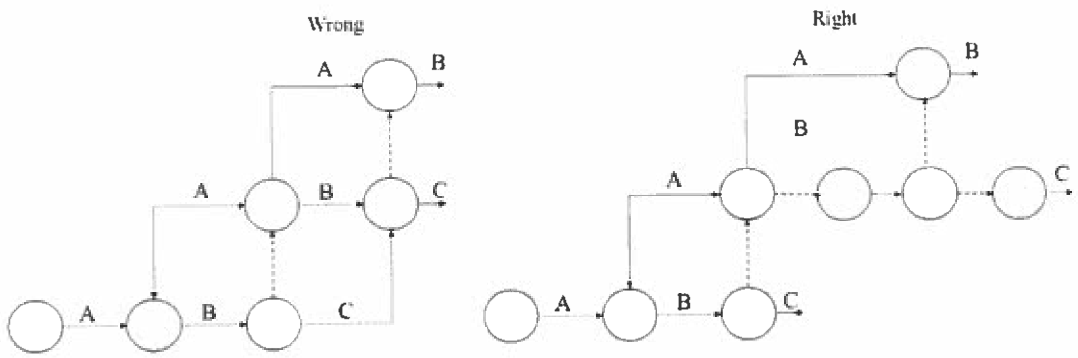


Figure 9: Rule 5 Demonstration

6. The shapes of the arrows do not matter. It can be displayed with straight, curved, or broken lines. The same node numbers should not be processed more than once, but for computer programs, consecutive numbering must be done in the direction of the arrow.

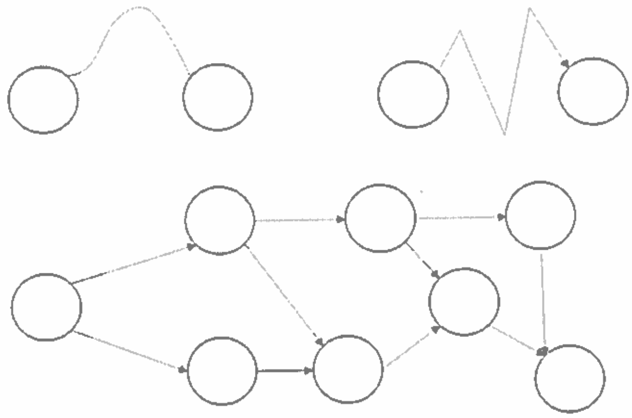


Figure 10: Rule 6 Demonstration

Creation based on transaction relationships. According to the figure 11;

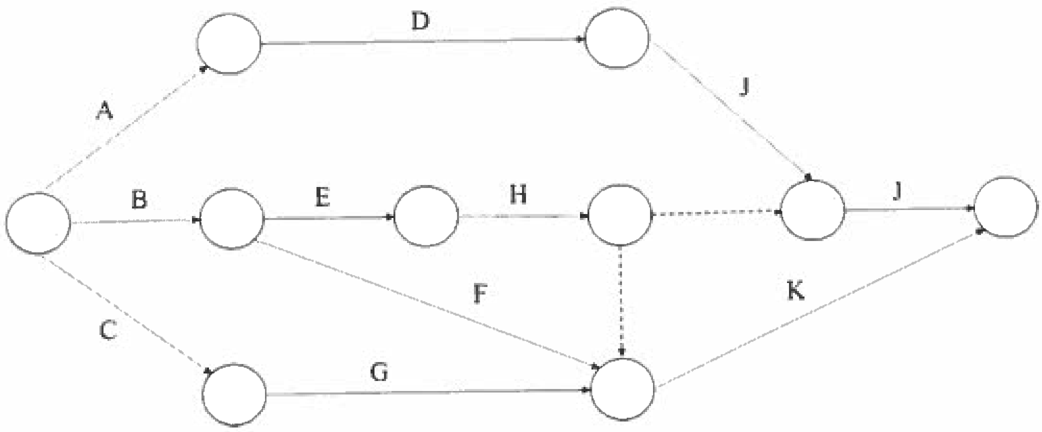


Figure 11: Rule 7 Demonstration

- Operations (A, B, C) are the first operations of the series.
- Operation (A) starts then operation (D); operation (C) starts then operation (G); operation (B) starts then operation (E) and operation (F).
- Operation (I) starts after operation (D), operation (H) starts after operation (E).

- Operations (H, F, and G) should be completed for the start of (K).
- Operation (J) starts after operation (H) and (I) completed.
- (J) and (K) are the last operations of the network.

2.2.3. Sample Network Diagrams

1. The (K) operation begins after (A) and (B) are complete, and the (L) operation begins after (B) and (C) complete.

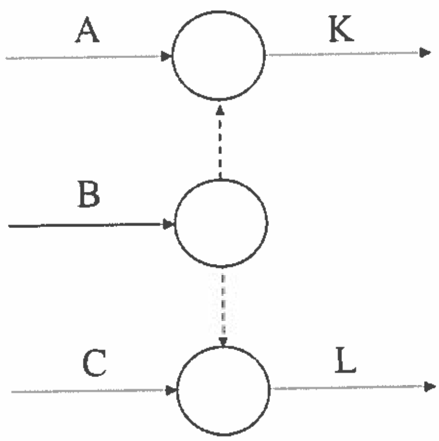


Figure 12: Sample Network Diagram 1

2. The (K) operation will start after (A), the (L) operation after (A), (B), and the (M) operation after (B), (C).

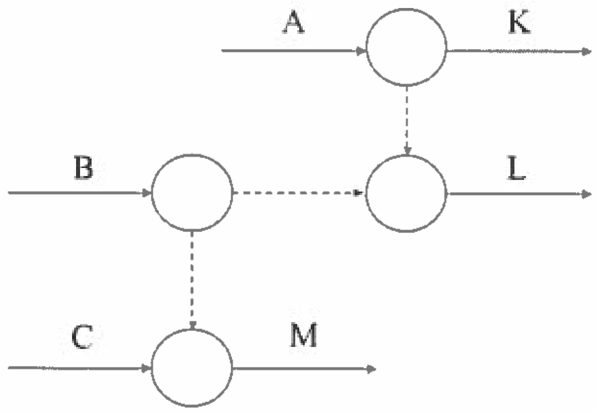


Figure 13: Sample Network Diagram 2

3. The (K) operation will start after (A), the (L) operation after (A), (B), and the (M) operation after (A), (B), (C).

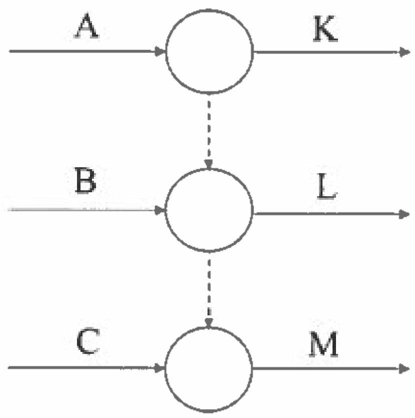


Figure 14: Sample Network Diagram 3

4. Displaying the network with the following connections between operations;
   - (P) is the first operation,
   - (M) and (L) start at the same time after (P),
   - (B), (E) are processes starting at the same time and ending at the same time, starting after (M).

- The (H) operation follows (L), but (M) must be completed to start.
- (G) and (S) are final processes; after (G) starts after (E) and (S) starts after (H).

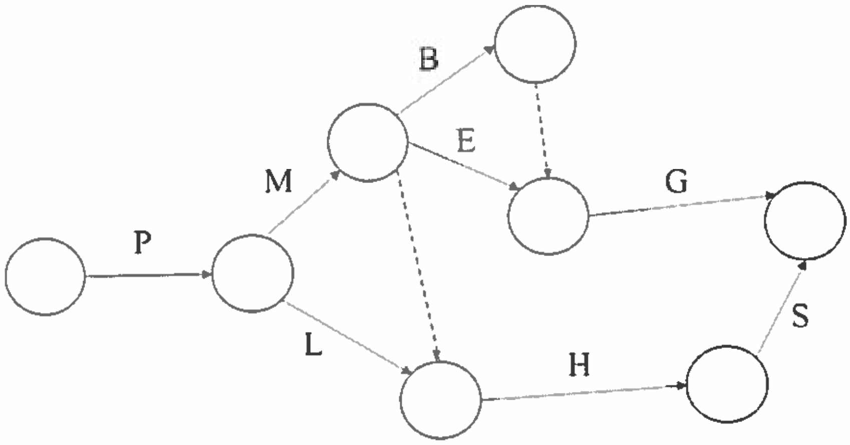


Figure 15: Sample Network Diagram 4

2.3. TRANSITION TO PERT FROM GANTT CHART

The process from Gantt Charts to PERT analysis consists of three steps. Gantt diagram and milestones tables (Significant Events Method) are the pioneers. Initially, only the activities in Gantt and the events that show both the end and beginning of these activities are indicated.

In figure 15, now the PERT tree has emerged. The relationship of the activities with each other is clearly visible in this network.

2.4. CRITICAL PATH METHOD (CPM)

The Critical Path Method (CPM) is now the most widely used networking methods. The reason why the projects generally fail to achieve success is that they cannot provide the time limit. However, the CPM removes this problem. It is a network analysis used without estimating the total duration of the project. This method was developed by J.E.Kelly and M.R.Walker in 1957. (Heizer and Render, 2001)

The purpose of developing this system is to program the stops for maintenance in the chemical plants and to finalize the project as soon as possible. The method is based on the determination of critical activities and the reassignment of resources to these critical activities.

In the CPM system, the time and costs for each activity in the network are specified by two estimates which are normal and crash. Normal time estimation is about finishing the project on time. Crash time estimation is the result of efforts to crash activities by using additional resources. (Meredith and Mantel, 2000). In other words, crash time estimation is costs that are expended to do the job quickly in order to minimize the completion time.

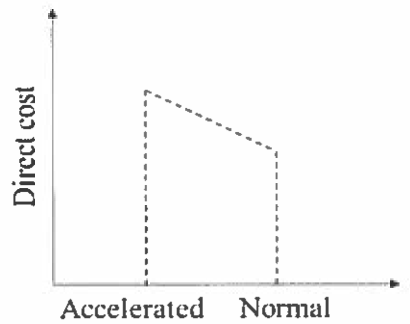


Figure 16: Time and cost relationship in the project

The critical path giving the method name is the series of activities that calculate the shortest completion time for a project. This path includes the longest and the least abundant path along the project network diagram. (Heizer and Render, 2001) Therefore, it indicates the shortest period that the project can be completed. In other words, it is the amount of time between the earliest start and the latest end dates calculated in the project. (Halaç, 1995) Naturally, the abundance will be zero for each activity on the critical path. Determination of the critical pathway is important in terms of controlling.

It is required that project managers should focus on these activities because any delays in the activities on this road will affect the entire project. This flexibility can be achieved by using activities that are not on the critical path. The project manager tries to make the use of labour, financial resources, tools and equipment efficient by adjusting the time of these activities according to the project schedule.

Figure 17 can be a simple example for CPM in terms of project completion times with network drawing and critical path.

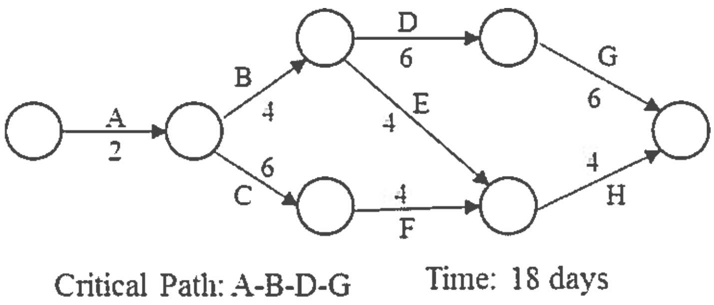


Figure 17: Critical Path on Network and Duration of Project Definition

The following six basic processes must be followed in order for project planning and control with CPM. These are;

1. Determining the activities related to the project and the project,
2. By establishing relations between activities, determining the situation of following each other,

3. Drawing of diagram, which determines the level of relationship between activities,
4. Doing estimation of time and cost for each activity,
5. Finding the critical path that has the most time on the diagram
6. Planning, programming and control operations with the aid of a diagram.

The rules that must be followed during schema drawing are:

1. An activity cannot bind itself before the end of previous activities,
2. The length of the arrows indicating the activity is not important, but the direction is important.

This specifies the priority-to-last relationship of activities relative to each other.

3. Two events can be directly linked to one activity at most,
4. Every event must be a number,
5. There should be a start event and an end event on the diagram. (Render and Stair, 1994)

2.5. CALCULATION OF OPERATING DURATION AND CRITICAL PATH DETERMINATION

There are four periods in the critical path method.

2.5.1. Earliest Start Time (ES): It is the earliest time that an activity in the project can begin. The earliest start times of activities must be small or equal to the earliest starting times of subsequent activities. (Kargül, 1996)

2.5.2. Earliest Finish Time (EF): The earliest time that an activity can be completed. (Render and Stair, 1994)

2.5.3. Latest Finish Time (LF): It indicates the latest end time of an activity in the project. Latest finish time, an activity can be completed at the latest however it does not cause any delay in any activity. (DeGarmo, Sullivan and Canada, 1984)

2.5.4. Latest Start Time (LS): It refers latest start time of an activity in the project (Render ve Stair, 1994).

2.6. CALCULATION METHODS

In order to determine the critical path, it is necessary to know these periods. Two methods are used to determine these times. The first one is the forward calculation method in which the earliest start times are determined and the other is the backward calculation method in which the latest end times of the events are calculated. The critical path and time calculated in the framework of these methods are shown in the table. Here S1, which refers to the idle operation, is used to determine the priority associations.

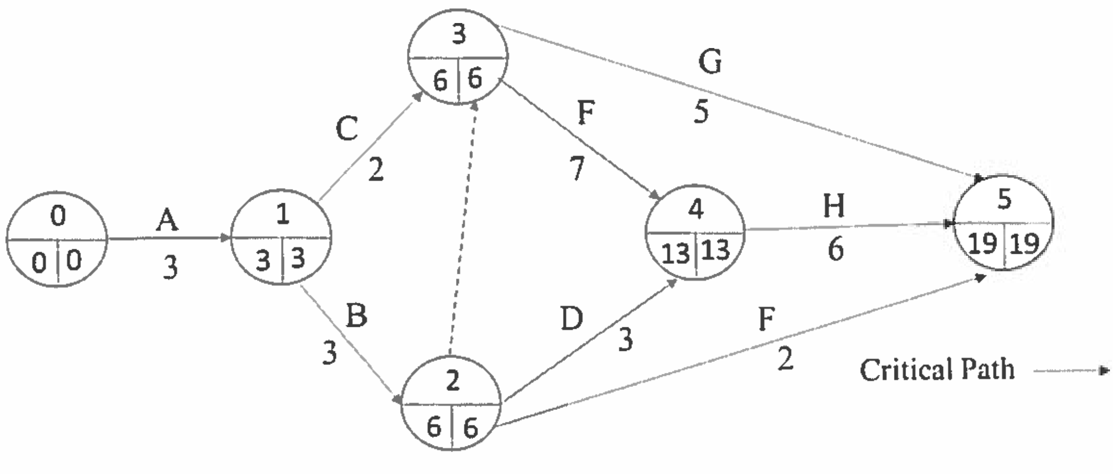


Figure 18: CPM Network

2.6.1. Forward Calculation: The calculation starts from the beginning of the project to the end of the project. In this calculation method, the earliest start times of events and periods are calculated at first. The earliest start times of activities must be small or equal to subsequent activities of the earliest start times. (Kargül, 1996)

Two assumptions are taken into consideration when the earliest start times are found. The first is that the project must start at the earliest zero point, and the second is that each event or process must start after the event or process is completed.

In calculating the earliest start times of the events and processes of the project; the start event of the project is taken as ES = 0 and the earliest start times of all events following the start event are found. For this, the transaction time is added to the early start time of the previous event. (Albayrak, 2009)

There is an important point to note when calculating the earliest start time. The activity being calculated can be linked to more than one activity. In this case, it is necessary to calculate separately for each activity and select the highest value.

In this case, the greatest of the ES_j's is taken, and this is maintained and the final event of the project is reached. (Albayrak, 2009)

ES_i refers to the earliest start time of activities that start with i and t_{ij} denotes the duration of the activity that starts i and j ($i < j$) events. The early start time is shown in the left part of the node point. The following formula applies to the earliest start times of each event in forward calculation.

$$ES_j = \max. (ES_i + t_{ij}) \tag{2.3}$$

The earliest completion time refers to the earliest time that an activity can be completed. The earliest completion time between events i and j is calculated below. (Render and Stair, 1994)

$$EF_{ij} = ES_i + t_{ij} \tag{2.4}$$

The earliest times of events taking from the sample; (Albayrak, 2009)

$ES_0 = ES_0 = 0$

$ES_1 = ES_0 + t_{01} = 0 + 3 = 3$

$ES_2 = ES_1 + t_{12} = 3 + 3 = 6$

$ES_3 = \max. (ES_i + t_{i3}) = \max. (3 + 2, 6 + 0) = 6$

$ES_4 = \max. (ES_i + t_{i4}) = \max. (6 + 3, 6 + 7) = 13$

$$ES_5 = \max. (ES_i + t_{i5}) = \max. (6 + 2, 6 + 5, 13 + 6) = 19 \tag{2.5}$$

2.6.2. Back Forward Calculation: Starting from the last event of the project, the starting event is calculated correctly. In this calculation method, the latest end times of the events and processes of the project are found. For this, ES = LF is taken first for the last event of the project. Secondly, the latest end times of all events are found. Third and finally, the transaction time is subtracted from the latest end time of each event. Here, the results obtained for each event are shown in the right part of the node. (Albayrak, 2009)

There is also a point to note when calculating the time. If there are more than one activity linked to the calculated activity, all of these activities are calculated separately as if they are in the way of going, but this time the smallest value is selected from all these values. The reason is that the same with the forward calculation method. (DeGarmo, Sullivan and Canada, 1984)

The following formula is applied to calculate the latest end times of each event backwards.

$$LF_i = \min. (LF_j - t_{ij}) \quad (2.6)$$

The latest start time is the latest start time of an activity in the project and is calculated using the following formula: (Render and Stair, 1994)

$$LS_{ij} = LF_j - t_{ij} \quad (2.7)$$

For example of figure, the latest end times of the events as below;

$$LF_5 = LF_j = 19$$

$$LF_4 = LF_5 - t_{45} = 19 - 6 = 13$$

$$LF_3 = \min. (LF_j - t3_j) = \min. (19 - 5, 13 - 7) = 6$$

$$LF_2 = \min. (LF_j - t2_j) = \min. (19 - 2, 13 - 3, 6 - 0) = 6$$

$$LF_1 = \min. (LF_j + t1_j) = \min. (19 - 2, 13 - 3, 6 - 0) = 6$$

$$LF_0 = (LF_i - t_{01}) = 3 - 3 = 0 \quad (2.8)$$

From the timings obtained by both methods above (Figure 18), the earliest start times of events are shown in the left part of the node point for each event and the latest end times are shown in the right part of the node point. The critical path of the project is determined by using forward and backward calculation methods. If a process provides the following three conditions, it is on the critical path.

$$ES_i = LF_i$$

$$ES_j = LF_j$$

$$ES_j - ES_i = LF_j - LF_i = t_{ij} \quad (2.9)$$

These three conditions indicate that there is no free trade-off between earliest and latest execution times of transactions. Because the free processes on the critical path are zero. Therefore, transactions whose free periods are zero cannot be delayed. In Figure 18, the above three conditions are critical because (A), (B), (S_1), (F), (H) processes are on the critical path. And the critical path is as (B), (S_1), (F) and (H). (Albayrak, 2009)

2.7. CALCULATION OF ABUNDANCE

The abundance of non-critical activities should be determined after the critical path had identified. Abundance is the period during which activities are delayed. There are four kinds of abundance for activities:

2.7.1. Total Float (TF)

Total Float allows the process to delay the start or completion times for a certain period of time without affecting the completion time.

The total abundance of (i-j) activity is the difference between the maximum duration of this activity and the time required for this activity to take place. It is calculated by the following formula:

$$TF_{ij} = LF_j - ES_i - t_{ij} = LF_j - EF_{ij} = LS_{ij} - ES_i \quad (2.10)$$

2.7.2. Free Float (FF)

It refers to the maximum time that an activity in the project can be extended without affecting the start-up time of the activity (s) following it. It is calculated with the following formula:

$$FF_{ij} = ES_j - ES_i - t_{ij} \quad (2.11)$$

2.7.3. Independent Float (IF)

It refers to the period during which an activity can be delayed without affecting other activities following it even if the there is no delay in previous activities. It is calculated with the following formula: (Sağın, 1974)

$$IF = EF_{ij} - LF_i - t_{ij} \quad (2.12)$$

2.7.4. Intermittent Abundance (AB)

Without affecting the project duration, refers to the longest period that an activity can be postponed. The difference from the total abundance is that it is thought that all activities before the activity are finished at the latest completion time. It is calculated with the following formula:

$$AB = LF_j - LF_i - t_{ij} \quad (2.13)$$

Where abundance is used:

- In calculating when the processes are not critical and flexible,
- To assist in the optimal use of resources such as materials, equipment and expenditure,
- In calculating the optimum investment period,
- To change in processing times, team size or number of teams

Table 11 explains how the abundances of operations are calculated.

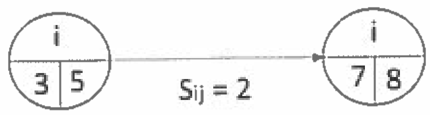
Events and Transaction	Abundance of Transaction
	$Tf_{ij} = LF_j - E_{si} - t_{ij} = (8\text{-}3) - 2 = 3$ $FF_{ij} = E_{sj} - E_{si} - t_{ij} = (7 - 3) - 2 = 2$ $IF = EF_{ij} - LF - t_{ij} = (7 - 5) - 2 = 0$ $AB = LF_j - LF_i - t_{ij} = (8 - 5) - 2 = 1$

Table 11: Calculation of abundances

As in this example, the abundance of all operations are calculate and shown in chart 9, 10, 11 and 12 columns.

This chart contains all the information about critical path calculations and time analysis. The critical path is the path that minimizes the total amount of events and operations. The total abundance of transactions on the critical path must be zero. When the total abundance is zero, the free time must be zero. In some cases, a non-critical operation may also have zero abundance. In the example of Figure 18, CPM Network, TF = FF is found because all events are on the critical path of the project. This feature is not always true. In general, the free share is smaller than or equal to total share.

Previous Event	Next Event	Transaction	Time	Earliest		Latest		TF	FF	IF	AB
				ES_i	EF_{ij}	LS_{ij}	LF_j				
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
0	1	A	3	0	3	0	3	0*	0*	0	0
1	2	B	3	3	6	3	6	0*	0*	0	0
1	3	C	2	3	5	4	6	1	1	1	1
2	4	D	3	6	9	10	13	4	4	4	4
2	5	E	2	6	8	17	19	11	11	11	11
3	4	F	7	6	13	6	13	0*	0	0	0
3	5	G	5	6	11	14	19	8	8	8	8
4	5	H	6	13	19	13	19	0*	0	0	0

***Critical Transaction**

Table 12: Events and Transaction Times

2.8. ADVANTAGES AND DISADVANTAGES OF CPM

The CPM technique specifies what activities should be undertaken firstly in the project management, planning, programming and control process. With CPM, it is ensured that the earliest start time and latest completion time of the project activities are known. CPM determines the total time the project can be completed, by this way it allows some unnecessary activity to be removed from the project and create significant savings in project costs. Prior knowledge of free times regarding project activities also affects project planning and control positively. (Barutçugil, 2008)

CPM is not only a widely used method, but also the use of this method does not mean that the project is planned in the best possible way. In this method, the slightest error could be made during drawing of network is reflected towards whole project. It is impossible to determine the activity relations and the order of the project through a program.

Therefore, the necessary information for network installation should be determined by highly experienced and knowledgeable people. As the number of activities included in the CPM-generated networks increases, the complexity of the project will increase and the preparation period will also prolong. (Kargül, 1996)

2.9. PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT)

2.9.1. An Overview of PERT

In 1958, the US Navy or the United States Navy Special Projects Department and the Booz, Allen & Hamilton consulting firm were thought to develop an advanced methodology for the management of the Polaris missile project. The Polaris project was the first to produce a nuclear-powered submarine capable of guided missiles. The presence of some 3,000 subcontractors who made various parts of the submarine was one of the factors that made the administration of the project difficult. The PERT method was used for the first time in this project.

While it is thought that the most important problem in the first feasibility studies related to Polaris Project will come out in the technical fields,

It is understood that the problem will arise not in the technical issues but in the areas of planning, coordination and control of the resources.

Polaris project Was able to be completed approximately 2 years earlier than originally scheduled due to PERT, which was developed to avoid possible problems that might prevent the project (for example, if a department could not perform assigned tasks, the necessary raw materials and equipment cannot be shipped within the specified period) and to anticipate when the targets will arrive. In short, PERT is the most popular project management technique in the planning and control stages of large scale, complex structured projects with CPM.

PERT is a method that minimizes production delays, plugging, and the various conflicts in the project and runs the various parts of the project together and provides a regular coordination between them. PERT accelerates the completion of projects. PERT can be thought of as a method that gives the opportunity to think timely on various problems and find solutions because it shows the positive and negative developments used in planning and budgeting the existing resources in order to finish a difficult job or project on time. It is understood from this, PERT is a guiding and informative method. However, it does not solve the problems in any way, but it provides solutions or best alternatives to the manager.

The PERT method is broader in scope than the critical trajectory method, since it allows processes that are not fully known to be considered in the program.

The critical path method (CPM) is one of the special cases of the PERT method.

2.9.2. Completion Times of Activities

It is accepted that the completion times of all the activities that constitute the network in CPM are known precisely. Especially in the projects implemented for the first time, the completion periods of the activities forming the network cannot be known precisely, so the duration of the activities in the project is not deterministic. In such cases, PERT technology should be used instead of CPM.

In PERT operations are executed with not by the completion times of the activities, but by their expected values. In other words, it is assumed that the periods of activity are random variables and they emerge according to a probability distribution. The expected completion time of any activity means that the time the activity will be completed with 50% probability means. That is, while PERT analysis determines the duration of activities; probability calculations are used to reflect the effects of uncertainties and the chance factor on the activities. There are three different types of activity durations for each activity, the most optimistic, the most pessimistic and the most likely to be used in this probability calculation.

These types of time are;

- The Most Optimistic Time (a): It can be achieved under appropriate conditions.
- The Pessimistic Time (b): It can be realized under adverse conditions.
- The Most Possible Time (m): Under normal circumstances, it can be realized.

As a result of the mathematical and statistical calculations made using these time estimates, the probability of occurrence of each process within the estimated time can be determined. As each estimate of the operations is shown below it must be between (a) and (b). Accordingly, the distribution range of the estimation values is b-a '.

The most probable duration (m) does not have to be equal to the median (a + b) / 2 of the distribution. (m) It may be on the right or left of the middle. Because of this feature, the average of process (S), end points a, b, and top point m, can be calculated with Beta distribution.

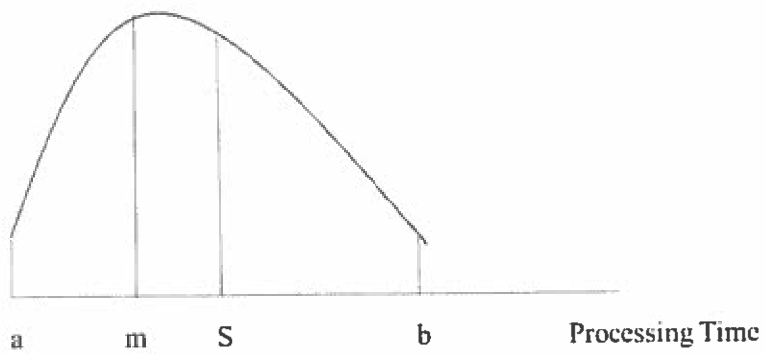


Figure 19: Beta Curve

Accordingly periods of activity;

a: The Most Optimistic Time

b: The Pessimistic Time

m: The Most Possible Time

S: Average Time

The average time can be expressed by the following formula;

$$S = \frac{a+b+4m}{6} \tag{2.14}$$

In this function, the average value at the limit of ±3σ must be 99.7%. Then, in the Beta distribution, the variance of the distribution can be calculated by the following formula, since the mean processing time is S, the variance is $V = \sigma^2$ and the value of the standard deviation is $\sigma = (b-a) / 6$;

$$V = \left[\frac{b-a}{6}\right]^2 \tag{2.15}$$

In this calculation, if V> 1, the degree of uncertainty is high. In this case, optimistic and pessimistic estimates are very different. If V <1, the uncertainty level is low. So optimistic and pessimistic estimates are not much different. (Albayrak, 2009)

It is evident from this that, as the difference between the most optimistic and the most pessimistic time grows; the standard deviation and variance will grow. The growth of standard deviation of an activity means that it will increase at risk.

2.9.3. Determination of Critical Path and Calculation of Project Completion Period

The critical path can be found after the standard deviations of the activities in all the roads going from the beginning to the end of the PERT project are calculated. And the sum of the standard deviations of activities on the critical path gives us the standard deviation of the project. At the same time the standard deviation of a project can be calculated by the following formula:

$$\sigma_p = \left[\frac{b-a}{6}\right]^2 \tag{2.16}$$

Once the standard deviation of the project has been calculated, the likelihood of completion of the project at a desired date can be found using the formula:

$$Z = \frac{T - Tp}{\sigma p} \tag{2.17}$$

T = End time of the project being tested

T_p = Duration of completion of the project

σ_p = Standard deviation of the project

2.10. ADVANTAGES AND DISADVANTAGES OF PERT

PERT provides a consistent framework for many phases of project management, primarily programming and control. The conceptual structure is clear and does not require complex mathematical knowledge. The graphical representation of the project network makes it easy to grasp the relationships between activities. Critical path and space analysis facilitates the identification of activities that need to be closely monitored. It ensures that project completion times can be calculated at a certain time. It determines the start and end times of the activities so that the project can run and finish without delay. The created project networks constitute a useful project documentation structure and enable the visibility of the responsibilities of the various activities in the graphical structure. It provides an appropriate communication environment between the project participants and the authorities concerned. It can be applied to a wide variety of projects and industries. It is also useful not only in monitoring programs, but also in monitoring costs.

However, there are some drawbacks about PERT. In addition to not having much disadvantage, the PERT method is a project management method that requires high attention. At PERT, project activities should be clearly defined, independent and decisive. Priorities and subsequent associations between activities should be identified and placed together in a network. Time estimates tend to be subjective and therefore difficult to determine by managers who may be overly optimistic or pessimistic. There is a possibility that too much attention will be concentrated on the critical path, but it is necessary to closely monitor the paths close to the critical path.

CHAPTER III

PROJECT MANAGEMENT IN START – UP COMPANY FOUNDATION

3.1. PROJECT MANAGEMENT PRACTICES IN TURKEY

Project management system with a rather old history in abroad, was started to be used in the 1960s in Turkey due to the necessities that the projects carried out by the World Bank loans are required to be prepared with network diagrams. The increasing competition and the complexity of projects with the opening of Turkish companies to foreign markets in the 1970s caused the project management system to be implemented gradually.

Project management system is implemented in Turkey and there are successfully completed projects in terms of time, quality and cost management, but due to the situation of the sectors, most firms consider project management as an additional cost. For this reason, apart from some companies operating in international projects, project management cannot be implemented systematically.

When the project management system is compared with other countries, it can be said that Turkey is still developing in this area. Cooperation between the sector and the state has not yet reached the desired level. The profit-oriented nature, the backwardness of the quality, the desire to acquire profits, the one-bossed or inward-looking structure of family companies have adversely affected the development of project management.

3.2. WHAT IS START-UP?

The start-up storm that emerged after the crisis of 2008 and which is supporting the new generation of entrepreneurs -the exit point in Turkey is rather late and behind the United States- is running fast all around the world. The concept of start-up is defined as "work or process to move something" or "new enterprise". Dictionaries define the concept of start-up as "the beginning, the term used for a company that starts at zero point."

Many people in the industry say that start-ups depend on the age, size, profitability and stability of the company, but the debate has been ongoing for a long time. Steve Blank, who teaches at Stanford, defines start-up as a "structure built to find a scalable and repeatable business model," while Warby Parker's co-CEO Neil Blumental, like Blank, defines as "Start-up is a company that tries to find an answer where the solution is certain, the success is not guaranteed".

The first question to ask when looking at the start-ups is: "Is every initiative a 'new venture'?" Can a new café, bookstore or restaurant, or any establishment be considered as the start-up? The experts who do not agree with the definition of start-up at least agree on this. One of the features that an operating system must have in order to be considered a start-up is "growth ability".

Paul Graham, one of the founders of Y Combinator, who supports the start-ups who are striving for baby steps, says scalability is the most important feature that distinguishes start-ups and any other business entering the market. Graham says the start-ups are "companies designed to grow fast." Graham uses the following statements about start-ups and the difference between newly established companies: "If all the companies were basically the same, but some of them grew faster because of the extra effort of the luck or the builders, we did not hear. We were just talking about very successful companies and fewer successes. But what's actually happening is that start-ups have different DNAs than other initiatives. Google was not a barber shop where its founders were unexpectedly lucky and hard-working. Google was different since the beginning." (Graham, 2012)

At this point, David S. Abraham who runs the Technology, Rare and Electronics Materials Centre and is author of The Elements of Power tells that start-ups have the ability to grow and differentiate what they are meant to. According to him "A company really needs to grow (A) to produce something that so many people would like, and (B) to reach and provide services. Barbers are quite good in item (A). Almost everybody needs haircut. The problem for barbers and other retail stores is item (B). Many companies choose one of the items (A) or (B), and the prominent features of successful start-ups are that they act in accordance with both."

The second question comes from a very place with the first question. So should a company be "young" in order to be considered a start-up? Like the question, the answer is similar to the above, it is not. Looking at the average, there is no clear data on how many start-up companies will start up, even though a large percentage of the start-ups fall outside of the initial definition in the first 3 years.

Jan Koum, who is the founder of $ 19 billion Whatsapp, uses the following statements, saying that they saw Whatsapp as start-up, in an interview after their company's fifth birthday. He thinks start-ups are not related in time. As for age, they say it's not a number, but it is about the feeling. For example, he does not feel like he is 38 years old. The company is also 5 years old, but it is moving fast, they are making quick decisions, they continue to produce; and then they are still a start-up.

Homejoy CEO Adora Cheung also has similar ideas to Koum. In an interview with Forbes, Cheung says, "Being a start-up is about your spirit," and, "if people are following your company and giving up on stability and pursuing a tremendous growth prospect, and if they keep their excitement about making an immediate impact, then you are still start-up." (Shontell, 2014)

Being a start-up depends on its ability to grow and to be able to produce, but why Apple with these features is not considered start-up. Although the two features mentioned above are preliminary in terms of definition, many start-ups are left to start-up with growth and aging. Things like being bought by a bigger company, having more than one office, over 20 million dollars per year, having more than 100 employees, expanding the board of directors, or selling one of the founders' shares. On the other hand, if it is thought that the company is not successful in the opposite case, then it becomes a start-up for companies in a way or another.

The third question that can be asked about start-ups is that start-ups can only be about technology, when it comes from Silicon Valley. The answer is no again. Start-ups that enter our lives in parallel with the increasing penetration of the internet and the use of intelligent devices around the world do not have to be related to technology as a definition, even if they use technology to solve problems.

3.3. HOW TO BUILD A CORE TEAM AT START-UP

In order for companies to survive, their departments must be in function. Although the department is a structure created by a group of employees to do a certain job in an enterprise, in newly established companies like start-ups, the "departments" often consist of one person. As the company grows, the number of departments increases, as do the number of employees in departments.

Newly established companies have some priority departments. Often the vital importance is given to the parts that will enable the company to save the day and to sustain its presence in the near future. Most of the time, these departments are "sales" and "marketing".

In order to establish a successful start-up, the necessary departments that are not among the priorities of the day should be provided and properly constructed. If the departments that do not generate revenue such as accounting, law, administrative work and are considered only expenses and if they are not built in time and correctly, the company will always cause back problems, pay penalties and assume unpredictable expenses. Although it is known what is true and what should be done; delaying necessities in deadly dynamism of business can bring the end of a newly established company very soon.

In start-ups, unlike other sectors, qualifications are not "sharp" for those who are new in the team. It is to be "willing" which is important in the start-up culture in which the added value is high, the job descriptions are not clear, and "explosions" occur in certain periods. Unfortunately, the lack of geometric growths that the industry is accustomed to when it is seated cannot be achieved with a clear order in institutional structures, and the start-up culture is a ruthless fact. For this reason, it is necessary to analyse the talents of the people before the organization chart and job descriptions while the building the company.

Start-ups always come with limited resources. Even if a company is established with millions of dollars, the resource is "limited". For this reason, the start-up founders take many roles as long as they have energy. Even if they do not have technical information, sometimes they pretend like CTO or the salesperson sometimes going to the customer or the accountant who collects the bill sometimes or the CEO who participates in the bank meetings or sometimes the office worker carrying the tea.

The Human Resources Department who's duty to set up these things, to add the right people to the team, to protect the motivation of employees will be the latest established department at start-ups. For this reason, founders and department managers have the most HR role until the company reach a certain size.

3.4. A START-UP EXAMPLE

In this section, the progress of the Company X, which is a technology, engineering and trading company, from establishment to investment will be examined. The objective of this project is to carry out 120 risk inspections until September 2017 which is the date determined by investment target, from February 2017 which is the founding date of the company, in order to prove to the investors that the company and business idea are working efficiently. The total period of time from the establishment of the company to the time of investment is 25 weeks.

The business plan is very important to achieve the specified goal. A correct business plan is a plan that needs to be updated as long as the job lasts, along with being important in the previous period when the idea is passed on. The business plan is important because it gives the possibility of "selling" the idea, provides financial assurance and sets priorities and milestones.

In this case study Company X is founded as a joint stock company and until the fund raising, there are 25 weeks to prove that the business idea is working and the company is working within the existing budget.

3.4.1. Project Management with CPM for Company X

After the establishment of Company X, there are some major activities to be completed to go for fund raising. At the end, how long the entire project should take and how much it should cost will be found out.

The project steps are;

A: Recruiting risk engineer – 5 weeks

B: Meetings with the insurance companies – 6 weeks

C: Training risk engineer – 3 weeks

D: Establishment of departments – 8 weeks

E: Meetings with investors – 2 weeks

F: 120 risk inspections – 11 weeks

G: Writing service agreements to be made to companies – 1 week

H: Development of software systems – 12 weeks

Activity	Previous Activities	Normal Time (Week)	Normal Cost ($)	Crash Time (Week)	Crash Cost ($)
A	-	5	3.000	4	4.000
B	-	6	25.000	4	30.000
C	A	3	8.000	-	8.000
D	A	8	12.000	5	16.000
E	B,C	2	6.000	1	8.000
F	B,C	11	9.000	-	9.000
G	D	1	3.000	-	3.000
H	E	12	15.000	8	20.000
TOTAL		**48**	**81.000**	**37**	**98.000**

Table 13: Project Example for Company X

On Table 13, the costs are specified in dollars and the durations are specified in weeks. We assume that the crashing costs involved in this project are all linear functions. The project costs incurred during the project are calculated as \$ 1000 per week when the project is continued. A 25-week period was set for completion of this project. A decision was made that a \$ 1000 / week penalty for each week in which the project is late and a \$ 1,000 / week award for each week in which the project is early. r = project is early (beyond promised delivery day).

- **Relevant decisions:** The CPM problem involves determining how much we must crash for each event. Equivalently, our respective decisions are the duration of all activities. Beyond activity durations, the project duration and the resulting project costs should be determined, but of course these are not independent decisions. So the decisions about activity durations will mean the corresponding project duration and cost.

- **Relevant restrictions:** The fact that our decision on the duration of our activities determines the duration of the project means that there are certain rules that should be followed in determining the duration of the project. There is a rule to state that the project has not been completed until the 6th node is reached (See the Figure 20). There is a similar rule saying that you can not reach Node 6 before you reach Node 5 and then you complete the activity of G, and so on. So, what is clear is actually the rules of this decision-making problem. They are open because it is often very difficult to recognize the rules (constraints) that need to be observed.

- **Measuring Performance:** In this example, we will make good decisions by reducing the total cost of the project to some extent. Decisions that result in a lower total cost (lower direct costs, lower overhead costs, lower penalties and higher returns) better cover us. Direct activity costs will depend on the duration of the activity. The overall costs incurred will be determined by the total duration of the project. Penalty costs and rewards will also be defined by how long the project will last and when the promised project will be completed.

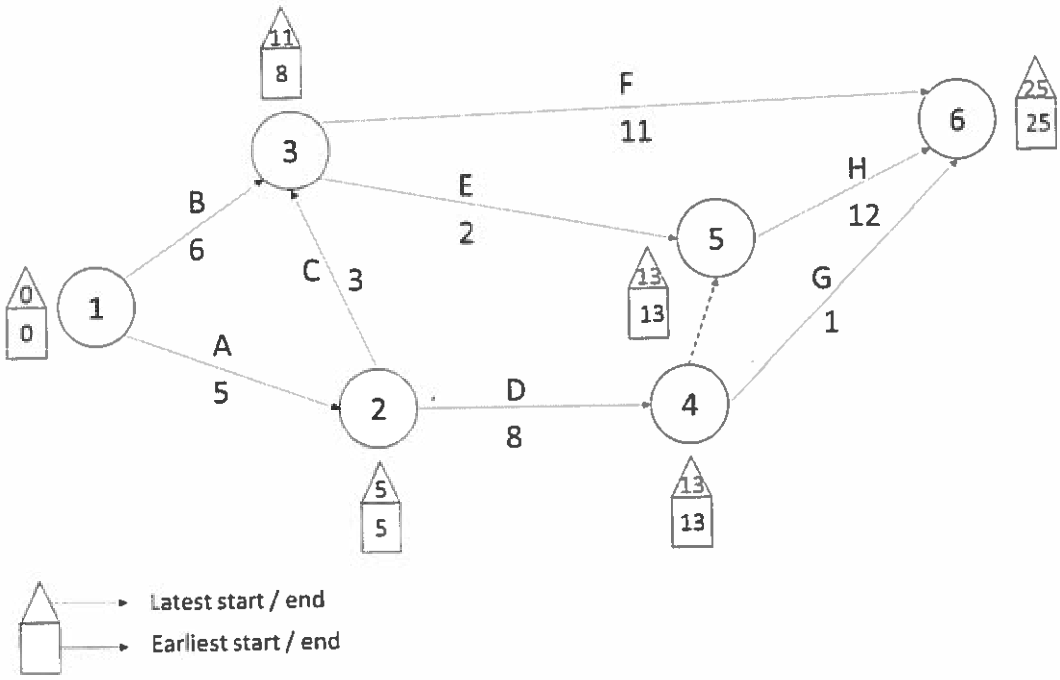


Figure 20: CPM for Company X

3.4.1.1. Modelling the CPM for Company X

-Defining the Decision Variables:

Let: t_i = Duration of activity i, for $i \in$ {A,B,C,D,E,F and G};

E_k = Start time of (any) activities following Node number k, for k = 0,1,2,3,4,5 and 6;

-Defining the constraint functions:

1. Network Constraints

$E_1 = 0$

$E_2 \geq E_1 + t_A$

$E_3 \geq E_1 + t_B$

$E_3 \geq E_1 + t_C$

$E_3 \geq E_2$

$E_4 \geq E_2 + t_D$

$E_5 \geq E_3 + t_E$

$E_5 \geq E_4$

$E_6 \geq E_3 + t_F$

$E_6 \geq E_4 + t_G$

$E_6 \geq E_5 + T_H$

2. Activity Duration Constraints

$4 \leq t_A \leq 5$

$4 \leq t_B \leq 6$

$t_C = 3$

$5 \leq t_D \leq 8$

$1 \leq t_E \leq 2$

$t_F = 11$

$t_G = 1$

$8 \leq t_H \leq 12$

3.4.1.2. Defining the Objective Function:

1. **Activity Costs:** It is possible to shorten the project period by carrying out a crashing operation on an activity at any stage of the project. However, with this crash, an increase in project cost can be seen. This increase in cost can be tolerated as it can be overcome with the decrease in the total project duration. When the cost increases caused by project acceleration are calculated, the formula used is as follows.

$$\text{Cost Slope} = \frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Crash Time} - \text{Normal Time}} \quad (3.1)$$

For Activity (A), Cost Slope will be calculate as below:

$$\text{Cost Slope A} = \frac{4.000 - 3.000}{4 - 5}$$

$$= -1.000 \quad (3.2)$$

For Activities (B), (D), (E) and (H), the cost slopes are calculated as;

-2.500$ / week

-1.333$ / week

-2.000$ / week

-1.250 / week

Normal Cost + Cost of crashing the activity = Normal Cost – Cost Slope x (Normal Time – t) (3.3)

or equivalently as:

Full Crash Cost – Savings due to not fully crashing =

Crash Cost + Cost Slope x (t – Crash Time) (3.4)

Another equivalent activity cost expression could also be written by defining the activity cost as;

Zero-duration cost – Savings due to positive duration

Thus, the activity costs of the project are given by:

For Activity (A): $4.000 - 1.000\ (t_A - 4)$ (3.5)

For Activity (B): $30.000 - 2.500\ (t_B - 4)$ (3.6)

For Activity (D): $16.000 - 1.333\ 0\ (t_D - 5)$ (3.7)

For Activity (E): $8.000 - 2.000\ (t_E - 1)$ (3.8)

For Activity (H): $20.000 - 1.250\ (t_H - 8)$ (3.9)

Activity (C) has a fixed cost of $8.000, activity (F) has a fixed cost of $9.000 and activity (G) has a fixed cost of $12,000.

Adding all these costs up, the total activity costs of the project can be written as:

$$98.000 + (4.000 + 10.000 + 6.665 + 2.000 + 10.000)$$

$$- 1.000\ t_A - 2.500\ t_B - 1.333\ t_D - 2.000\ t_E - 1.250\ t_H$$

$$= 98.000 - 1.000\ t_A - 2.500\ t_B - 1.333\ t_D - 2.000\ t_E - 1.250\ t_H \qquad (3.10)$$

2. **Overhead Costs:** The overhead costs for the project are as follows:

   $1.000 * E_6$ (3.11)

3. **Penalties and Rewards:** E 6 is longer than the promised project duration of 25 weeks even crash times are calculated, there will be penalties.

If the project ends in the normal time $=1.000 * (E_6 - 25)$

$=1.000 * (48 - 25)$

$=23.000$ $ (3.12)

If the project ends in the crash time $=1.000 * (37 - 25)$

$=12.000$$ (3.13)

If the project ends in the normal time, 23.000$ penalty will be paid. If the project ends in the crash time, 12.000$ penalty will be paid but with the crash time the project cost will increase by 17.000$ and the total cost of project together with penalty will increase by 29.000$ more.

If E6 is smaller than the project duration, this represents the rewards that will be received. However, in this case the normal time and the crash time of the project is higher than the expected completion duration, so there will be no reward.

Activity	Duration	ES	EF	LS	LF	TF	FF
A	5	0	5	0	5	0	0
B	6	0	6	5	11	5	2
C	3	5	8	8	11	3	0
D	8	5	13	5	13	0	0
E	2	8	10	11	13	3	3
F	11	8	19	14	25	6	6
G	1	13	14	24	25	11	11
H	12	13	25	13	25	0	0

Table 14: Durations of Activities for CPM

4. The Objective Function

The goal of this CPM problem is to minimize the summation of all of these costs.

Thus, adding all these costs up, the objective is to minimize:

$= 98.000 - 1.000\, t_A - 2.500\, t_B - 1.333\, t_D - 2.000\, t_E - 1.250\, t_H$

$+ 1.000\, E\,6$

$+ 1000\,(E\,6\ - 25)$

$= 73.000 - 1.000\ t_A - 2.500\ t_B - 1.333\ t_D - 2.000\ t_E - 1.250\ t_H + 2.000\ E\ 6.$

(3.14)

The formal presentation of this CPM problem would appear as follows:

4.4.1.3. Mathematical Model Of The Example CPM Problem:

t_i = Duration of activity i, for $i \in \{A,B,\ldots,H\}$;

E_k = Start time of (any) activities following Node number k, for $k = 0,1,2,\ldots,6$.

Minimize 73.000 - 1.000 t A – 2.500 t B – 1.333 t D – 2.000 t E – 1.250 t H + 2.000 E 6 (3.15)

subject to:

$E\,1 = 0$
$E\,2 \geq E\,1 + t\,A$
$E\,3 \geq E\,1 + t\,B$
$E\,3 \geq E\,1 + t\,C$
$E\,3 \geq E\,2$
$E\,4 \geq E\,2 + t\,D$
$E\,5 \geq E\,3 + t\,E$
$E\,5 \geq E\,4$
$E\,6 \geq E3 + t\,F$
$E\,6 \geq E4 + tG$
$E\,6 \geq E5 + TH$
$4 \leq t\,A \leq 5$
$4 \leq t\,B \leq 6$
$t\,C = 3$
$5 \leq t\,D \leq 8$
$1 \leq t\,E \leq 2$
$t\,F = 11$
$t\,G = 1$
$8 \leq t\,H \leq 12$

4.4.1.4. Solving the CPM Problem

Here's how the above CPM model could be input into LINDO:

MIN - 1000 T A - 2500 T B - 1333 T D - 2000 T E - 1250 T H + 2000 E 6 (3.16)

```
S.T.
! Network constraints
E1 >= 0
E2 - E1 - TA >= 0
E3 - E1 - TB >= 0
E3 - E1 - TC >= 0
E3 - E2 >= 0
E4 - E2 - TD >= 0
E5 - E3 - TE >= 0
E5 - E4 >= 0
E6 - E3  - TF >= 0
E6 - E4+ - TG >= 0
E6 - E5 - TH >= 0

! Activity duration constraints
TA >= 4
TA <= 5
TB >= 4
TB <= 6
TC = 3
TD >= 5
TD <= 8
TE >= 1
TE <= 2
TF = 11
TG = 1
TH >= 8
TH <= 12
```

The optimal solution calculated by LINDO appears on the solution window as:

```
LP OPTIMUM FOUND AT STEP     13

 OBJECTIVE FUNCTION VALUE

 1)     -5665.000

    VARIABLE        VALUE          REDUCED COST
         TA         4.000000          0.000000
         TB         6.000000          0.000000
         TD         5.000000          0.000000
         TE         2.000000          0.000000
         TH         8.000000          0.000000
         E6        17.000000          0.000000
         E1         0.000000       2000.000000
         E2         4.000000          0.000000
         E3         6.000000          0.000000
         TC         3.000000          0.000000
```

E4	9.000000	0.000000
E5	9.000000	0.000000
TF	11.000000	0.000000
TG	1.000000	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	0.000000
3)	0.000000	-1333.000000
4)	0.000000	-667.000000
5)	3.000000	0.000000
6)	2.000000	0.000000
7)	0.000000	-1333.000000
8)	1.000000	0.000000
9)	0.000000	-1333.000000
10)	0.000000	-667.000000
11)	7.000000	0.000000
12)	0.000000	-1333.000000
13)	0.000000	-333.000000
14)	1.000000	0.000000
15)	2.000000	0.000000
16)	0.000000	1833.000000
17)	0.000000	0.000000
18)	0.000000	0.000000
19)	3.000000	0.000000
20)	1.000000	0.000000
21)	0.000000	2000.000000
22)	0.000000	-667.000000
23)	0.000000	0.000000
24)	0.000000	-83.000000
25)	4.000000	0.000000

NO. ITERATIONS= 13

According to LINDO calculation, the optimal termination time of the project is 17 weeks.

3.4.2 Project Management with PERT for Company X

CPM accepts predetermined and definite terms of activity; PERT agrees that these times are likely. It is assumed that the normal project period is normally distributed in PERT. How long the project steps for Company X will be completed with PERT are calculated as follows;

Activity	Previous Activities	Estimated Time(s)		
		The Most Optimistic Time (a)	The Most Possible Time (m)	The Pessimistic Time (b)
A	-	3	5	7
B	-	4	6	8
C	A	1	3	5
D	A	5	8	11
E	B,C	1	2	3
F	B,C	9	11	13
G	D	1	1	1
H	E	10	12	14

Table 15: Durations of Activities for PERT

According to Table 15, for all the activities, estimated times are given. According to this table, average duration and standard deviation (variance) of every activity will be calculated according to below equations;

Equation of average duration: $S = \frac{a+b+4m}{6}$ (3.17)

Variance: $\sigma_p = \left[\frac{b-a}{6}\right]^2$ (3.18)

Activity	Previous Activities	Estimated Time(s)			Average	Variance
		The Most Optimistic Time (a)	The Most Possible Time (m)	The Pessimistic Time (b)		
A	-	4	5	6	5	0,111111111
B	-	4	6	8	6	0,444444444
C	A	2	3	4	3	0,111111111
D	A	5	8	11	8	1
E	B,C	1	2	3	2	0,111111111
F	B,C	8	11	14	11	1
G	D	1	1	1	1	0
H	E	8	12	16	12	1,777777778

Table 16: Calculation of Average Duration and Variance

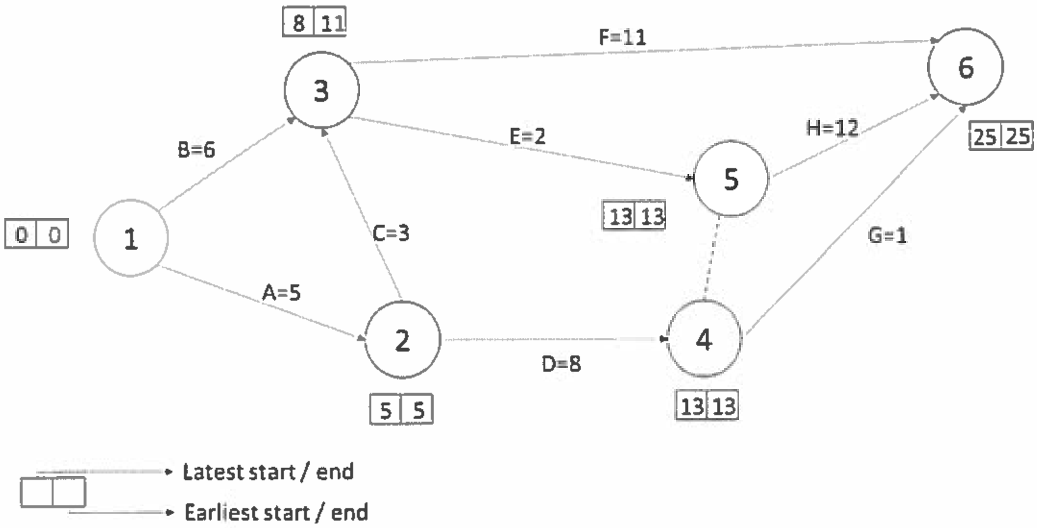


Figure 21: PERT for Company X

The 1st node is our starting step. The earliest events are calculated when a calculation is made on the network. According to table, the earliest beginning time for Activity (A) is 0 which is also the beginning of the project and earliest end time is end of 5 weeks. The earliest start time of Activity (C) is 5th week and earliest end time is 8th week. The earliest start time of Activity (D) is 5th week and earliest end time is 13th week. The activity that is passing through node 5 from node 4 is called a dummy activity, and there is no need to specify any time for this activity. For Activity (H), the earliest beginning time is 13th week and the earliest end time is 25th week and also the latest beginning time is 13th week and the latest end time is 25th week. At the end, the beginning and end time must be same like in node 6, it is 25 weeks.

The critical path of the project is A, D and H. Activity (A) takes 5 weeks. Activity (D) takes 8 weeks and Activity (H) takes 12 weeks. When the duration of A, D and H Activities are calculated, the total project time is found as 25 weeks. The activity from nodes 4 to nodes 5 is also critic but since it is dummy activity, it is not included to process.

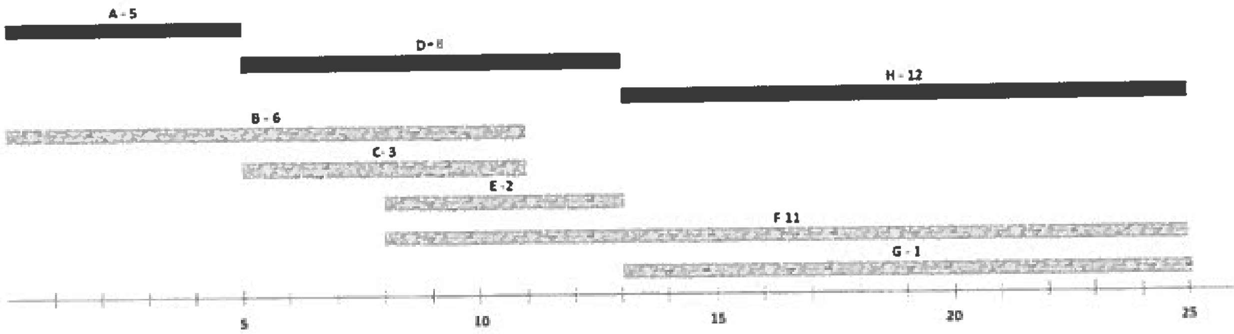


Table 17: Gantt Chart for Company X

According to table 17, the duration of the project is 25 weeks and every line on the horizontal refers a week. Activities (B), (C), (E), (F) and (G) are non-critical activities. Activity (B) must be completed in 6 weeks. For Activity (B), the earliest start time is the first week and the latest end time is 11th week but project duration will be only 6 weeks, not 11 weeks. For the non-critical activities, project team can decide within the determined weeks to complete the process adhering to the specified period of activity. For Activity (C), the earliest start time is the 5th week and the latest finish time is the 11th week but the duration of process will be 3 weeks.

For Activity (E), the earliest start time is the 8th week and the latest finish time is the 13th week but the duration of process will be 2 weeks. Activity (F) must be finished within 11 weeks and the earliest start time is 8th week and the latest end time is 25th week. The earliest start time for Activity (G) is 13th week and the latest end time is 25th week and it must be completed within 1 week. This project can be finished in 25 days and no sooner.

Since the critical path for the project is (A), (D) and (H);

$$E(T) = 5 + 8 + 12 = 25$$

$$Var(T) = 0{,}111 + 1 + 1{,}777 = 2{,}889$$

$$\sigma = \sqrt{Var(T)} = 1{,}70 \qquad (3.19)$$

The probability of the project ending before 26 weeks can be calculated as follows;

$$P\{T<26\} = P\,\{\frac{T-\mu}{\sigma} < \frac{26-\mu}{\sigma}\} = P\,\{Z < \frac{26-25}{1{,}70}\}$$

$$P\,\{Z < 0{,}59\} = 0{,}5882 \qquad (3.20)$$

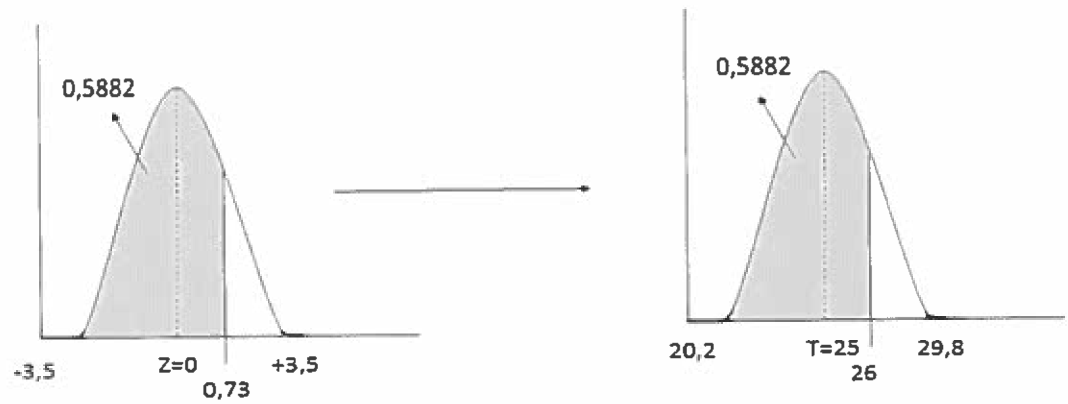


Figure 22: The probability of the project ending before 26 week

The probability of the project lasting longer than 28 weeks can be calculated as follows;

$$P\{T > 28\} = P\{\frac{T-\mu}{\sigma} > \frac{28-\mu}{\sigma}\} = P\{Z > \frac{28-25}{1,70}\}$$

$$P\{Z > 1,76\} = 1 - P\{Z < 1,76\} = 1 - 0,9216 = 0,0784 \qquad (3.21)$$

Accordingly, the probability that the project lasts longer than 28 weeks, as low as 7.84%.

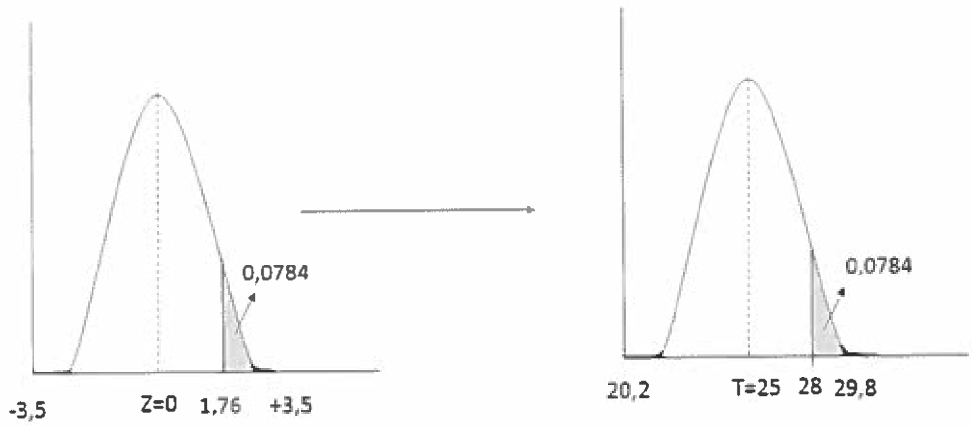


Figure 23: The probability that the project lasts longer than 28 weeks

How many weeks will the project be completed with 90% probability?

$$0,9 = P\{Z < t\} = P\{Z < \frac{t-\mu}{\sigma}\}$$

$$Z_{0,9} = \frac{t-\mu}{\sigma}$$

$$1,28 = \frac{t-\mu}{\sigma} => 1,28 * 1,70 = t - 25 => t = 27,76$$

$$E(T) = 5 + 8 + 12 = 25$$

$$Var(T) = 0,111 + 1 + 1,777 = 2,889$$

$$\sigma = \sqrt{Var(T)} = 1,70 \qquad (3.22)$$

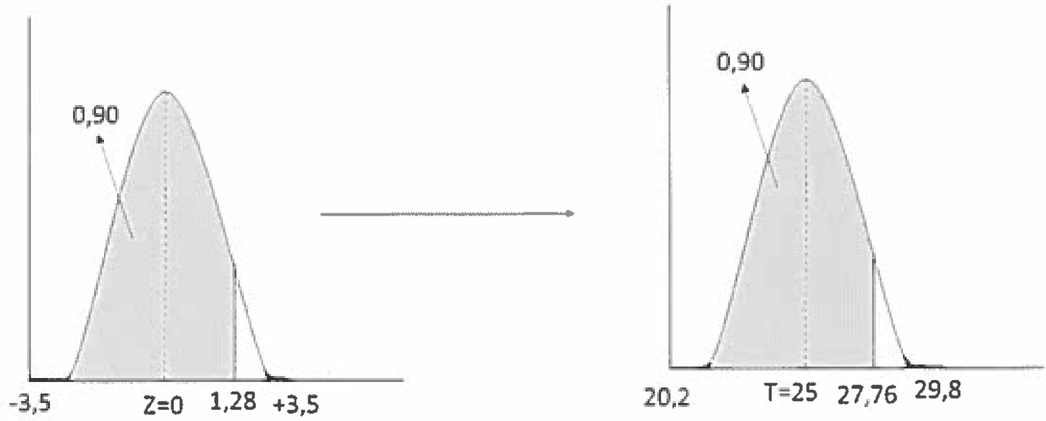


Figure 24: How many weeks can the project be completed in 90% probability?

CONCLUSION

Prior to the development of the CPM and PERT methods, investment business schedules were made with Gantt Charts. Although this method is useful in some cases, it does not have to show the logical connections of events to each other. Certain rules apply to non-complex projects, as some activities cannot be started until the end of an activity, others can continue at the same time. However, it was not possible to get answers such as which activities should definitely end up in the specified period, which influences the total duration of the investment more, how to find the most economical employee, and how to shorten the investment period and reduce the cost of the project.CPM and PERT techniques serve the same purpose. Both methods involve project planning, programming - implementation and control phases. The actual outcome of both methods is to determine at what date the project will be completed. The two techniques are similar to each other and they are fundamentally important. These are related to the period of activity of the provinces. In CPM method, activity period is definite, while PERT technique is probable. The second important difference concerns the areas of use of these methods. The CPM method deals with project issues that have already been done and are still being done. For this reason, the periods of activity can be determined precisely based on previous experience. However, this is not the case for the PERT technique. The field of application of PERT technology is based on projects that are applied for the first time. Therefore, the periods of activity are estimated, expected, and not precise. Since the PERT technique will be applied to a project to be realized for the first time, cost analysis is very difficult and does not produce healthy results. Concepts such as cost analysis, accelerating the project are analyses performed within the CPM method. The most obvious feature of CPM method is that it takes place within the solution method of cost element.

It is the realization of the activities that are important in the CPM method. In this method, importance is given to the realization of many activities from the events. The CPM method is separate from the PERT technique. The PERT technique is a very effective method of operation.

It may thought that the PERT technique is more realistic because it is probable at first and contains three different times, but this method is less preferred than the CPM method. This situation has two important reasons. First, it's hard to predict the three times it's supposed to fit into the beta distribution. In addition, if the person who determines the duration of the activity requires excessive assurance, he can determine the worst-case time high and this affects the results of the analysis. Second, activity durations may not follow the beta distribution.

If the project is to be finished before the target date, the project completion time can be calculated as soon as possible with the crash activities of the project and the additional cost of this crash by the time - cost analysis. Crashing non-critical activities during the crashing phase does not shorten the project duration, but instead leads to additional financials for the firm. For this reason, the identification of critical activities as well as non-critical activities has significant effects on the way the project will follow. Semi-critical activities should also be closely monitored as critical activities and immediate intervention in case of any disruption is of great importance for the duration of the project completion.

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