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THE GRADUATE SCHOOL OF SOCIAL SCIENCES
ECONOMICS AND ADMINISTRATIVE SCIENCES

MASTER THESIS

**A Time-Cost Tradeoff Analysis of a Construction Project in Baghdad City using
Project Management Techniques**

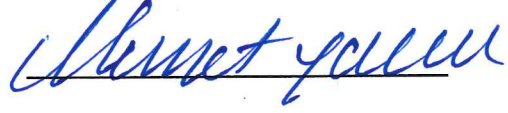
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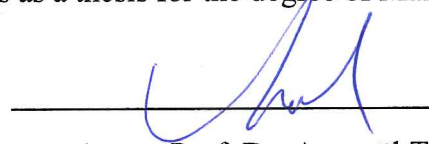
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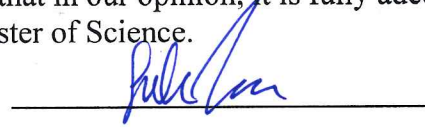
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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

A Time-Cost Tradeoff Analysis of a Construction Project in Baghdad City using Project Management Techniques

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M.B.A, Master of Business Administration

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One of the most remarkable challenges facing the project management at present, that is ensuring the completion of the project in spite of being subject to specific constraints, including time limitations and other financial resources allocated to the project, so this requires accurate calculation of the time and cost. The project of building the Muslim bin Aqeel school in AL-Taji area is one of the huge projects that the ministry of Sunni Endowment seeks to accomplish in Baghdad province. This project was chosen as a project in which the work is delayed, which led to delay in its completion at the scheduled time. On this basis, the project was studied again according to scientific and mathematical methods to create a model that finds a suitable tradeoff between time and cost to accelerate the accomplishment process, by using one of the methods of scheduling and management of the project which is the critical path method CPM, To plan the project, determine the relationships of activities, calculate the slack and critical times to determine the longest duration and the cost required to complete the project. The problem of time-cost tradeoff TCTP and the discrete time-cost tradeoff problem DTCTP, are modeled, using the mixed integer programming model, then by converting the model into an optimization

programming language OPL model. Here, IBM ILOG CPLEX Optimization Studio is used to find the optimal to the problem. The results showed that it is possible to reduce the delivery time by 19.29% less than the expected time by increasing the total cost by 5.77%.

Key Words: project management, CPM, Discrete time-cost tradeoff DTCT, Mixed integer programming, OPL.



ÖZET

BAĞDAT'TAKİ BİR İNŞAAT PROJESİNİN PROJE YÖNETİM TEKNİKLERİ KULLANILARAK MALİYET-ZAMAN ÖDÜNLEŞMESİ ANALİZİ

Ibrahim ABD

İşletme Anabilim Dalı Yüksek Lisansı

Tez Danışmanı: Dr. Öğr. Üyesi Şule TARIM

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Proje yönetiminin şu anda karşı karşıya olduğu en önemli zorluklardan biri, projeye ayrılan zaman kısıtlamaları ve diğer finansal kaynaklar da dahil olmak üzere belirli kısıtlamalara tabi olmakla birlikte projenin tamamlanmasını sağlamaktır. Bu da zamanın ve maliyetin doğru hesaplanmasını gerektirir. AL-Taji bölgesindeki Muslim bin Aqeel okulunu inşa etme projesi, Sünni Vakıflar Bakanlığı'nın Bağdat'ta gerçekleştirmeyi amaçladığı dev projelerden biridir. Bu proje, çalışmanın ertelendiği bir proje olarak seçilmiştir ve bu da planlanan zamanda tamamlanmasını geciktirmiştir. Temelde bu proje, bilimsel ve matematiksel yöntemlere göre, başarı sürecini hızlandırmak için zaman ve maliyet arasında uygun bir taktik oluşturan, kritik olan projenin planlama ve yönetim yöntemlerinden biri olan CPM metodunu kullanarak yeniden çalışılmıştır. Bu metod projeyi planlamak, aktivitelerin ilişkilerini belirlemek, projenin tamamlanması için gereken en uzun süreyi ve maliyeti belirlemeyi duruş ve kritik zamanları hesaplamada kullanılır. Zaman-maliyet değişim TCTP ve ayrık zaman-maliyet değişim problemi DTCTP problemi, karma tamsayı programlama modeli kullanılarak modellenmiştir, daha sonra model bir optimizasyon programlama dili olan OPL modeline dönüştürülmüştür. Burada, IBM ILOG CPLEX Optimizasyon Stüdyosu, problem için en uygun olanı bulmak için kullanılmıştır.

Sonuçlar, toplam maliyeti% 5,77 oranında artırarak, teslim süresinin beklenen süreden% 19.29 daha az düşürülmesinin mümkün olduğunu göstermiştir.

Anahtar Kelimeler: Proje Yönetimi, CPM, Ayrık Zamanlı Maliyet Değişimi DTCT, Karma Tamsayı Programlama, OPL.



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LIST OF ABBREVIATIONS

CPM	Critical Path Method.
PERT	Program Evaluation and Review Technique.
PMI	Project Management Institute.
PMBOK	Project Management Body of Knowledge.
FF	Finish to Finish.
FS	Finish to Start.
SS	Start to Start.
SF	Start to Finish.
AOA	Activity on Arrow.
AON	Activity on Node.
ES	Early Start Time.
EF	Early Finish Time.
LS	Late Start Time.
LF	Late Finish Time.
ST, FT	Slack Time, Float Time.
NC	Normal Cost.
CC	Crash Cost.
NT	Normal Time.
CT	Crash Time.
MP	Mathematical Programming.
LP	Linear Programming.

MIP	Mixed Integer Programming.
SCOOP	Scientific Computation of Optimum Programs.
IP	Integer Programming.
TCTP	Time-Cost Tradeoff Problem.
DTCTP	Discrete Time-Cost Tradeoff Problems.
MIS	Management Information Systems.
IDE	Integrated Development Environment.
OPL	Optimization Programming Language.



CHAPTER I

INTRODUCTION

Construction projects are important tasks that can not be dispensed to any country or society and can be one of the basic industries that support the national economy of each country. The construction industry affects all forms of daily life and has an active role in securing production plants, airports and transport routes. Including housing, hospitals, schools, roads, and bridges used by all members of the community.

1.1 The Historical Development of Project Management.

In theory, project management has emerged since the emergence of human civilizations such as Babylonian civilization, Egyptian, Roman, Persian, Chinese, etc. The most important feature of project management in these civilizations is that they had completed huge projects, such as Pyramids, Great Wall of China, etc. However, these projects were completed without clear resource and time constraints, as they did not provide us with documentation that would enable us to understand how to work (Al-Fadl & Al-Obaidi, 2010, p.24). Therefore, project management is not a new concept for organizations and managers, but ideas and concepts have been highlighted through effective management and have undergone many modifications and improvements (Stelth, 2009, p.11).

In 1917, the scientist Henry Gantt introduced a resource scheduling scheme, one of the oldest scheduling methods known in his name as the (Gantt Chart), it is a table interrupt time with the appropriate resources to complete the project (Schroeder, 2007, p.285). The chart was developed to allow project managers and supervisors to determine the scheduling of each worker's work and then to review and evaluate the actual production. The Gantt chart represents a visual means of showing progress. In the first half of the

20th century, Gantt Chart was the dominant Technique for planning and scheduling projects and for all small, large and medium sizes (Bordoli & Baldwin, 2014, p.3)

After the Second World War and with the emergence of large and complex projects, there was an urgent need to innovate a new method of planning characterized by providing an integrated picture of the project activities, and indicating the relationships of succession and precedence between the project activities as well as overlap between them (Dawood & Others, 2012, p.200). Especially with the need of industrialized countries to implement mega projects (infrastructure projects), which represents the time the basic constraint, and therefore active many researchers in finding methods of high efficiency based on the quantitative basis, and these researchers two teams of advisers in the United States and the third teamwork in the United Kingdom.

In the United States a team of consultants in cooperation with (Du Pont) Company for Chemical Industries, had developed a planning and maintenance management technique at (Du Pont) from December 1954 to February 1959, This team had developed a method for Planning and Scheduling called the Critical Path (CPM), which was used to reduce the maintenance time in (Du Pont) to a minimum. The other team had worked from 1954 until 1958 in cooperation between the US Navy with the (Lock head) company in the project design and development of a rockets Polaris, where they developed a new method called Program Evaluation and Review Technique (PERT). The third team worked in the United Kingdom in 1957 in the Operations Research Department of the Central Electricity Authority and developed a method known as (The Longest Irreducible Sequence of Events), which was later known as the Major Sequence. The application of this method resulted in good results from 1958 to 1960, and the early successes of these techniques led to their widespread adoption in project management and planning (Bosnina, 2011, p.36).

In 1969, Project Management Institute was established to serve the interests of the project management field. In 1981, the Board of Directors of the Institute announced the implementation of this document which became the (PMBOK). It includes the accepted standards and principles Guidelines for all practitioners.

So, by reading the scientific literature we can say that the oldest document available in project management field is the Gantt chart where this man (Henry Gant) the prominent role in the invention of the first methods of planning and control of projects through the method (Gannt Bar), which is used up until now.

The historical development of project management can be summarized into three phases:

1. The pre - fifties: characterized by the lack of knowledge for the management of projects except for Gantt scheme.
2. The fifties and pre - nineties: It is characterized by the innovation and use of quantitative methods CPM & PERT.
3. The post-1990s: This phase is characterized by the use of technology, information technology and knowledge management, and the emergence of specialized institutions and organizations in project management, like (PMI) the American Project Management Institute, and (APM) the British Project Management Authority, as well as several ready-made programs that help to manage the projects according to modern and scientific techniques.

1.2 The Project Concepts.

The project includes a set of interrelated, time-bound, cost-driven work activities that lead to the achievement of the organization's strategic objectives using its assets (Anderson et.al, 2007, p.3), It is expressed as a useful or useful change that uses project management techniques to plan and monitor the work so that a product can be delivered to satisfy the needs and expectations of the customer and the owner (Bruke, 2009, p.3), according to the current study, we confirm that the definition of a construction project (is the kind of project that usually starts with an architectural idea for a purpose and is developed to meet the required purpose. The operational maps are then prepared and implemented across multiple stages) (Bosnina, 2011, p.35).

Regardless of the type of construction, all construction projects have a common denominator, The project must be planned, designed and executed according to specific technical specifications, within a specified budget and a predetermined period of time

(Sumaidai, 2002, p.7), and it is the main constraints of each project that will be highlighted in this study.

1.3 The Main Objectives of the Project.

The performance of a project is measured by three criteria. Had the project been completed early or in time? Had it been achieved within the limits of its budget? Was it consistent with "specifications that satisfy customer satisfaction? Therefore, each project has three interrelated purposes, namely, the compatibility of the project with the budget and completion according to the specified time schedule and the proportion of compliance with specifications that satisfy the customer (Mantel et.al, 2008, p.6).

In view of the importance of these three objectives, we will address the following:

1. Schedule: Is the process of converting the project plan into a schedule for the operation of the program from the moment it starts work through all consecutive activities and overlapping events and main stations until the moment of termination of the project (deadline) and then set the time required to implement the project from the start to the moment of completion (Khairuddin, 2012, p.137).

We can say that the time schedule reflects the time required to implement the project within the timetable set for it since the start-up and establishment until achieving the benefit of the project and delivery on time.

2. Quality: Means the high degree of qualitative or value as stated in the Oxford Dictionary. The International Standard for Quality Terms 1994 includes a definition of quality which is a set of characteristics of the product or service its suitability to meet needs or conformance to purpose, and control over the quality of the construction project is a process To adjust the quality of each project activity according to the specifications established in the contract documents in order to achieve the required quality of the project (Bohan, 2012, p.45).

3. Project Budget: After completion of the planning process of the technical aspects of the project and determine the time necessary to implement it, there is an "important" element of planning that needs to be completed before project management starts to implementation, its important to determine the budget needed to obtain the necessary resources to achieve the objectives of the project (Mantel et.al, 2008, p.108). The project budget was defined as a process of guessing or predicting the resources required by the project, the number of resources and when would project need it? How much will these resources cost? It is also known as a plan for the disbursement of funds from the beginning of the project until its end (Calmes, 2006, p.63). We can conclude that the project budget represents the planned budget of the project by the landlord based on the direct costs of the activities detailed and the indirect costs of the project which are approved at the stage of establishment of the project. These three constraints are the most important objectives of the project and there is a reciprocal and important relationship between them.

1.4 Project Characteristics.

Most projects generally have a set of core characteristics, especially those related to the main objectives of the project's constraints and the golden triangle (scheduling, budget, and quality), projects may differ in their characteristics but there are fixed characteristics collected by all writers and researchers; (Gido & Clements, 2006, p.4); (Slack et al., 2004, p.554); (Nagarajan, 2004, p.3):

1. Objective Clarity: is the result or product that is defined within the scope, scheduling and cost framework.

2. Task Chain: the project is complex, "which requires dividing it into partial tasks, which in turn are divided into non-duplicate activities that are interrelated and must be completed in a sequence to achieve the goal.

3. Resources: The various material resources required to perform and fulfill the tasks and activities of the project and include all material and human resources (people, organizations, equipment, etc.).

4. Life Cycle & Due Date: The project is an organic organism with a life cycle where it starts slowly and then activity increases until it reaches the peak and then goes down until it ends when the project is completed and has a specific date for delivery.

5. Client: represents the body that finances the project to complete it and can be (person, organization, government or private sector).

6. Complexity: Achieving project objectives requires many different tasks. The relationship between these tasks may be complex. The complexity is related to the size, value, and number of people involved in the project.

7. Uniqueness: Each project has unique characteristics that distinguish it from other projects. It can be said that there are not two projects that are quite similar.

8. Uncertainty: Where each project has a certain amount of uncertainty, it is necessary to document some of the assumptions and estimates that may affect the objectives of the project (project budget, time schedule, and the quality), so the project manager spends a lot of time preparing for the unexpected changes and resorting to the swap between the objectives of the project.

9. Interdependent: In the case of the organization implementing several projects, the project management faces continuous overlaps with the functional divisions and such sections (marketing, finance, manufacturing, etc.). The project manager should have a clear picture of these overlaps at each stage of the project and appropriate relationships with each functional section to prevent conflict and crisis.

10. Conflict: The project manager faces a conflict-oriented set of positions, from which the projects compete with the functional divisions of the organization themselves for the available human and financial resources. The conflict arises as a result of multilateralism interested in the project. In any multi-stakeholder project (project team, parent organization, suppliers, direct beneficiaries of the project, etc.), each party has its own objectives that conflict with any other party at any stage of the project, which requires a clear strategy for the management of the parent organization to balance the parties interested in the implementation of the project.

1.5 Project Life Cycle.

As we have said before, the project is an activity with a starting and ending point and between them is a group of activities that are carried out to reach the end point and completion of the project, so every project goes through the so-called life cycle of the project. The project life cycle is defined as the stages that link the beginning of a project to its end. When an organization wishes to implement a specific project, it relies on an economic feasibility study for the purpose of making the decision to start or leave the project. The project life cycle helps project managers to indicate the need to deal with the feasibility study. The transition from one stage to another in the project life cycle is determined by one of the forms of delivery or technical transfer. The audit process is carried out for the purpose of observing the required quality and then it is approved and allowed to move on to the next stage (PMBOK, 2000, p.11). As there is a difference in the characteristics between project and another and vary between the degree of risk and uncertainty and complexity, so the completed companies are subjecting their projects to several stages in order to achieve the best management of control, generally these stages regardless of the project activity and duration and size, which is commensurate with all projects but varies from project to project depending on the nature and size of the project (Muhammad, 2012, p.89).

A large group of researchers agreed that the project goes through four stages; (BMBOK, 2008, p. 16); (Larson&Gray, 2011, p.7); (Lewis, 2001, p.31):

1. Start-Up Phase: At this stage, objectives are set, install specifications, prepare tasks and determine responsibilities.

2. Planning and Development Phase: At this stage, the effort begins to increase, and the indicators developed through the feasibility studies are used. The work of this stage includes: scheduling preparation, determine resources to implement project plans, determine manpower, determine budget and identify potential risks.

3. Implementation or Executing Phase: This stage is carried out in accordance with the basic plan developed in the previous phase. The project is also monitored to make

sure that it goes according to plan. The main tasks of this stage are: reporting on the progress of work, notifications of required changes, quality control, and forecasting.

4. Closing and Termination Phase: At this stage, the activities of the project are checked to ensure that the project has been completed according to the required specifications and plan. This stage may include training the clients on the project outputs, and then preparing the final reports and delivering the required documents. The work of this phase can be summarized as follows: audit and evaluation, resource release, customer training and document transfer.

In the end, the project is not completed by the completion of its activities, but it is completed when the project management organizes its tasks through the implementation of the work of the final stage and delivery of the project (Rad, 2012, p. 16).

While a section of researchers divided the project lifecycle into three: start-up phase, implementation phase and termination phase, (Willim, 2008, p. 3) (Kheireddine, 2011, p. 34).

While the project brochure was divided into six phases (Harmsen, 2006, p. 6):

1. Initiation Stage.

2. Definition Phase.

3. Design Phase.

4. Development Phase.

5. Implementation Phase.

6. Follow-Up Phase.

Despite the different life cycles in the projects, there is agreement that all of them have a beginning and an end and a period of implementation. Failure to agree on the number and naming stages of the project's life is not a defect in the management of the projects,

but it is a natural situation considering that the projects vary in size, scope, and characteristics.



CHAPTER II

METHODOLOGY OF SCIENTIFIC RESEARCH

INTRODUCTION

The methodology of research is the cornerstone of the scientific research project, which makes the path that will be used to address the research problem will be determined, that is how it can verify its assumptions and achieve its objectives and indicate its importance according to scientific research methodology.

2.1 Problem Description.

Most of the construction projects have been characterized by a low level of performance, which is characterized by high costs and increased completion time. There are a number of important strategic and vital projects related to important segments of the society, such as the construction projects of schools and hospitals in Iraq, due to the increase of students and the expansion of residential areas, which requires a meticulous study through the project in order to project completion in time. According to the optimal time schedule and the best trade off time/cost of completion of the project, to provide several alternatives to help the decision-making process appropriate to the conditions of implementation of the project, as it is implemented in a repeated and different circumstances, especially the country like Iraq which has been facing an economic crisis since 2014.

The high cost and duration of project implementation for the planned cost, is one of the results of retaining and relying on very simple planning methods like using the Gantt chart and follow-up of the implementation phase by the entity responsible for implementation through reports of progress of work by the supervisor only, therefore,

the problems experienced by the projects of Baghdad Governorate can be summed up as the subject of the current research in the form of inquiries and in the following manner:

1. Is the Gantt method used with progress reports in follow-up to the implementation phase of the project? Is this method one of the methods that highlight the level of project performance accurately in terms of the two dimensions (time and cost)?.
2. Does the ministry have a work plan that provides the best time schedule while providing several alternatives to different implementation conditions for the school project, especially since the need to repeat the implementation of the project is ongoing ?.
3. Is there a decrease in the benefits and positive return from the project and delays in benefiting from it as a result of delay in completion and increase the cost ?.

These questions are among the most important reasons for studying the alternative methods of planning used by executing agencies for projects in Iraq generally and particularly in Baghdad city and work to replace them in more effective ways.

The main problem that will be addressed and studied by applying the critical path method (CPM) is all about the performance (time and cost) of the project.

2.2 Aim of Study.

The Main Objectives to Be Achieved in this Study are:

- A. Calculation (normal time, downtime, normal cost, and cost of collapse) for the school project.
- B. Provide a number of alternatives in accordance with the terms of implementation by gradually implementing the project crash, while providing the optimal solution in terms of time / cost of trade outside the project.

C. Contribute to reduce the delay of achievement and reduce the impact on projects, especially the school project as it will be implemented in the future in multiple locations and different circumstances in each case.

D. Investigate the effect of CPM on performance enhancement and its contribution to reducing project delays and cost control through the findings of the research and its analysis.

2.3 The Importance of This Study.

The application of the project management methodology is necessary and important to make the project management processes part of the daily work culture within the institutions. Exceeding the cost and duration of the construction projects related to the life of the individual and society leads to loss of value for these projects.

It is hoped that the research will contribute to achieving the following:

- 1.** Provide a practical application on how to use CPM as an effective planning method that is not used by the project department in the governorate, through a vital project in Baghdad governorate for the purpose of planning and monitoring the work by the project's network plan.
- 2.** To improve generally the level of project management performance for the Sunni Endowment in Iraq, based on the scientific approach presented in this research through the practical application of the mentioned method.
- 3.** Assist in the decision-making process related to selecting the appropriate alternative for the time period and cost estimated to suit the circumstances of the implementation of future projects according to the results of the current research.
- 4.** Inform researchers in the academic field as well as the practitioners, on a practical application of project planning and its role in monitoring the project by measuring the values of performance indicators.

2.4 Project and Research Sample.

One of the investment projects of the Sunni Endowment Fund was selected, which is the construction of several schools in the outskirts of Baghdad city, in proportion to the increase in the population.

The project on the construction of a Muslim Bin Aqeel school was chosen in ALTaji area north of Baghdad, this project has been selected because the project is still under implementation, noting that there are difficulties in completing the work during the specified period due to the lack of quick and scientific solutions to address the delay, and this is what most of the projects in Iraq suffer from, and we must stop on this problem and study it to find out the causes and find solutions that benefit them.

2.5 Methods Used in finding Results.

The practical aspect of the research is divided into two parts:

A. Calculate the traditional and non-traditional relations between activities, and to determine the time and cost of critical activities, by applying the critical path method(CPM), as well as calculating the acceleration time of the project by applying the mathematical laws to accelerate the project time.

B. Conversion of the project data into equations using mixed integer linear programming including the objective to be achieved, whether to reduce the time or cost of the project, with the constraints of the project activities. Use (IBM ILOG CPLEX Optimization Studio) program which is a giant software in operations research to analyze and choose the optimal solution. By converting mixed integer linear programming into the OPL language accepted by the program.

2.6 Sources and Methods of Data Collection.

2.6.1 Preliminary Sources:

All preliminary data was used to address the practical aspect of the study, through:

A. Interviews were conducted with the managers of the departments involved in the management of the construction projects to discuss the community and the sample of the research to obtain information and data about the project to highlight the importance of the techniques mentioned in the planning, and the extent of the culture of project management among employees of the ministry.

B. Study of project documents and work reports Which represents the field of research through visits and field life of some of the implementation steps for the project with the engineering committees responsible for the implementation and supervision of work.

C. Adoption of discussion, dialogue and analysis to finalize the research results.

2.6.2 Secondary Sources:

Secondary sources were used to address the theoretical framework of the study, through:

A. Foreign and Arabic books and references related to the subject of the study.

B. Periodicals, articles, research and literature on the subject, around the world.

Perhaps one of the most important obstacles to research is the lack of accurate and detailed documentation of data, among those responsible for the project and lack of interest in statistics, where most of the information on the practical aspect of the study was collected through visits and meeting with the resident engineering committees

responsible for implementation, and to strengthen the data documented with additional information resulting from asking many questions.

2.7 Previous Studies.

In this paragraph, we will review the previous local, Arab and international studies related to the current study, to find out the most important topics that were discussed, to identify the methods, procedures, results achieved, and the extent of use it and comment on them.

2.7.1 (Hafeezah: 2014).

"The trade-off between traditional and modern business networks in planning and monitoring projects", Master Thesis in Economics - University of Mohammed Khudair-Algeria.

The study aimed to determine which type of business networks are the best the traditional or Modern? In the planning of projects through the statement of how to use network analysis in general, and prove that, through this study which was seeking to solve the problem of not using quantitative methods in the process of planning and monitoring projects in the Arab world, specifically Algeria, The quantitative approach to data analysis was based on the practical application of critical path method to build a residential complex through ready-made software.

The main results of this study are that the estimated time to complete the project in the critical path was less than the estimated time by the institution or contractor, the time in the critical path closer to the actual time to complete the project. And recommended using modern methods because they do not neglect the qualitative effects on construction projects.

2.7.2 (Abdul Majid: 2012).

"Using project scheduling methods, PERT and the critical path in time-cost trade off for project completion - applied study at the Technical Institute - Baghdad".

The aim of the study was to seek optimal use of resources and improve performance by coordinating project activities and reducing time and cost, in order to find a solution to the problem of underestimation of time and non-exploitation of resources available in the project (building marketing center in Kirkuk)

The researcher used the quantitative method through the application of laws and equations of methods (CPM, PERT).

The results showed that there is a difference of 48 days between the planned and actual completion period, with a waste of resources led to a loss of 90%, due to poor follow-up and the diagnosis of deviations and treatment at the appropriate times, which led to fines on the delay on the implementing agency more than 19 million Iraqi dinars.

2.7.3 (Shaaban: 2009).

"The possibility of applying critical path method at ALNajaf International Airport" - Master Thesis - University of ALKufa-Iraq.

The study aimed at using the critical path method in determining the standard times of the project activities and the time factor pressure through the process of acceleration and access to the costs of saving time. The purpose of the study was to answer the question of whether using the critical path method would lead to the pressure of the time factor of the activities of ALNajaf International Airport Project by taking advantage of the time surplus and interventions between activities.

The study concluded that the crashed time for the completion of the project was 461 days, which was before in 475 approximation days, as a result, the project could be accelerated by decreasing the days which would have costed 44 million Iraqi dinars.

2.7.4 (Tamrakar: 2013).

Analysis and Improvement by the "Application of Network (PERT/ CPM)".

The aim of the course was to provide a methodology for the critical path method (CPM) and pert, to present the method of implementation in the basic project companies.

The reason for the study was to subject the processes and procedures of projects for analysis and improvement through new methods, where the quantitative approach was adopted to calculate the standard times for the activities of one of the electricity projects implemented by the Bansal Projects Company.

Where the results showed that the implementation of techniques (Critical Path Method and Pert) lead to significant changes in the performance of project companies in terms of reducing the completion time of the project and reduce costs, in addition to increasing the effectiveness and efficiency of processes and procedures improve control over and take benefit from resources and the total value to improve project management and ease control.

2.7.5 (Kelleher: 2004).

An Investigation Of The Expanding Of The Critical Path Method By Enr's Top 400 Contractors - University of Virginia.

The aim of this study was to examine the extent of change in the use of the critical path method in the construction industry in large, small and medium enterprises, and in comparison with two previous studies similar to those in 1974 and 1990.

The purpose of the study is to compare the importance of the critical path method in the previous periods with the present time and what will happen in the future,

The descriptive analytical method was used through the online questionnaire. The sample of the study was faculty members and students at the Virginia University of Technology.

Where the results confirm that 98% of the companies that the critical path method is a tool for good management and has a role in achieving the current and future success.

The current study is consistent with most previous studies and the importance of optimal utilization of resources to improve the performance of projects by emphasizing the use of methods of network analysis, especially (CPM).

The main advantage of this study is to focus on the critical path method and to rely on it to calculate the project duration, provide information about the times and costs of project activities and identify critical activities, then begin the process of planning the project crashing and calculating the crash cost for per unit of time to do the time/cost tradeoff according to the project goal.

The results will also be presented through an **IBM ILOG CPLEX Optimization Studio** program. In order to obtain the optimal solution through this application, the project data model should be written in a way that is consistent with this type of program. Therefore, the data and constraints of the project will be converted in the form of linear programming equations and then converted to OPL (language of simulations for this program).

Since we are working on a time-cost tradeoff in a construction project, a number of activities have a specific crash time (discrete crash time), so we cannot model such activities by linear programming, but they can be formulated using the integer programming equations.

Therefore, all project data are drafted in the form of a model using mixed integer programming, and this is the novelty of this study.

CHAPTER III

SCHEDULING AND BUSINESS NETWORKS IN PROJECT MANAGEMENT

Introduction

Network models are an effective tool in project management, especially the medium and large projects consist of a large number of overlapping and complexed activities that require planning methods that enable managers to plan and schedule project activities in a manner that facilitates the process of implementation and control of the project, to ensure optimal utilization of all available resources.

Networks provide a clear picture of understanding relay relationships and precedence and achieve accurate scheduling of start and finish times for each activity. This will facilitate monitoring of project implementation by comparing what was planned and what was actually implemented.

3.1 Schedule of the Project.

3.1.1 The Concept of the Scheduling Process in the Project:

Usually each project has a planned deadline, and to help ensure that the end date of the project coincides with the actual completion of the project, there must be a detailed timetable, this schedule includes a list of the main stages, tasks, and activities of the project completion, and should also include a list of those responsible for the performance of these tasks, and show the relationships of continuity and interdependence and precedence between tasks and activities (Benator & Thumann, 2003, p. 10). Scheduling is done by converting the work plan into a schedule and

resource table through planning methods (Mantel et.al, 2008, p. 145). Such as a Gantt chart, critical path method (CPM), and (PERT).

Scheduling is defined as transforming the project work plan into an operational schedule, it is the key tool for project management (Merdith & Mantel, 2012, p. 331). It has also been defined as a detailed plan that is carried out by loading the resources for short periods of time to accomplish certain tasks, The project scheduling is vital to the successful implementation of the project and the achievement of its objectives (Krajewiski, 2013, p. 529).

Finally, (Calmes, 2006, p. 63) defined it as giving us a plan of action and what we do every day or every week until the work is fully completed.

We agree with the definition of the writer (Khair ALdin), he analyzed scheduling to its basic elements and he said that (it is the process of converting the project plan into a timetable for the operation of the program from the moment it starts work and through all the activities and events consecutive and overlapping and the main stations (Milestones) until the end of the project (deadline), this process results in determining the time required to implement the project from the moment the project starts until the end of the project (Khair Aldin, 2012, p. 137).

Therefore, the planning phase comes after planning the project and identifying the elements and the main activities, processes and Resources needed to implement it and finish its effectiveness, and the preparation of its organizational structure.

There are several procedures to build and prepare a project schedule as follows: (Meredithet.al, 2008, p. 88):

- A.** Clearly define and arrange project activities.
- B.** Identify the types and quantities of resources required for each project activity.
- C.** Guess the precedence relationships of activities with guessing the duration of each activity.

D. Select and load all Milestone stations for the project with priority relationships also set.

Therefore, aggregating the main stations of the project and the duration of project tasks and precedence relationships, gives the result to obtain the main scheduling of the project, which helps the project manager to compare the actual time and actual resources of activities with the planned at any level, so we see that the main scheduling plan can be counted as a control and monitor document for the project.

3.1.2 Project Scheduling Stages.

The project scheduling process is in three basic stages, respectively:

3.1.2.1 Planning Stage.

This phase involves the collection and analysis of data on each project activity, identify the resources required for each activity, especially the time, add to determine the nature of the relationship between the activities, and fix the date of project termination (due date), so that the project network can be built on the basis of these data, then determine the budget of the project, and indicate the amount of fine for completion late than the deadline (Acuña, 2010, p. 154).

3.1.2.2 Scheduling the Activities Stage.

The Project Manager decides at this stage to estimate the time needed to complete each project activity, with an assessment and calculation of the physical and human resources needed for each activity, and critical path determination, after that the total costs required for completion and the total duration for the project are estimated (Heizer & Rander, 2011, p. 93).

3.1.2.3 Control Stage.

Another important stage of project management using scheduling is project control, its function is to coordinate resources from manpower, funds, equipment, machinery and

time within a specific time frame to achieve project objectives for satisfactory performance and results (Abdulla et.al, 2011, p. 45).

3.2 Project Networks.

The main problem with scheduling is often when tasks are scheduled without resource scheduling, and no systematic objective functions are used for measurement and evaluation (Francis & Philippe, 2003, p. 151). Therefore network planning is a scientific approach to project planning and organization through a network that reflects the chronological and logical sequence of the project activities and the interrelationship between these activities. The process of implementing the project is determined according to the planned program and identifying the necessary resources and their appropriate timing (Hafeza, 2014, p. 13).

3.2.1 Time Charts.

The charts, sometimes called the graph bar, were developed by Henry Gantt in 1915 and included in the project management plan as a visual presentation tool that includes clarification of project activities and completion times (Cooke, 2015, p. 35), until 1980, the tasks and activities of the project were often carried out manually through Gantt charts, due to the shortcomings in the bar charts and to meet the requirements of modern management efforts have been made to develop them and search for more efficient and appropriate methods for large and complex projects. One of the most important modifications is the discovery of Network Planning and the most prominent types are (critical path method CPM and PERT), perhaps the most important drawbacks of the Gantt chart, which led to new approaches, are: (Lewis, 2007, p. 71):

- A. The lack of clarity of relations of precedence especially in relationships that cannot be inferred from the scheme.
- B. Cost considerations are not considered in this chart.
- C. Lacks Gantt charts to provide alternatives to accelerate the use of additional resources.

D. Lack of expected data on activities compared to other methods, especially the critical path method.

3.2.2 Network Planning.

Using the network planning is the response to the expansion and complexity of projects and the creation of more efficient means in the planning, scheduling and controlling of projects, and to overcome the above defects and problems.

Almost in the mid-1950s, two methods of network analysis were developed independently, in both, the matrix diagram was used to establish sequence relationships and parallels between activities. In 1956, a critical path method was introduced by Du Pont Company, which was widely spread and focused especially in the construction industries. After that in 1958, PERT was introduced as a method of evaluation and review of the project by the consulting firm (Booz – Allen, and Hamilton), to improve and manage the US submarine missile program Polaris, the program was large and required planning, scheduling, and supervision of the activities of more than (3000) contractors. In order to achieve it, this method was developed, which contributed efficiently to the estimated time of the project by about two years (Wong, 1964, p. 54).

Due to the many advantages that are available in the networks planning especially the possibility of using it in the planning of large projects and complex nature, which includes a lot of activities, as most of the workers in the planning of construction projects prefer to use these methods in the manner of the chart, because the latter method is only suitable for small projects (Naseer, 2007, p. 119).

3.2.3 Key Networks Elements.

There is a set of key elements that make up the network diagram so that it can be drawn in the final form by translating these elements into a plan that facilitates monitoring the project for the purpose of controlling its course within the plan. The most important elements are:

- **Activity:** One of the main elements of the project expressed in a two- nodes and requires implementation of human, material resources and a period of time, add to It is the smallest unit of physical work in the project and has a cost (Aziz & others, 2011, p. 188)
- **Critical Activities:** Activities that are on the critical path and the delay in their completion are delaying the project (Morder, 1983, p. 23).
- **Dummy Activities:** These are activities that do not take time and require no resources, its time is zero, and marked by a dashed line (-----). It is merely a representation of activity dependence to avoid confusion (Morder, 1983, p. 24).
- **Event:** is the starting and ending point of activities, and the event does not take any time period and consume any resources of the project (Ried & Sander, 2002, p. 523).
- **Critical Path:** A continuous chain of critical activities, the longest on the network, giving the minimum time to complete the project, and any delays in the activities of this track delay will make the whole project delayed (Passenheim, 2009, p. 43).

Next figures Drawings show how items are related to each other and some undesirable situations as in the latter:

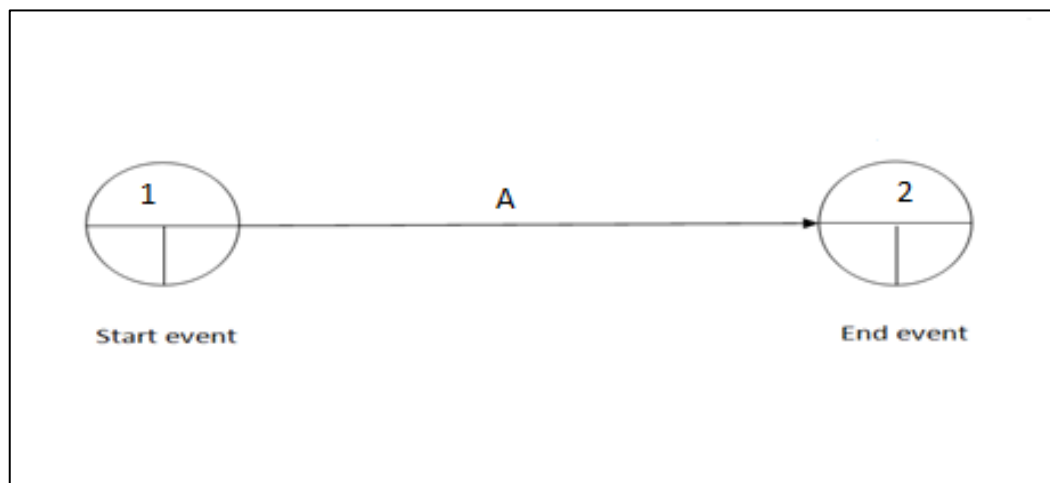


Figure 1: For Each Activity has a Start and Finish.

Source: Al-Anshasi, Adnan Ali, (1997). "Management of Engineering Projects", First Edition, Palestine, Gaza, p. 177.

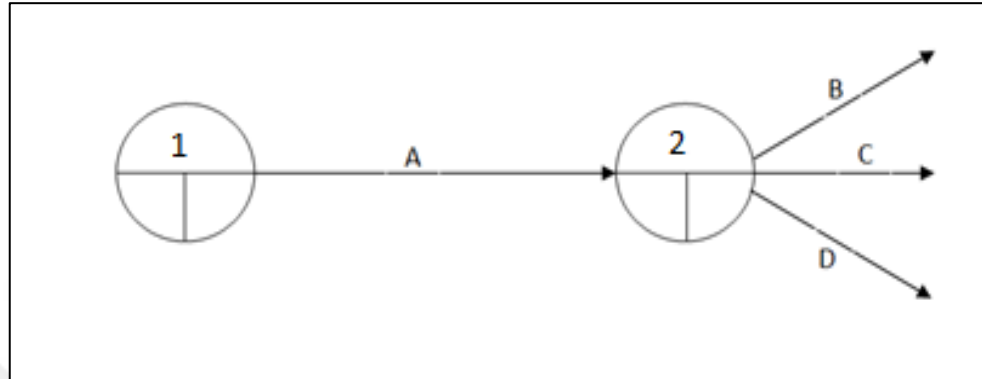


Figure 2: The end event for the previous activity is the start event for subsequent activities.

Source: Pinto, Jeffrey K., (2007). "Project Management Achieving Competitive Advantage, BY Pearson Education, Inc. Upper Saddle River, New Jersey, p. 288.

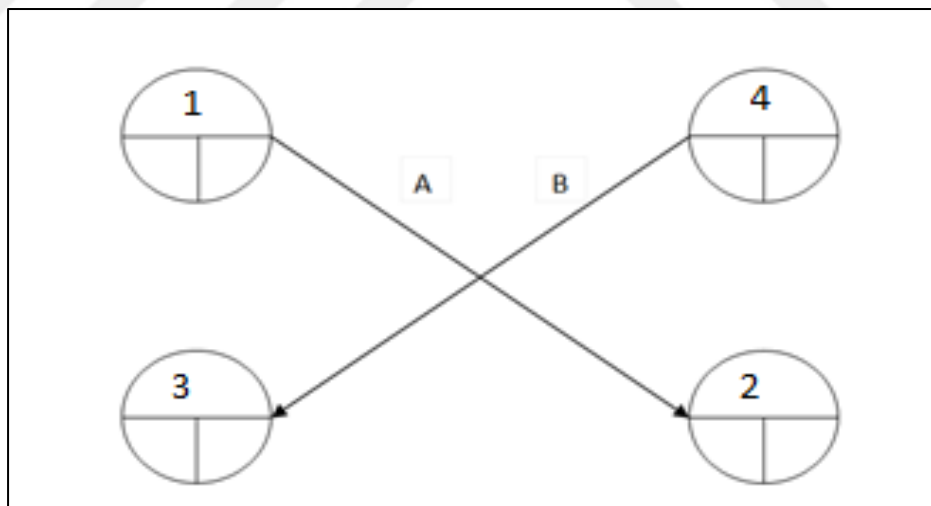


Figure 3: Intersection of Activities (Unwanted status)

Source: Al-Fadl & Al-Obaidi, (2010). "Project Management Quantitative Approach", Dar Al-Rawqq Publishing and Distribution, p. 187.

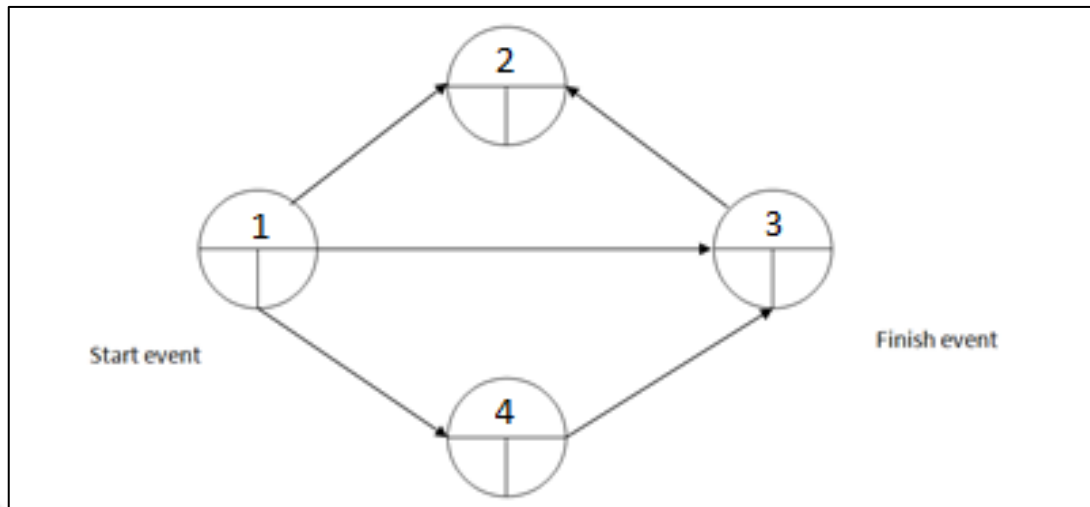


Figure 4: Return Activity From a Subsequent Event to a Previous Event (Wrong Case)

Source: Al-Anshasi, Adnan Ali, (1997). "Management of Engineering Projects", First Edition, Palestine, Gaza, p. 177.

3.2.4 Logical Relationships Between Activities in the Network Diagram.

The network diagram shows the logical sequence of activities. Logical relationships between activities must be determined before drawing begins. There are two basic relationships: (Burke, 2009, p. 132):

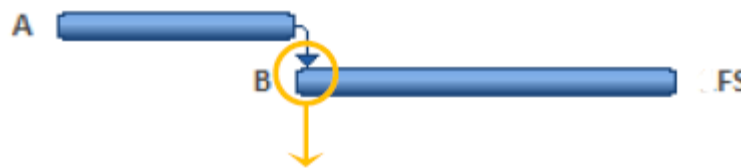
A. Parallel Relationships: activities that are performed at the same time and are more efficient in the use of time than serial activities.

B. Serial Relationships: These activities are implemented one by one since, at the beginning of the development of networks, these relations were the most common.

The failure to determine the relationship between activities in terms of synchronization and precedence leads to the inability to use the network efficiently and effectively to complete the project on its final date, therefore, it is necessary to divide the project into specific activities that can be distinguished from each other, with precise start and end dates and identification of the type of overlap with other activities (Mantel et.al, 2008, p. 147).

This leads to a vital and dynamic plan for the project using a different classification of the relations between the beginnings and endings of the activities, including the conduct of the project activities without collision and intersection and without wasting time, which can be specified in four following relationships: (Rad, 2013, p. 20):

1. Finish to Start (FS): It is the most used relationship between activities, where the activity ends and start the other, we can note that the start of activity (B) is affected by the previous activity as it is associated with the relationship (FS) cannot be implemented without the completion of the implementation of activity (A), which is common relationship between activities by about 90%.



2. Finish to Finish (FF): Which is the relationship between the two activities associated at the time of termination for both of them, where we note that the end of activity (B) is affected by the end of activity (A) because the relationship they are associated with (FF), both activities must be terminated at the same time.



3. Start to Start (SS): This is the relationship between the two activities that are linked together at the start time, so Activity (A) should begin to let activity (B) begins.



4. Start to Finish (SF): It is a rare and undesirable relationship and most specialists are advised to avoid it because it is a relationship that complicates planning and makes confusion.

Of all the above, two important observations must be made to avoid suspension and intersection of activities “dangling activities” (Rad, 2013, p. 20):

- The first relationship (FS) is the most used relationship, it is used to ensure that there is no undesirable intersection during the implementation process.
- Avoid the use of the relationship (SF), because it creates a situation of undesirable overlap between activities and thus complicates the process of implementation of the project.

3.2.5 Formulas and Design Forms of Business Networks.

There are different forms of network design work, and the reason for this difference is due to the type and nature of the project, as well as the nature of the activities of the project, there are two basic formulas for the design of business networks:

A. Designing networks based on activities on arrow (AOA): The activities are expressed through arrows, this means that the design of the work networks is based on the expression that the activities in the project are in arrow, the period of activity is written on the arrow, and for events it is expressed through the node or the circles. This formula is usually applied in PERT technique (Heizer & Render, 2011, p. 100). Figure (3.5) illustrates the representation of activities on arrows:

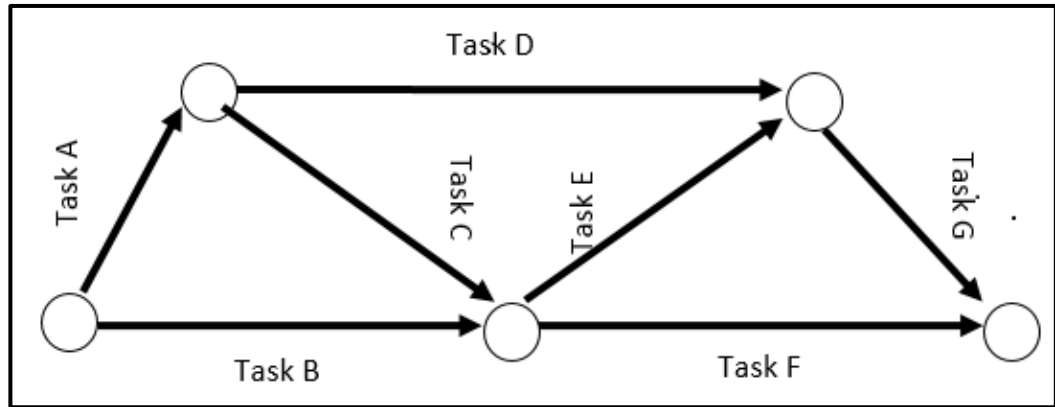


Figure 5: Design of Arrows-Based Work Networks (AOA).

Source: Lewies, James, (2007). Fundamentals of project management, 3th, New York: Project Management Institute, Inc. p. 72.

B. Designing Networks Based on the Activities On Node (AON): In this kind of formulas for the network's nodes are (Node) reflect activity while the arrow reflects the event, this formula is applied in (CPM), and writes the periods of time in the activity box or node as in Figure (3.6) (Krajewski, 2010, p. 78), this type is called multiple names such as (scheme of precedence, circuit diagram or linkage) and its features are easier than the first type in terms of its comprehension by users of the scheme (Lewis, 2001, p. 225).

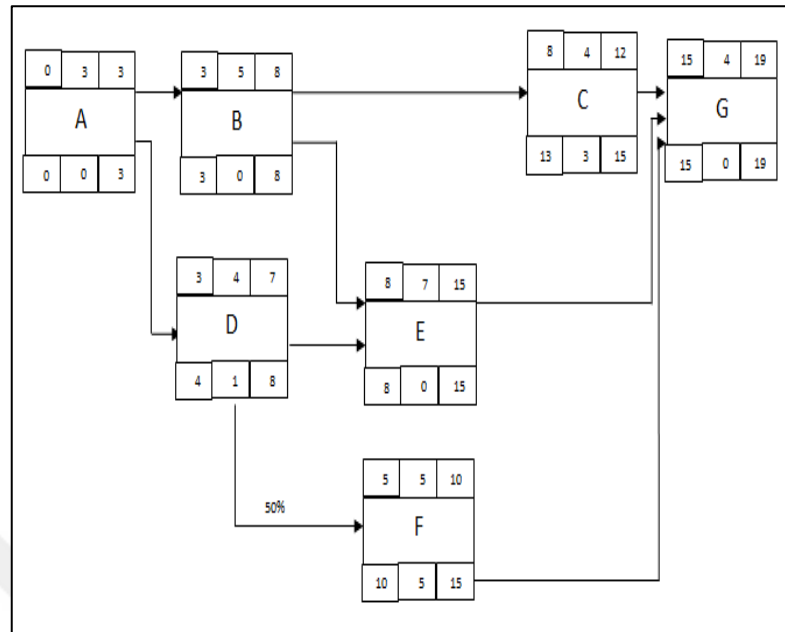


Figure 6: Design of Networks on the Basis of the Node (AON).

Source: Lester, Albert, (2014). Project Management, Planning, and Control, 6th, United States: Published by Elsevier Ltd. P. 116.

Both methods can be used in network analysis techniques, but project networks will be drawn in the practical aspect of current research according to the second method because they are more common in practical fields and have the following features: (Hillier & Lieberman, 2010, p. 401):

- The (AON) method is easier to create and configure than (AOA).
- The method of representation (AON) is easily understood by users, including managers, rather than (AOA).
- The method of representation (AON) is easily reviewed and scrutinized when project changes are made or made more than (AOA).

3.2.6 Advantages of Network Scheduling Schemes.

There are many ways in which the scheduling of projects, perhaps the most important are the critical path method CPM, the Program Evaluation and Review Technique PERT, the system of scheduling the specific operations and conduct the distribution of manpower, these methods have achieved widespread in the field of application in

organizations and in all types of projects (Mishra & Soota, 2005, p. 120), because they were characterized by many of the advantages addressed by most of the literature and scientific books on networks, including the following; (Kerzner, 2009, p. 494); (Lewis, 2001, p. 256):

A. Network diagrams form the basis of all planning and forecasting processes.

B. It helps the manager of the project in how resources are used to achieve cost and time objectives.

C. Provides a clear vision and allows managers to control a unique program.

D. It assists management in evaluating alternatives by identifying the time delays that affect project completion, with the possibility of determining the excess time between activities and the critical elements that lead to compliance with the deadline.

E. Can be considered as a means of examining the progress of work.

F. Demonstrates the independence of activities within the project.

G. Specifies the longest path or critical path.

H. Is a way to estimate the time and cost of the project, the most important in the project constraints and the most influential on the project plan.

3.3 The Difference between the PERT and the Critical Path Method CPM.

The critical path method has emerged from construction projects, while the PERT technique has evolved through R & D projects. Both ways share the same way in building the project network and in identifying the critical path on the network, and both of them is a method of planning, scheduling and project control.

There are some fundamental differences between the two methods, the PERT method is related to uncertainty regarding the estimated time of activities, while the critical path method deals with time estimates as somewhat inevitable, and the critical path method also extends to time and cost tradeoff (Mishra & Soota, 2005, p. 143).

According to the current study, project times and critical paths will be calculated according to the Critical Path method CPM because it is more suitable for projects where resource allocation problems, as well as activity times, are known and documented such as construction projects, therefore, the focus will be on explaining the critical path method and how to calculate time for project activities by applying its steps.

3.4 Network Calculations.

Network analysis involves two basic processes; (Lester, 2014, p. 106):

1. Draw the network and appraise the individual activities times.
2. Analyzing those times, in order to find critical activities and the amount of Float time in non-critical activities.

These processes are carried out through a set of calculations for network planning and analysis, using equations and mathematical relationships to find many values that represent indicators that help specialists and project managers to manage the risks of uncertainty in the project, the most important of which is the sequence that the researcher believes necessary:

A. Calculate Early and Late Times for Activities

Networks assume estimates of activity times, and the time of the activity being confirmed is determined the typical time frame for carrying out that activity.

The timing of the activities depends on the ability and experience of the project's management or its implementers and previous experiences with similar activities, the activity time usually indicates the arrow of the activity in the network (AOA) and on the node in the network (AON).

Both PERT and critical path method CPM to calculate early and late times include two types of Computations:

A.1 Forward Computations: These calculations usually start from the first event in the network and are sequentially extended to the last event in the network, this type of calculation is necessary to find the start and end times of the activities to determine the possible time to start the project, the early date of the first activity represents the start date of the project as a whole (Passenheim, 2009, p. 50).

The following figure shows the forward path of the calculations

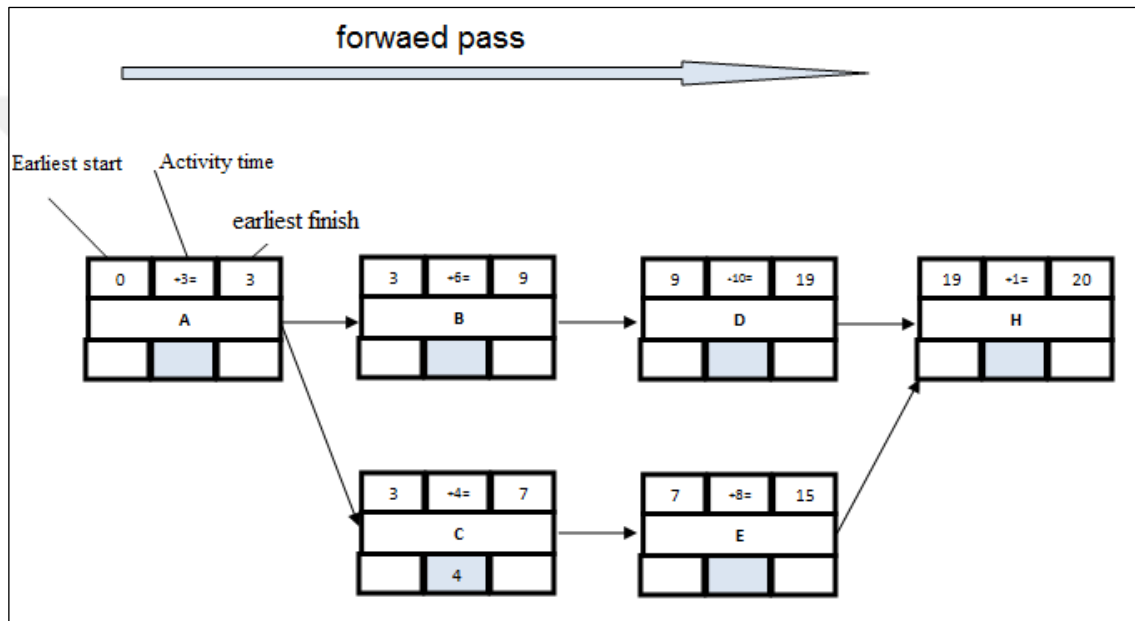


Figure 7: The Forward Path to Calculate the Early Times

Source: Peterson, Christine, (2013). The Practical Guide to Project Management, BookBoon.com, p. 31.

A.2 Backward Computations: These calculations are carried out for the purpose of calculating the latest start and finish times of the activities it starts from the endpoint of the forward end of the last event in the network down to the first event.

Through this method, late start and late completion of each activity are determined, where the late start date for any activity is the maximum date that the activity can begin without delaying the project from its expiry date, while the late completion date is the

maximum date that the activity can end without causing delay in the project as a whole (Schwalbe, 2007, p. 236).

The following figure shows the backward path of the calculations:

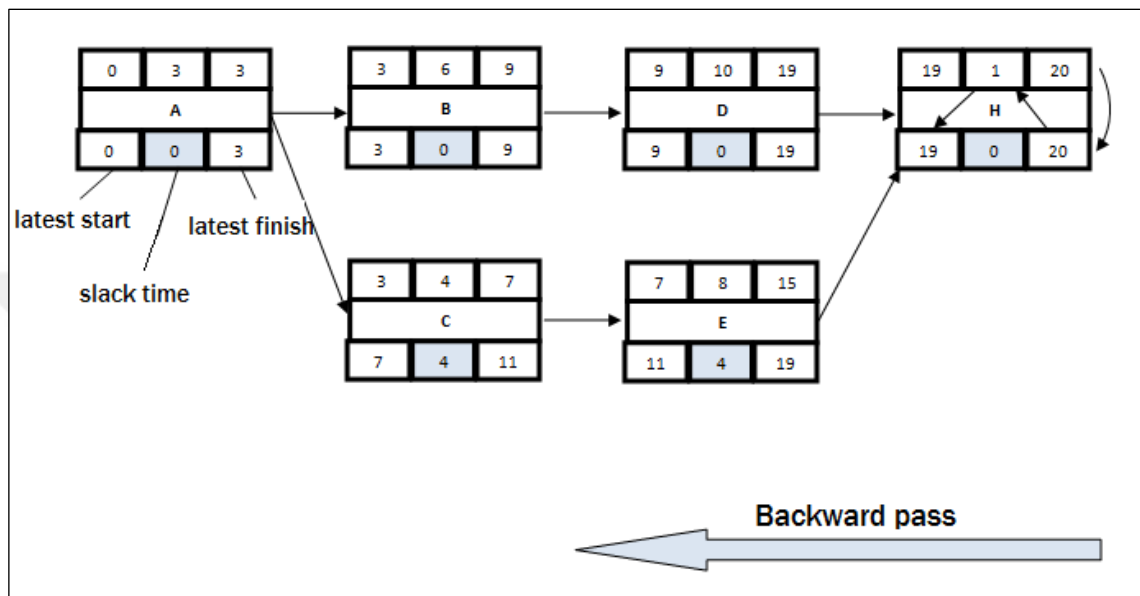


Figure 8: The Backward Path to Calculate the Late Times.

Source: Menesi, Wail, (2010). Construction Scheduling Using Critical Path Analysis with Separate Time Segments, Waterloo, Ontario, Canada, p. 15.

For the purpose of determining the time needed to complete the activities of the project it is necessary to calculate the early and late times and clarify them as follows and according to the sources; (Hillier & Lieberman, 2010, p. 477); (Stevenson, 2007, p. 774):

1. Earliest Start Time (ES): This time for the first activity in the network is zero, and for the following activities it is as early as possible to start the activity.

2. Earliest Finish Time (EF): equal to the early start time of the activity, plus the duration of the activity itself.

$$EF = ES + T$$

T: represents the time required to complete the activity.

3. Latest Start Time (LS): Starts by selecting subsequent activities for each activity in the network, after which the late start time and the late termination time are calculated minus the time that the activity takes.

$$LS = LF - T$$

4. Latest Finish Time (LF): It is the late start time of the activity plus the time of that activity.

Therefore, the full time available to perform the activity is equal to the difference between the early start time of the activity and the late completion time of the activity itself.

$$\text{Maximum Time Available} = LF - ES$$

When we want to calculate the early and late times for the activity there are several rules to be observed:

1. The early start time of the first activity in the project network at the first node should be equal to zero.
2. If there is one arrow linked to the node (one activity), the early start time for this activity (ES) will be the same time of early finish (EF) of the previous activity, for a node that is connected to more than one arrow within it, the early start (ES) time for subsequent activities is equal to the largest early finish (EF) time of previous activities
3. The late finish time of the last activity (LF) is equal to the time of early finish (EF) for the same activity, for the last node in the network.
4. If there is one arrow (one activity) goes outside of the node, the late finish time (LF) for the incoming activities will be equal to the late start time (LS) of the outbound arrow representing the subsequent activity, as the node owns more than one arrow goes out, the time of the late finish (LF) activities coming from it will be equal to the largest late start (LS) time of the exiting arrows.

B. Calculate the Float or Slack Time

The commencement of the activity may be delayed from the early start date without delaying the completion of the project on time, which occurs when there is a surplus of

time, and the surplus time (Float) is an amount calculated mathematically and a changeable value during the progress of the project and recorded in the project work plan (Action plan) and has more than one label (Slack, Float or excess path). In general, it represents the difference between the early start, early finish, late start and late finish (Pinto, 2007, p. 284).

It is necessary to maintain a certain amount of Float-Time as much as possible as it is the insurance and guarantee to complete the project within the specified time, more sources and literature agreed that there were three types of slack in activity time:

B.1 Total Slack: The maximum amount of time can be delayed by completing the activity without causing delay at the time of completion of the project as a whole, it is the difference between the (early, late) start and finish times (Nigel, 2002, p. 141).

If the (TS) value of the activity is zero, the activity is called the critical activity and is located on the critical path. If the activity is delayed, the activity that follows will be delayed, resulting in the delay of the project as a whole (Lewis, 2011, p. 524).

$$TS = LS - ES / TS = LF - EF$$

B.2 Free Slack (Float): It is also called the Minimum Slack (Fs) or (FF). It is equal to the early start time of the subsequent activity minus the time of early termination of the current activity, the activity can be delayed without delaying the early start of the following activities (Morder et.al, 1983, p. 79). It can be calculated according to the following formula:

$$FF = ES (\text{Succeeding}) - EF (\text{Activity})$$

The free slack (FS) of an activity is part of the total slack (TS) of that activity and can be used without affecting the sequence of activities (Nigel, 2002, p. 142).

B.3 Independent Slack (Float): It is the time that still available between the late finish of the activity and the early start of the next activity (Anshasi, 1997, p. 176). The independent slack time can be calculated using the following mathematical relationship:

$$IS = ES (\text{Succeeding}) - LF (\text{Activity})$$

We note from the previous mathematical relationships that the overall surplus represents the total slack from the two other types:

$$TS = Fs + Is$$

$$\text{Also: } IF \leq FF \leq TF$$

Because the free slack of an activity is equal to or less than the total slack of that activity, and because the total slack implicitly includes the independent slack, most project managers do not use the free slack and the independent slack but only using the total slack.

The outputs of the paragraphs discussed in the above paragraphs are fixed in the activity node in case the network is drawn according to "AON" and as shown in the diagram of the node in Figure (3.6). As follows:

Early start ES	Duration	Early finish EF
Activity description (A)		
late start LS	Total slack (TS)	Late finish LF

Figure 9: The data that installs in the activity node.

Source: Slack, Nigel, (2004). Operation Management, 4th, Published by Pearson Education Limited, P. 597.

C. Finding the Critical Path and Identifying Critical Activities

The path in any network can be defined as a set of interrelated activities from the beginning of the project to its end, and all activities (and thus all paths) must be completed to complete the project. (Vanhouke, 2012, 25).

Through scientific literature can diagnose the critical path and critical activities, it is through the sequence of the following steps:

- Completion of the above-mentioned arithmetic paragraphs for the purpose of determining the early and late times of the network as a whole.
- Specifies the number of paths for the network.
- Calculating the length of each path according to the times that have been identified.
- Choose the longer path that represents the critical path.
- Identify critical activities through the critical path.

Accordingly, determining the time required for each activity depends on the method followed. The differences between the CPM and PERT methods have already been clarified, the most important of these is the value of the estimated time for each activity. The CPM is often referred to as a reporting technique, while PERT is described as a probability approach. This description of both types is based on how the time required to complete each project activity is determined by the amount of certainty that is estimated for the project (Acuña, 2010, p. 8).

3.5 Project Crashing.

After completing the previous four arithmetic steps, the project management and planning staff can calculate the project's acceleration time based on the information and values provided by those paragraphs, project implementation is usually done using specific resources within the normal time required to carry out its activities. When needed to implement the project in a shorter time and the completion of the project early, The resort will be acceleration for some of the project activities (Crashing), by

using additional resources to reduce the time of these activities and thus reduce the completion time of the entire project, and the process of acceleration is the process by which the crashing of the completion time of the project with the willingness to bear the additional costs of this acceleration (Pinto, 2007, p. 322).

Usually, the acceleration process is not used except in certain cases, including those: (Khairuddin, 2011, p. 166):

- A.** There is an error in the basic scheduling of the project, such as estimating inaccurate execution times.
- B.** The creation of internal or external conditions that lead to the delay of certain critical activities, which necessitates the acceleration of certain activities in order to comply with the time of termination.
- C.** The acceleration may be in accordance with the owner's request to terminate the project before the specified time for a monetary reward.
- D.** There is a change in the laws and regulations that require amendments to the way the project is implemented or terminated early.

With all of the above mentioned on the methods of project scheduling and acceleration processes, we note that there is a "clear" correlation between time and cost, and the goal of the acceleration is to reach the optimal relationship between the cost and time through the process of exchange between them (Time-Cost Tradeoff), so the ultimate goal of network techniques is not only to develop planning, scheduling, and project monitoring but also to assess the possibility of access to the best relationship between cost and time, taking advantage of the excess time to accomplish the desired goal at the lowest possible cost, and sometimes it may be desirable to extend the duration of the project if There are a significant cost savings (reverse case), so the cost-time relationship is very important in project management. The following figure shows the reciprocal relationship between time and cost:

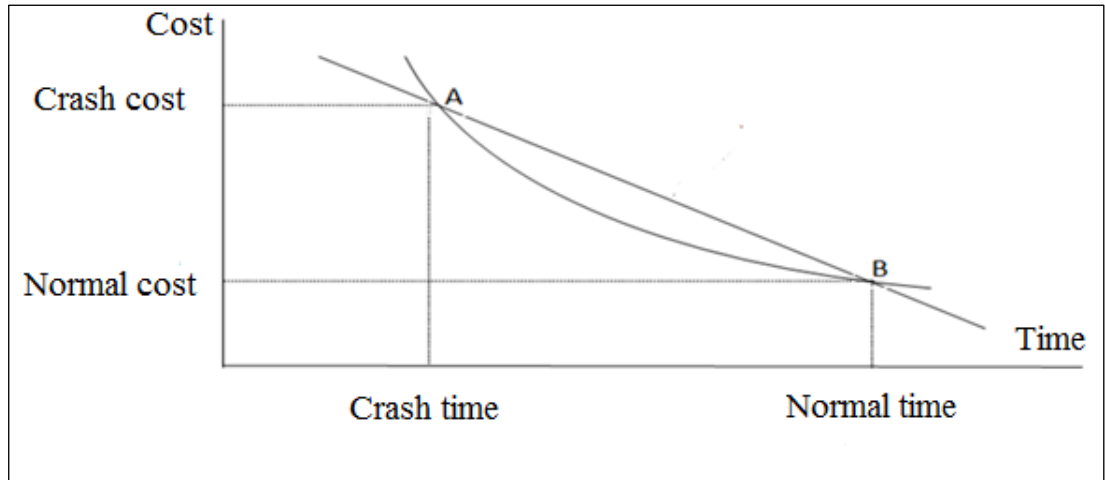


Figure 10: The Relationship between Time and Cost.

Source: Nahmais, Steven, (2009). Production and Operation Management, 4th, Published by McGraw.Hill Companies.Inc., 1221, P. 514.

The project shall have a normal cost according to the normal completion period and shall have another cost at the highest value according to the accelerated time period (crash point). Thus, there are two types of fixed times followed by two types of costs; (Stelth, 2009, p. 14); (Jacobs & Chase, 2008, p. 35):

- 1. Normal Time:** the time required for activity associated with the natural resources allocated to the activity and under normal conditions.
- 2. Crash Time:** The amount of time it takes to complete an activity if the administration wants to allocate additional resources for this activity.
- 3. Normal Costs:** the total expenditure used to implement the effectiveness within the normal time.
- 4. Crash Costs:** total natural and additional resources according to (crashing time).

The cost of crashing one-time unit is calculated according to the following (Cost Slope) Equation: (Telsang, 2008, p. 398):

$$\text{cost slope} = \left(\frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}} \right)$$

Cost slope: The cost added to shorten the duration of the activity for one-time unit, in other words, it is the (cost of speeding one unit of time) (Krajewski, 2013, p. 81).

Returning to figure (3.9), we note the relationship between the vocabulary of the cost of one-time unit (cost slope), showing the amount of the cost difference in proportion to the amount of time difference.



CHAPTER IV

MATHEMATICAL PROGRAMMING AND IBM-CPLEX

Introduction

The manager or decision maker faces operational, administrative, pricing and other difficulties that may constitute an obstacle to find the right decision, by studying many of the literature in terms of finding optimal solutions we found that in the view of the owners of the quantitative doctrine in the administration that the mathematical approach is the best solution to the problems of the manager, and the mathematical models are able to help for better understand the surrounding phenomena.

In short, the quantitative methods or so-called decision and information sciences or quantitative analysis or management science can be defined as the using of a variety of different sciences and modern scientific tools to analyze and study the administrative problems (business management, accounting, economics, etc...), social and other solutions of these problems after conversion to quantitative models, it includes several branches, including statistics, operations science, mathematics, and computer science (ALAli, Ibrahim, 2004, p. 177-208).

According to the methodology of the current study, this chapter will revolve around two axes: the first one is to learn about the science of operations research, specifically mathematical programming and how to formulate problems models by using it is equations. The second one will discuss the applications of computer science for

quantitative methods and how to formulate problems through to obtain the optimal solution

4.1 First Axis: Mathematical Programming M.P.

The application of operational research methods specifically mathematical programming in project management will lead to the management of the project or the responsible authorities to take appropriate measures to prevent any defect expected to occur, in accordance with plans considered and based on the scientific basis to achieve the main objectives of the project.

Mathematical programming is defined as the mathematical discipline used for the methods and theories of creating a minimum and maximum functions on groups defined by linear and nonlinear constraints, it is one of the branches of operations research and includes wide problems in the series of the decision-making and finding optimal solutions (Render, Barry, Ralph M. Stair Jr. & Michael E. Hanna, 2003, P. 233-333).

As it is considered the mathematical programming that are used in the various economic activities of the production and service facilities alike, especially with regard to the problems of production, distribution, storage, transport, and others that require solving a set of critical administrative decisions by the decision makers and the relying on scientific foundations and programs away from Principle of intuition and guesswork, this is characteristic of the management science it incorporates a broad scientific approach to decision making as it attempts to use mathematical methods and modern computer capabilities to solve difficult and irregular problems facing decision makers and provide optimal solutions.

4.1.1 Linear Programming L .P.

Linear programming is one of the most important means of solving many administrative, economic and military problems. In 1923 the French mathematician Jean Baptiste

Fourier had pointed out the potential contribution of linear programming in the future, The first use or application of linear programming by economist George Stigler was in the early 1940s, with the aim of identifying the components of the daily diet which provides the body with minimum requirements of vitamins, iron, and other materials at the lowest possible cost. It was later developed and used effectively In 1947, George B. Dantzig, who was then part of a research group known as Project SCOOP (Scientific Computation Of Optimum Programs), for a US Air Force, created a modest method to solve the problem of general linear programming.

The unusual computational efficiency and the power of simple mode, coupled with the high-speed digital computers availability, have made linear programming the ever-designed, most powerful method, and the quite applied, optimization method in the environment of business. Since then, many additional methods of problem-solving have been created, which reduced the assumptions of the model for linear programming and making the applications of the mathematical programming approach more widespread (Seah, J. Almalkawy, N. & Alhory, F., 2008, P. 15).

Linear programming is defined as a mathematical model to distribute a range of resources and limited possibilities to a number of competing needs for these resources within a set of constraints and fixed factors so that this distribution achieves the best result possible, linear programming models are the simplest and easiest mathematical models that can be established to address the dilemmas facing industrial, governmental, and companies of productive nature. The expression of Programming means putting in place steps to solve a particular issue or subject to achieve a certain goal, a Linear expression is the assumption that the phenomenon we are studying is linear (in the form of a straight line) and this assumption is often used to bring the reality closer to an easy mathematical formulation. Therefore the model, in general, is a part of the specifications of the whole so that all that is positive in the model is positive in all and everything negative in the model is negative on all, the model can be a mathematical formula on the specifications of a particular situation through a number of sports relations that Express the problem or situation that is studied in one way or another (Abdul Rasoul, 2001, P. 21).

4.1.1.1 Linear Programming Model Requirements.

The linear programming problem requires five basic characteristics: (Al-Hamed, M., Al-Azzawi, 2013, P. 9-10):

A. Defining the Goal: What it seeks to achieve is either an increase in profits or a reduction in cost, expressed in a mathematical form called an objective function.

B. Providing a Number of Alternatives: Linear programming is used when we have alternatives to solve the problem, if there is one alternative to solving the problem, there is no need to use it.

C. Resource Limitations: We need to use linear programming when resources are limited (scarce) such as human resources, materials, or machine hours, which are conditions for achieving the objective.

D. Linear Relationship: linear relationships must exist in the objective function and in the constraints (resources), so that any change in the quantities of production leads to increased profits or a reduction of the costs linearization with increasing quantity of production as well as the exhausted resources linearly with increased production quantity.

E. Non-Negative Constraints: This condition meets one of the assumptions of linear programming, which is a non-negativity condition. Therefore, a constraint cannot produce negative variables.

4.1.1.2 Formulation or Construction of a Linear Programming Model.

As we have already pointed out, the formulation of a particular administrative problem in the form of linear programming requires the construction of a mathematical model representing the administrative situation or problem. Thus, the administrative position or the problem must be understood accurately, which is the first step to solve it. The formulation of the linear programming model can outline its steps accordingly; (Al-Naimi, M., Al-Hamdani, R. & Al-Hamdani, A., 2011, P. 12); (Salkim, Harrey, M., 1975, P. 34):

A. Quantifying the Objective: It is expressed in the objective function, which is a phrase in the equation required to be maximized or minimized. It is usually in a financial or natural form, depending on the nature of the problem to be analyzed. The objective should be expressed quantitatively, such as the objective of maximizing profit or securing as small as possible of cost or to save as much time and effort as possible.

B. Identifying Constraints: The available resources must be specific, and those resources have to be measurable and expressed in a mathematical form in the form of equations.

C. The Condition of Non-Negativity: The decision variables in the problem must be positive or zero, but not negative.

The general formulation of linear programming can be described as follows:

$$MAX \text{ or } MIN (Z) = \sum_{j=1}^n C_j X_j$$

Subject to

$$\sum_{i=1}^m \sum_{j=1}^n a_{ij} x_j (\leq, =, \geq) b_i$$

$$X_j \geq 0 \quad (i = 1, 2, \dots, m) \quad , \quad (j = 1, 2, \dots, n)$$

Where:

a_{ij} , b_i , c_j : Constants which determine the context of the problem. Z : Represents the objective function. X_j : Decision variables. b_i : Identified resources. a_{ij} : The number of specific resources of type i that need to be allocated for per unit of j. c_j : The profit or cost of allocating resource i to produce one unit of j.

4.1.2 Integer Programming I.P.

With the large volume of organizations and multiple aspects of their activities appeared many variables and problems that affect one way or another in the possibilities of making the right decision, which requires the need to look for a new approach that helps to solve a number of the critical decisions facing the top management of the organizations. The linear programming model that has been mentioned above is continuous, meaning that the decision variables are pliable to be fractional. Often this is a factual assumption. For example, we can produce 4.3 gallons easily from a divisible material such as oil or water. It may also be reasonable to accept a solution that gives hourly production of cars at 6.4, if the model is based on average production per hour, the production has an explanation of production rates.

However, in many decision-making positions, the value of decision variables is in the form of integers. For example, when choosing the lowest-cost combination of the planes to be purchased according to the price, maintenance, and absorptive capacity. In such a case it is unreasonable to have the planes prepared in a fractional form also when selecting the most profitable combination of projects to be created and based on available financial resources, it is not appropriate for the number of projects to be in the form of fractional. Therefore, sometimes optimal fractional solutions are not realistic and the decision must be reconsidered.

The integer programming is one of the branches of mathematical programming. In 1958 it represented by the American mathematician Ralph.E.Gomory when he introduced the Gomory Cutting Places algorithm. It is looking at finding the optimal solution for problems containing the integer decision variables (Taha, H. A., 1979, 258). In general, the integer programming problem IP model is the same as the model of linear programming problem LP but some or all of the decision variables are an integer. It is formulated as follows

4.1.2.1 Integer Programming Types.

Depending on the types of decision variables, integer programming can be divided into four sections: (Grafinkel, R. S. & Nemhauser, G. L., 2003, P. 1-15):

A. Pure Integer Programming Models: If the standard units for all decision variables are indivisible and integer, in this case, they are called a Pure Integer Programming Models. Therefore, it has special algorithms for cutting the area of possible solutions for linear programming to reach all the integer values of the decision variables, because the integer programming is a subset of the possible solutions area for linear programming. The method which deals with this type of problems is called the Branch and Bound Method in which all the decision variables are an integer. It is formulated as follows:

$$\text{MAX or MIN } (Z) = \sum_{j=1}^n C_j X_j$$

Subject to

$$\sum_{i=1}^m \sum_{j=1}^n a_{ij} x_j (\leq, =, \geq) b_i$$

$X_j \geq 0$ and integer

($i = 1, 2, \dots, m$) , ($j = 1, 2, \dots, n$).

B. Mixed Integer Programming: If the problem contains two types of decision variables, the standard units of the first are divisible, in linear form, while the second one its decision variables units are in the form of an integer, that is mixed. In this case, it has a special algorithm which is called Gomory Cutting plan method that ignores the integer and solves it as linear programming problem and then the integers units are

selected from the solution. The mathematical formula for the mixed integer programming is not different from the formula for pure linear programming except in the constraint where some items are added.

$X_j \geq 0$ and some integer

C. Binary Integer Programming: In this type, the values of decision variables are binary, simply they are either zero or one, there are many realistic applications for this type, including how to determine the optimal number of service centers and positioning. As for its formulation, it shares the same formulation of pure integer programming and mixed integer programming in terms of the objective function and decision variables but there is a limitation in the formulation of the constraints. It is noted that some integer programming problems have a special structure and methods to solve them such as Transportation Problem, Assignment Problem, and also use certain methods to solve the integer problems such as the Simplex Method then use the Cutting Method or Branch And Bound Method method. The disadvantage of this method it requires a large number of steps, especially as the number of decision variables increases.

$X_j = 0$ or 1

D. Mixed Binary Integer Programming: In this problem, some of the decision variables are binary, and others are either integer or mixed values. It is formulated as follows:

$$\text{Min } Z = \sum_{j=1}^n C_{ij}X_i + \sum_{i=1}^m F_i y_i$$

Subject to:

$$\sum_{i=1}^m X_{ij} = d_j$$

$$\sum_{i=1}^m X_{ij} - y_i \sum_{j=1}^n d_j \leq 0$$

$$X_{ij} \geq 0$$

$$Y_i = 0 \text{ or } 1 ; i = 1, 2, \dots, n, j = 1, 2, \dots, n$$

Where:

X_{ij} : quantity transferred from i to j .

C_{ij} : the cost of moving one unit from i to j .

4.1.3 Modeling of Project Crashing Problems.

In many optimization problems, decision variables are in a linear form, it solved by applying linear programming technics, while others are in the form of integer decision variables, it solved by using the technics of integer programming.

As well as for the problems of project crashing, the duration of activity can be accelerated and reduced through the allocation of additional resources. Typically, this means increasing the direct expenses of the project implementation, this process is called the time-cost tradeoff problem (TCTP). In this case, the times of activities shall be in a linear form, which can be reduced from its time and is not affected by any restrictions. But there is another type of activities that have a restricted form of durations. In other words, there is a limited time sequence for activities termination time. For instance, in construction projects one of the projects includes activity (A) it's about pouring cement of the roof, the time of completion of this activity cannot be crashed and switch to the next activity because the cement drying time cannot be reduced. Therefore, the use of linear programming for the tradeoff between time and cost in such kind of activities be incorrect. Such problems are called the discrete time-cost tradeoff problems (DTCTP).

Over the three decades that had followed the emergence and development of project management techniques, the importance of the time-cost tradeoff problem (TCTP) had been recognized (Elmaghraby, S. E., 1993, P. 199-215).

In large-scale literature, the variances of problems assumed that the type of relationship between time and cost was linear (continuous), while the second type the discrete time-cost tradeoff problem (DTCTP) did not find much interest and was relatively few and dispersed, perhaps one of the main reasons for the lack of attention to this issue of the problem, due to the difficulties inherent in finding the best solution to the problem in this case. But there are at least two important reasons to consider the problem of separate exchange as an important problem, which are, the First: The cases of discrete alternatives are many and their occurrence is common. Second: discretization gives a suitable way to formulate a model for any time-cost relationship in general (Panagiotakopoulos, D., 1977, P. 183-195), (Robinson, D.R., 1975, P. 158-166).

Since then, many methods have been used to solve the problem of time and cost. The first attempt was made in 1965, by Meyer and Shaffer, where the integer mixed programming formula has been followed for the problem, on the other hand, in 1967 by Butcher, in 1975 by Robinson, where some dynamic programming methods were provided, in 1970, the approach presented by Crowston, branch-and-bound method, was one of the presented solutions, In 1979, results were also offered on the improvement of dynamic programming by Hindelang and Muth, in 1990 Tavares, has reviewed the discrete time-cost tradeoff problem under special constraints in which many of the solution methods were restudied and the results led to improving a lot of these methods (Csordas, H., 2011, P. 37-48).

As for the problem of the current study, the discrete time-cost tradeoff problem will be formulated by using the mixed integer programming equations described in this chapter.

4.2 Second Axis: The Applications of Computer Science for Quantitative Methods.

Quantitative methods science is concerned with identifying the uses of the computer and making use of them in achieving the optimal quantitative management solutions.

Perhaps most management science fields used by quantitative methods in computer applications are the Decision Support System as well as management information systems (MIS) to organize the data in order to coordinate, classify, analyze, and transform them into useful relationships and information then save them in a manner that

is easy to retrieve when needed. The most important programs that quantitative methods benefit in decision-making are as follows: win QSB, CPLEX, Lindo, and statistical applications Excel, SPSS, and Office MS for operations research applications, and others.

4.2.1 IBM ILOG CPLEX Optimization Studio.

This program is one of the most prominent optimization software, Especially in arithmetical (mathematical) and constraint programming, where the term of CPLEX is a shortcut to the Simplex method, which is one of the known techniques for solving linear programming, In 1988 CPLEX Optimization Inc. introduced the product (CPLEX) commercially for the first time. Then in 1997, it was purchased by ILOG Company, after that, IBM company acquired ILOG, in 2009.

IBM ILOG Optimization Studio is a merge of some independent features into a single package. It contains

- A.** IBM ILOG CPLEX Optimizer for the mathematical programming problems optimization.
- B.** IBM ILOG CP Optimizer for programming of constraint.
- C.** Optimization Programming Language (OPL) to formulate the problem model.
- D.** Integrated Development Environment (IDE).

CPLEX Optimization Studio provides an effective way to create distinct optimization models for mathematical programming problems.

All mathematical algorithms for solving linear programming problems, mixed-integer problems, and quadratic programming problems are already supported by CPLEX Optimizer.

CP Optimizer boosts all steps required to solve time-scheduling problems, including resources, activities, and tasks. While the modeling interfaces to several languages such

as Java, .net, Python, and C++ languages, including connectors to Matlab and Microsoft are all in the CPLEX Optimizer.

It is also attainable with full compatibility through most of the other widespread optimization modeling stuff, like GAMS, AMPL, MPL and Microsoft Solver Foundation.

4.2.1.1 Integrated Development Environment (IDE).

It is the space to make a project, evolve and rectify the model of the problem by using OPL language and its Script, utilize external data, scan and scout about various accessories of the model, turn on and debug and set the model, and eventually, create the results and test the solution. Next figure showed a snapshot of the IBM ILOG Optimization Studio IDE.

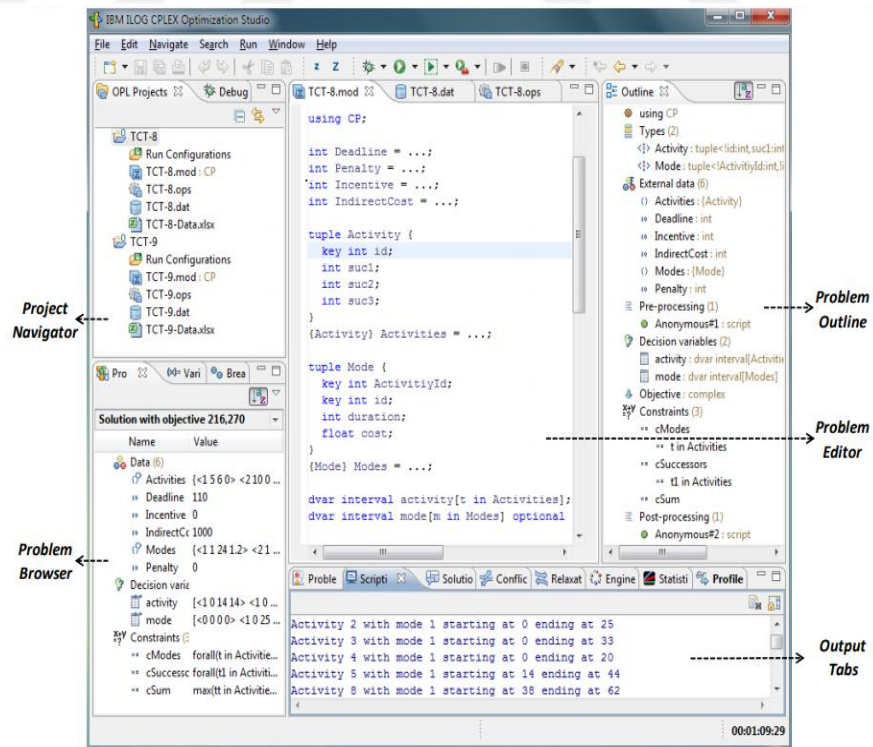


Figure 11: IBM ILOG Optimization Studio IDE.

4.2.1.2 Optimization Programming Language (OPL).

OPL is the language for modeling the optimization problems which in particular facilitates the figuration and solving of combinatorial optimization problems. In term of it is the language for modeling the optimization problems, OPL supplies high-level options, notations group and means of data mode to reduce the formulation time of optimization problems (Hentenryck, P. & Michel, 2000, P. 98).

OPL has been redesigned so that it is more appropriate with its linked script language. Also for the non-modeling forms, for instance, pre-processing, subsequent processing, and flow control. IBM ILOG Script for OPL is a scripting language (IBM ILOG OPL Reference Guide).

4.2.1.3 OPL Projects in IBM ILOG Optimization Studio.

In the IBM ILOG Optimization Studio a problem statement has ingredients as the following:

- A. Model Files:** Model (.mod) folders include all the OPL reports or representations.
- B. Data Files:** Data (.dat) folders are used for split-up the instance data from the model.
- C. Settings Files:** Settings folder (.ops) is used to modify the default values of parameters and options.
- D. Run Configurations:** Are used to back diverse enforcement configurations.

OPL project is a method used to link a problem model (.mod) together with one and more settings (.ops) and data (.dat) folders, It is possible for a project to has one or more model files according to the complexity of the problem. The next picture shows the OPL project Tab.

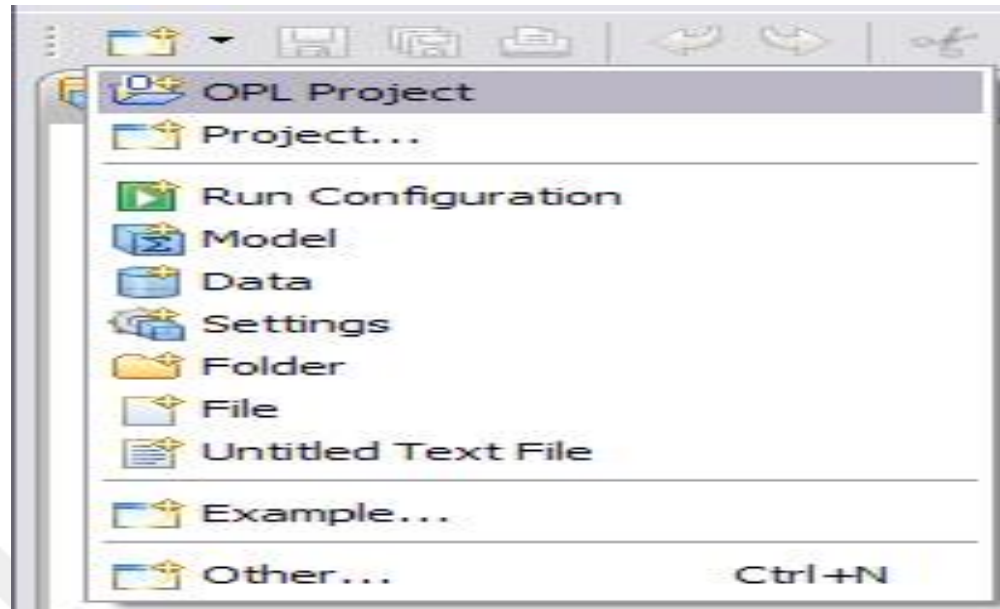


Figure 12: OPL Project Navigator Tab.

Relationships between data files, settings, and model files are defined by Run configurations files. data elements are confirmed by the model file but do not necessarily to initialize them. while The data files involve the arrangement of data elements stated in the model. The project file arranges all the regarding data, settings, and model files as well as Run configurations in the origin folder for the OPL project, it also prepares an appropriate path to maintain the connection between runtime options and linked files (IBM ILOG Optimization Studio V12.2 - Language User's Manual).

the handling projects processes for making, joining and deleting their related files such as settings, model, and data files, All are done in OPL Project Navigator.

4.2.1.4 Modeling Project DTCT Problems Using IBM ILOG CPLEX Optimization Studio.

The DTCT model of any optimization problem in IBM ILOG Optimization Studio is defined as an OPL project consisting of the following components:

- Each model definitions that is formulated using OPL are placed in a (.mod) file.

- The external data are accessed by linking to the spreadsheet through (.dat) file.
- In (.ops) file the optimization engine settings and parameters are determined according to the problem requirements.
- Define and maintain relationships between the files of settings, model, and data, are in the run configuration file.
- The external data are all saved in the spreadsheet file.

The data, decision variables, objective function and constraints statement, written in OPL language are contained by the model file, In addition, it contains some scripting phrases for OPL language. The model definition sections in OPL language are in details as follows:

1. Representation of Data: In the (.mod) file the (.dat) file is pointed out to in order to divide the data from the model, in large optimization problems, split the model from the data is an important feature for the superior organization of the model. The data referred to in the model file (.mod) are the project deadline, the number of activities, the sequence of activity in the project, the subsequent activity, duration and cost of each activity in its various forms, the cost of penalties and incentives for late or early termination, the cost and the deadline are represented as a numerical value while a combination of different data structures is used to represent the rest of the activities.

2. Decision Variables: they are the method of building for each activity so that one method for per activity will be chosen in the optimization operation in order to meet the constraints and objective function. In the model formulation in OPL language, decision variables are realized by the keyword “dvar”.

3. Objective Function: is to reduce either the total cost or the duration of the project, according to the election or chosen of ways of building for each activity. It is the total of sanction or reward for the duration of the project and direct cost. The objective function represented in OPL model by the keyword “Minimize”.

4. Constraints: in the (.mod) all the activities relationships are identified and specific the total completion time for the project to the deadline. In OPL statements constraints are represented by the keyword (subject to {}).

The getting knowledge and learning how to formulate a mathematical programming (mixed integer programming) to use it in formulating the (DTCT) problem in the first axis of this chapter, as well as knowing the steps that are led to building the model in OPL language, and how to apply in IBM ILOG Optimization Studio. Are the main goal of this chapter, This chapter served as a prelude to the practical part of the present study, where the methods which had discussed will be applied to solve the research problem.

CHAPTER V

IMPLEMENTATION

Introduction

This paragraph seeks to give an introduction to the Department of Engineering in the Sunni Endowment Bureau, and the types of projects it provides, planning, implementation, and supervision policies followed by it. As well as the project of the research sample, identify its dimensions in terms of justification for the establishment of the project, what is the purpose of its establishment, the quality of services that will be provided through it, how to start work on it, what are the financial and temporal determinants of the project, as well as identify the parties responsible for the design, implementation and financing of this project and who is the party and the segment benefiting from its results.

First: Engineering Department in the Sunni Endowment

The Engineering Department in the Sunni Endowment Bureau has two basic functions through the technical committees namely the direct implementation of some projects in the country and supervising the implementation of the projects executed by the contracting companies that receive the project tender, that is, the various projects may be tourism, residential, investment, and as a result, it is under a basic category of projects, namely construction projects.

The department is a key partner in the committees of receiving projects from the implementing agencies and then handing over the project to the beneficiary, the

department performs its tasks through the engineering and technical staff available in it. It has more than (110) engineers and (150) technicians in various specialties. They follow at least (250) projects in different fields between direct execution and supervision together or may be supervised only by During the supervisory committees, the planning process in the organization as a whole to implement and follow up the work is through reports only progress work, especially in the medium and simple projects, and in the more complex project's follow-up through the Gantt chart.

Second: School Project Muslim Bin Aqeel - Baghdad Province The project of establishing a school means the project of creating a new generation properly if it is implemented in accordance with its determinants in order to achieve the lofty goal of this project. In view of the importance of this goal, an important axis of the research side

1) The idea of a unified model for the design of Baghdad governorate schools

The concept of standard design according to standards or sometimes so-called traditional design of schools is a design due to the decision of the Department of Islamic Education to implement a set of schools with a similar design with some differences in the number and area of classrooms relative to the type of school.

There are three approved numbers for the school grades (12, 18, and 24) and in some designs, theater, cafeteria and laboratory. The selected project for current research is a class (18) with the additions listed. There is another type of design from schools, called model schools, it takes other designs, which are referred by design and implementation to the contracting companies, this type of school is not selected for this study, because the prevailing design is the traditional design. And to provide the best cost and time trade off to this project to the project management in the Sunni Endowment as well as the companies executing the project, to benefit from the results of the research in making decisions appropriate to the circumstances of the project differentiated.

2) School Project Specifications

The building area of the sample of the project is (6600) m², with (18) classrooms with (7) laboratories with an area of (42) m² for each laboratory, a theater hall with an area of (120) m² and a cafeteria with an area of (60) m². The estimated cost of the project amounted to (1,173,494,000) Iraqi Dinar, the completion period (300) days, and began work on the project (9/10/2017), and the date of delivery of the project (9/8/2018), and the project under implementation throughout the current research period and the completion rate until the end of the applied side amounted to approximately (70%).

The financing of school projects with standard criterions from (2003) so far is through the budget of the organization of management and investment funds of the Sunni Endowment. The implementation of schools will be through direct implementation or referral of the project to a contracting company.

The Muslim Bin Aqeel school project has been implemented by the company (Emaar Al Mamorah), the project executing company through a technical committee consisting of (one civil engineer, three supervisor of work, four technicians) cadres resident in the project site from its inception to completion, under the supervision one of the technical committees of the department of engineering in the Sunni Endowment and consists of (three civil engineers, one electricity engineer, one environment engineer, two technicians).

The current chapter revolves around two axes:

- The first axis presents the practical application of the critical path method (CPM) to the project of establishing the model school after its development through the addition of laboratories, recreational club, and sports hall.

In order to calculate the project's crash time and compare the costs versus the benefit of the process of accelerating and finding several alternatives, it is possible to choose the appropriate alternative according to the circumstances surrounding the planning and implementation stages, the application of this method has been selected for this type of project as it is a duplicate construction project (standard design) as well as the continuous need for it.

- The second axis, which distinguishes this search for others, is the formulation of the project time-cost crash problem to the mixed integer programming model and then convert it to the OPL language model, the final model will be analyzed by using IBM ILOG CPLEX Optimization Studio software and optimize the objective function.

5.1 First Axis: Proposed CPM Network for School Project.

The project includes several activities to complete the construction of this school's upgraded design, the initial design of which was carried out in advance in other locations in Baghdad governorate, and the executed projects were not even subject to the Gantt chart, the executing company executes the project according to a time plan that is subject to the vision of the resident engineer, but without a scientific name for the method of planning mentioned in the special literature in the field of project management.

So we found a great welcome by the Engineer to subject the project to the planning methods of the scientific methodology according to the methods studied, including the methods of network analysis and the application of the acceleration process to benefit from the results. Therefore, the project diagram has been initiated through the preparation of a timeline of information that allows for the drawing of a network plan according to the CPM method (Activity description, activity code, activity duration, previous activities (Predecessors), identification of relations between activities and direct cost of activity).

For the purpose of accuracy in work, the table was prepared through field visits to the work location and in cooperation with the resident engineer and supervisors of implementation and follow-up. Where data is installed in the next table to represent the baseline data for the network diagram:

Table 1: List of Activities for the School Project.

No	Activity	Activity Description	Duration (Day)	Predecessors	Cost (ID)
1	A	Start	0d		0
2	B	Demolition, Site planning	10d		10200000
3	C	Dirt Excavations	10d	B	7200000
4	D	Pour concrete into foundations	20d	C	114000000
5	E	Brick construction under foundations	10d	D	82800000
6	F	Pour the damp-proof course	5d	E	13650000
7	G	Burial in soil and mixed soil	7d	F	17925000
8	H	Construction above the insulating layer	15d	G	77550000
9	I	Casting bridges and the roof of the ground floor	30d	H	181200000
10	J	Brick construction of the first floor	8d	I	42000000
11	K	Casting bridges and ceilings for the first floor	30d	J	66000000
12	L	Marble works for surfaces	12d	K	36270000
13	M	Installation of doors and windows	18d	K	49122000
14	N	working in Interior Walls	60d	S	83820000
15	O	Floor works	100d	J S	193100000
16	P	Works of Alabaster	60d	N S	127500000
17	Q	Painting	70d	O S	9157000
18	R	Bathroom Works	125d	I S	21000000
19	S	Electrical works 1	20d	H F	10400000

Table...(Continued)					
20	T	Electrical works 2	100d	K	15600000
21	U	The outer fence	30d	O F S	15000000
22	V	The End	0d	L;M;N;S;P;T;R;U ;Q	0

Source: Project Documents - Engineering Committee Supervising the Implementation

Based on the previous table, which shows the sequence of activities in the project and the duration of each activity, we can now draw the project network and calculate the times for each node according to the steps explained in the theoretical aspect of the current study. The following figure illustrates the initial project network:

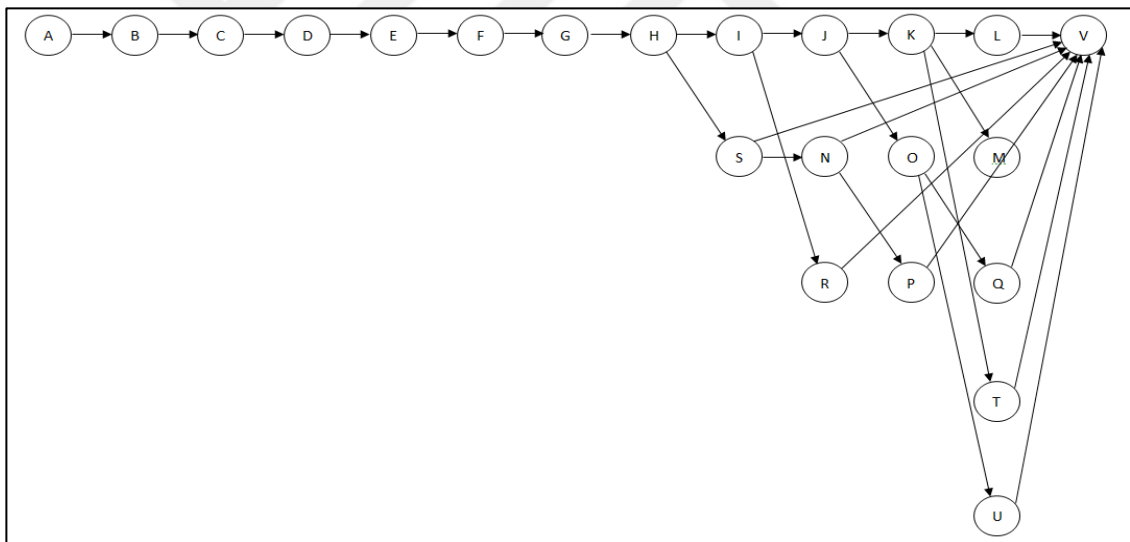


Figure 13: Project Network for the School Project

The following table presents the start and finish dates of each activity in the absence of any impediments and causes of delay, as well as determining the start and end time of each activity to meet the completion date of the project, in addition to determining the time of the slack for each activity:

Table 2: Computation of the Critical Path Method for School Project Activities.

No	Activity Name	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)	On Critical Path
1	A	0	0	0	0	0	0	Yes
2	B	10	0	10	0	10	0	Yes
3	C	10	10	20	10	20	0	Yes
4	D	20	20	40	20	40	0	Yes
5	E	10	40	50	40	50	0	Yes
6	F	5	50	55	50	55	0	Yes
7	G	7	55	62	55	62	0	Yes
8	H	15	62	77	62	77	0	Yes
9	I	30	77	107	77	107	0	Yes
10	J	8	107	115	107	115	0	Yes
11	K	30	115	145	155	185	40	No
12	L	12	145	157	273	285	128	No
13	M	18	145	163	267	285	122	No
14	N	60	97	157	165	225	68	No
15	O	100	115	215	115	215	0	Yes
16	p	60	157	217	225	285	68	No
17	Q	70	215	285	215	285	0	Yes
18	R	125	107	232	160	285	53	No
19	S	20	77	97	145	165	68	No
20	T	100	145	245	185	285	40	No
21	U	30	215	245	255	285	40	No
22	V	0	285	285	285	285	0	Yes

By observing the network, we can specify the number of paths in it that link the start node and the finish node, and determine the length of each path which is the total

estimated duration of activities along the path, the next table shows the paths of the project's network and indicates the critical path which is the longest path, its length according to the results of calculations (285) days is the least time to finish the project. As in the next table:

Table 3: The Paths for the Network Plan According to the Normal Times of the School Project.

Path Sequence	Path	Path length
First Path	A , B , C , D , E , F , G , H , I , J , K , L , V	157
Second Path	A , B , C , D , E , F , G , H , S , N , V	157
Third Path	A , B , C , D , E , F , G , H , S , V	97
Fourth Path	A , B , C , D , E , F , G , H , S , N , P , V	217
Fifth Path	A , B , C , D , E , F , G , H , I , R , V	232
<u>Sixth Path</u> <u>(Critical Path)</u>	<u>A , B , C , D , E , F , G , H , I , J , O , Q , V</u>	<u>285</u>
Seventh Path	A , B , C , D , E , F , G , H , I , J , O , U , V	245
Eight Path	A , B , C , D , E , F , G , H , I , J , K , T , V	245
Ninth Path	A , B , C , D , E , F , G , H , I , J , K , M , V	163

For the purpose of carrying out the process of compressing the time periods of project activities, it is necessary to determine the extent to which each activity can be accelerated and does it have an acceleration period? and specifying the maximum acceleration of activities that could be accelerated by increasing their resources if possible, as well as determining the total crash cost of each accelerated activity. By coordination with the engineering committee resident of the project consisting of five engineers and to benefit from the expertise of specialists in this area and the adoption of the method of interview and field visits to the site of the implementation of the project, a table was prepared with the basic data needed to calculate the project's crashing times, for the completion of activities and the crash cost, as well as the normal times and costs that were pre-configured and taken from table (1)

Table 4: Cost-Time Slope of the Activities.

Activity	Normal		Crash		Crash Cost-normal Cost (Δc)	Normal Time-Crash Time (Δt)	Cost Slope ($\Delta c/\Delta t$)
	Duration (Days)	Cost (ID)	Duration (Days)	Cost (ID)			
A(start)	0	-	-	-	-	-	-
B	10	10200000	6	12000000	1800000	4	450000
C	10	7200000	7	9300000	2100000	3	700000
D	20	114000000	20	114000000	0	-	-
E	10	82800000	7	84250000	1450000	3	483333
F	5	13650000	5	13650000	0	0	-
G	7	17925000	7	17925000	0	0	-
H	15	77550000	10	83550000	6000000	5	1200000
I	30	181200000	30	181200000	0	0	-
J	8	42000000	8	42000000	0	0	-
K	30	66000000	30	66000000	0	0	-
L	12	36270000	12	36270000	0	0	-
M	18	49122000	13	50722000	1600000	5	320000
N	60	83820000	50	107820000	24000000	10	2400000
O	100	193100000	80	231500000	38400000	20	1920000
P1	60	127500000	60	127500000	0	0	-
P2	50	154000000	50	154000000	0	0	-
P3	35	185000000	35	185000000	0	0	-
Q	70	9157000	50	25157500	16000500	20	800025
R1	125	21000000	125	21000000	0	0	-
R2	115	23000000	115	23000000	0	0	-
S	20	10400000	20	10400000	0	0	-
T	100	15600000	100	15600000	0	0	-

Table...(Continued)							
U	30	15000000	30	15000000	0	0	-
V(finish)	0	-	-	-	-	-	-

5.2 Second Axis: Implementation and Results.

After we have finished from the calculation of activities times and costs in their natural and accelerated cases, accordance with what we have mentioned and explained in Chapter four, “how to formulate the discrete time-cost tradeoff problem by the use of mathematical programming (mixed integer programming) and convert it to optimization programming language OPL”.

The discrete time-cost tradeoff problem model of the construction project of the Muslim bin Aqeel School was constructed, and the time constraints of each project activities were identified, as well as the new deadline required to complete the project through it which is 230 days. The following snapshot shows part of the problem model written by OPL

```

dvar float+ yc;
dvar float+ yq;
dvar int+ p1 in 0..1;
dvar int+ p2 in 0..1;
dvar int+ p3 in 0..1;
dvar int+ r1 in 0..1;
dvar int+ r2 in 0..1;
dvar float+ p_duration;
dvar float+ r_duration;

// the model
minimize 450000*yb+700000*yc+483333*ye+1200000*yh+320000*ym+2400000*
subject to {
xc-xb+yb>=10;
xd-xc+yc>=10;
xe-xd>=20;
xf-xe+ye>=10;
xg-xf>=5;
xh-xg>=7;
xi-xh+yh>=15;
xj-xi>=30;
xk-xj>=8;
xl-xk>=30;
xm-xk>=30;
xn-xs>=20;

```

The code is annotated with three categories on the left side:

- Declarations Decision Variables:** Points to the first eight lines of code (dvar float+ yc; to dvar float+ r_duration;).
- Objective function:** Points to the line starting with 'minimize'.
- Constraints:** Points to the block starting with 'subject to {' and ending with 'xn-xs>=20;'. The individual constraint lines are: xc-xb+yb>=10; xd-xc+yc>=10; xe-xd>=20; xf-xe+ye>=10; xg-xf>=5; xh-xg>=7; xi-xh+yh>=15; xj-xi>=30; xk-xj>=8; xl-xk>=30; xm-xk>=30; xn-xs>=20;

Figure 14: Part of Model (Mod.) File of (DTCTP) Model

The model was implemented by using the IBM ILOG Cplex Optimisation Studio, where the program took only about 9 seconds to solve the problem. The next table shows the optimal solution for the discrete time-cost tradeoff problem for the Muslim bin Aqeel construction project

Table 5: Optimization Results for (DTCTP) for School Construction Project.

Activity	Final activity duration (day)	Reduced value (day)	Total crush cost (ID)
Xb	6	4	1800000
Xc	7	3	2100000
Xd	20	0	0
Xe	7	3	1450000
Xf	5	0	0
Xg	7	0	0
Xh	10	5	6000000
Xi	30	0	0
Xj	8	0	0
Xk	30	0	0
Xl	12	0	0
Xm	18	0	0
Xn	60	0	0
Xo	80	20	38400000
Xp	60	0	0
Xq	50	20	16000500
Xr	115	10	2000000
Xs	20	0	0
Xt	100	0	0
Xu	30	0	0

However, the table above shows the cost to be added to complete the project in 230 days is 67750500 ID. Therefore, through the use of project scheduling methods and the scientific approach for optimizing the problems we could reduce the duration for completing the construction project of Muslim bin Aqeel School by 45 days, which increases the original cost of the project from 1173494000 to 1241244500 ID.

CHAPTER VI

CONCLUSION

The main objective of this study is to highlight the mechanisms for the implementation of construction projects in the province of Baghdad, specifically projects belonging to the Ministry of Sunni Endowment, to address cases of disorganization, where most of the projects take more than expected execution time.

The reason for this is related with unfamiliarity the managers with scientific applications of projects implementation. Therefore, one of the projects was selected and scheduled according to one of the scientific methods of scheduling projects, which is the critical path method CPM and calculated the critical activities times and the acceleration times, which in itself is a monitoring tool to measure the progress of work in the project. And because of the multiplicity of activities and their complexity in construction projects due to differences in alternatives, the model of the discrete time-cost tradeoff problem was modeled using the mixed integer programming, then convert it to the optimization programming language OPL, thereafter by using IBM ILOG Cplex the problem model solved. The results showed that it is possible to reduce the delivery time by 19.29% Less than the expected time by increasing the total cost by 5.77%.

The study demonstrated the important role played by project management techniques in the organization of the projects work and address the delay in the times of completion, we recommend using it by contractors and decision-makers in the implementation of projects, especially in the province of Baghdad and Iraq in general.

The study also highlighted the uses of operation research science in formulating decision-making problems and optimizing the solution for the large and complex

problems. We can understand from the existence of many problems in decision-making and delay many of the projects, that there is no existence of the use of these sciences in the context of the work of the Ministry of Sunni Endowments in Iraq. Therefore, the Ministry's Higher Management should take note of this point and take it into consideration to improve the workflow.

Finally, IBM ILOG CPLEX Optimization Studio is one of the most important software used nowadays in solving the problems around al of world because of it contains features, characteristics, and speed in the solution of problems, so advised by many researchers and decision makers.

REFERENCES

1. Stelth, P., (2009). Projects' Analysis through CPM (Critical Path Method). Master in Management Science, the School of Doctoral Studies, Isles International University (European Union).
2. Schroeder, Roger, G. (2007). Operation Management A Contemporary Concepts and Cases. 3rd ed., The McGraw – Hill Companies, inc. USA.
3. Baldwin, A., & Bordoli, David. (2014). A Handbook for Construction Planning and Scheduling. John Wiley & Sons, Ltd.,UK.
4. Burke, R. (2009). Project Management: Planning & Control Techniques. 4th ed., John Wiley& Sons, LTD, New York.
5. Anderson, D.R., Sweeney, D., & Williams, T.A. (2000). An Introduction to Management Science: Quantitative Approaches to Decision Making. New York: South-Western College Publishing.
6. Meredith, j. R., Mantel, S. J., Shafer, S. M., & Sutton, M. M. (2008). Project Management in Practice. 3rd ed., John Wiley & sons, Inc., New York.
7. Calmes, J. 2006."Project Management – Made Easy". by Entrepreneur Media, Inc.,USA
8. Gido, j. & Clements, J. P. (2006)."Effective Project Management". 2nd ed., printed by Thomson higher education in Canada.
9. Slack, N., Chambers, S., & Johnston, R., (2004)."Operations Management". 4th ed., An imprint of Pearson Education, England, New York, west publishing.
10. Nagarajan, k. (2004)."Project Management". 2nd ed., printed in India at Saras graphics, New Delhi.
11. Guide, A. (2000). A Guide to Project Management Body of Knowledge. Project Management Institute, Newton Square, Pennsylvania, U.S.A.

12. Guide, A. (2008). Project Management Body of Knowledge (PMBOK Guide).
In Project Management Institute Newtown Square, Pennsylvania, U.S.A.
13. Guide, A. (2004). Project Management Body of Knowledge (PMBOK Guide).
In Project Management Institute Newtown Square, Pennsylvania, U.S.A.
14. Larson, E. W., & Gray, C. F. (2011). "Project Management: The Managerial Process". 5th ed., Published by McGraw-Hill/Irwin, New York.
15. Lewis, J. P. (2001). "Project planning scheduling and Control". 3rd ed., by The McGraw-Hill Companies, Inc., New York.
16. Lewis, J. P. (2007). "Fundamentals of Project Management". 3rd ed., The McGraw-Hill Companies, Inc., New York.
17. Lewis, J. P. (2011). "Project planning scheduling and Control". 5th ed., by The McGraw-Hill Companies, Inc., New York.
18. Rad, N. K. (2012). "Guide for the Most Famous Project management". by bookboon.com.
19. Rad, N. K. (2013). "Project Scheduling Rules". by bookboon.com.
20. Willim, M. (2008). "The Principle of Project Management". printed by site point Pty. Ltd. In Canada.
21. Harmsen, H., & Et, A. (Workgroup) (2006). "Project Management Handbook". This work is licensed under the Creative Commons Attribution- Non-Commercial-Share-Alike 2.5 License, San Francisco, USA.
22. Benator, B., Thumann, A. (2003). "Project Management and Leadership Skills for Engineering and Construction Projects". Published by The Fairmont Press, Inc., New York and Basel.
23. Meredith, J. R. & Mantel, S. J. (2012). "Project Management: Managerial Approach". 8th ed., John Wiley& sons, Inc., New York.
24. Krajewski, L. J. & Ritzman, L. P., & Malhotra, M. K. (2013). "Operations management: processes and supply chains". 9th ed., Pearson Education Inc.USA.
25. Heizer, J. & Render, B. (2011). "Principle of Operations Management". 6th ed., Pearson Education Inc., New Jersey.
26. Abdullah, A. A., Mukmin, M. N., & Samad, Z. A. (2011). Application of Project Management Methods in the Construction of Bungalow House Project: A Case

- Study in Kuala Terengganu, Malaysia. *International Journal of Economics and Management Sciences*, 2011 Vol.1, No.2, 42-58.
27. Chretienne, P., & Sourd, F. (2003). "PERT scheduling with convex cost functions". *Theoretical Computer Science*, 292 ,145–164.
 28. Cooke, B. (2015). " Management of Construction Projects". by John Wiley & Sons, Ltd.,UK.
 29. Wong, Y. (1964). "Critical Path Analysis for New Product Planning". *Journal Marketing*, Vol. 28, 63-59.
 30. Moder, J., Phillips, C., & Davis E. (1983). "Project Management with CPM/PERT and precedence". 2nd ed., Published by Van Nostrand Reinhold Company Inc., New York.
 31. Reid, D. R., & Sanders, N. R. (2002). "Operation Management". John Wiley & Sons, Inc., Asia.
 32. Passenheim, O. (2009). "Project Management". by Bookboon.com.
 33. Al-Anshasi, A. A. (1997). "Management of Engineering Projects". First Edition, Palestine, Gaza, p177.
 34. Al-Fadhl & Al-Obaidi, (2010). "Project Management Quantitative Approach". Dar Al-Rawqq Publishing and Distribution.
 35. Dwood, L. N., AL-Zubaidi, S., & Mohamed, (2012). Using Critical Path Method for Planning Maintenance Work in an Electric Power Plant. *Journal of Engineering and Technology*, vol. 30, no: 8, p.197-211.
 36. AL-Sumaidaie, G., (2002). Adopting Criteria for Evaluating the Performance of Construction Project Execution Administrations to Avoid Time Spoils. Master of Construction Engineer, The University of Technology, Iraq.
 37. Khairuddin, M., (2012). Contemporary Project Management. First Edition, Amman, Jordan.
 38. Pinto, J. K., (2007)."Project Management Achieving Competitive Advantage". BY Pearson Education, Inc.Upper Saddle River, New Jersey, p:288.
 39. Al-Fadl & Al-Obaidi, (2010). "Project Management Quantitative Approach". Dar Al-Rawqq Publishing and Distribution, p.187.

40. Rad, N. K. (2012). "Guide for the Most Famous Project management". by bookboon.com.
41. Rad, N. K. (2013). "Project Scheduling Rules". by bookboon.com.
42. Lester, A. (2014). Project Management, Planning, and Control. 6th, United States: Published by Elsevier Ltd., P.116.
43. Hillier, F. S. & Lieberman, G. J. (2010). "Introduction to Operations Research". 9th ed., The McGraw – Hill companies, Inc., New York.
44. Kerzner, H. (2009). "Project Management: A Systems approach to planning, scheduling and controlling". 8th ed., John Wiley & sons, Inc., New Jersey.
45. Mishra, R.C., & Soota, T. (2005). "Modern Project Management". Published by New Age International (P) Ltd., New Delhi.
46. Lester, A. (2014). "Project Management Planning and Control". 6th ed., Published by Elsevier Ltd, USA.
47. Nasir, A., (2007). Management of construction projects. Second Edition, Cairo.
48. Aziz, S., Abdul Majeed, M. & Mohamed, J., (2011). Designing a Genetic Algorithm to Find the Critical Path to Optimizing the Enterprise Business Network. Al-Rafidain Journal of Computer Science and Mathematics, 9(1), p.187-210.
49. AL-Ali, I., (2004). Introduction to Operations Research. Syria, Tishreen University, Lattakia, p.177-208.
50. Peterson, C. (2013). The Practical Guide to Project Management. BookBoon.com, p. 31.
51. Schwalbe, K. (2002). "Information technology project management". 2nd ed., Thomson course technology a division of Thomson on son learning, Inc., printed in Canada.
52. Schwalbe, K. (2007). "Information technology project management". 5th ed., Thomson course technology a division of Thomson on son learning, Inc., U.S.A.
53. Menesi, W. (2010). Construction Scheduling Using Critical Path Analysis with Separate Time Segments. Waterloo, Ontario, Canada, 2010, p. 15.
54. Stevenson, W. J. (2005). "Operations Management". 8th ed., The McGraw – Hill Companies, Inc., USA.

55. Stevenson, W. J. (2007). "Operations Management". 9th ed., The McGraw – Hill companies, Inc., USA.
56. Smith, N. J. (2002). "Engineering Project Management". 2nd ed., Published by Blackwell science Ltd, USA.
57. Vanhouke, M. (2012). "Project Management with Dynamic Scheduling". Springer-Verlag Berlin Heidelber.
58. Nahmais, S. (2009). Production and Operation Management. 4th ed., Published by McGraw.Hill Companies. Inc., 1221, P. 514.
59. Jacobs, R. F. & Chase, R. B. (2008). "Operation and Supply Management". McGraw – Hill, New Delhi.
60. Render, B., Ralph M., Stair J. & Michael E. H. (2003). "Quantitative Analysis for Management". 8th ed., Prentice-Hall, New Jersey, USA, 233-333.
61. Salkim, H. M. (1975). "Integer programming Addison". Wesley publishing Co., Inc., Reading, Mass chapter 2, 34.
62. Jihad, S., Al-Malkawi, N., & Al-Houri, F. (2008). Quantitative Research, Process Research and Application. Amman, Jorden, (15).
63. Al-Moussawi, A., (2001). Introduction to Operations Research. Jordan, p. 22-25.
64. Al-Azzawi, M., (2013). Quantitative Methods in Administrative Sciences. Jordan, p. 9-11.
65. Al-Naimi, M. and Al-Hamdani, R., (2011). Operations Research. Jordan, p. 12.
66. TAHA, H. A. (1975). Operations research an introduction. Macmillan, New York, USA, Chapter 8, p.258.
67. GRAFINKEL R. S. and NEMHAUSER G. L. (2003). "Integer Programming". Math3902 Operation Research, CHAPTER 1, (1-15).
68. Elmaghraby, S.E. (1993). "Resource allocation via dynamic programming in activity networks". European Journal of Operational Research 64, 199-215.
69. Panagiotakopoulos, D. (1977). "A CPM time-cost computational algorithm for arbitrary activity cost functions". INFOR 15, 183-195.
70. Robinson, D. R. (1975). "A dynamic programming solution to cost-time tradeoff for CPM". Management Science 22, 158-166.

71. Bohan, H., (2012). Developing a proposed system of organizational structure to manage multiple construction projects at the same time. Master Thesis, Department of Civil Engineering, University of Baghdad.
72. Shaaban, M., (2012). Modern management of projects using value acquired - concept and application. King Fahad National Library, Riyadh.
73. Hafeeza, S., (2014). A Comparison of Models of Traditional and Modern Business Networks in Planning and Project Control. Case Study in Quantitative Methods. Faculty of Economic and Commercial Sciences, University of Mohamed Khader, Algeria.
74. Hentenryck, P., Michel, L., Perron, L., & Régis, J. C. (1999). Constraint Programming in OPL. In Nadathur, G. (Ed.). Principles and Practice of Declarative Programming (Vol. 1702, pp. 98– 116). Berlin, Heidelberg: Springer Berlin Heidelberg. Retrieved from <http://www.springerlink.com/content/w7v4135554847126/>
75. ILOG, I. (2010). Ibm Ilog Cplex Optimization Studio. V12.2, OPL Language Reference Manual, International Business Machines Corporation.
76. ILOG, I. (2010). Ibm Ilog Cplex Optimization Studio. V12.2, OPL Language Reference Manual, International Business Machines Corporation.
77. Csordas, H. (2011). Activities with Multi-Parameters in Time-Cost Trade-Off. Hungary, Pollack Periodica, Vol. 6, No. 2, p. 37–48.
78. Kelley Jr, J. E. (1961). Critical-path planning and scheduling: Mathematical basis. Operations research, 9(3), 296-320.

APPENDIX A

The OPL modeling of the DTCTP in IBM ILOG Optimization Studio for the Muslim Bin Aqeel school construction project

```
* OPL 12.6.0.0 Model
* Author: pc
* Creation Date: Jul 1, 2018 at 12:04:27 PM
*****/

// variable

dvar float+ xb; : The linear value of normal duration for activity B.
dvar float+ xc; : The linear value of normal duration for activity C.
dvar float+ xd; : The linear value of normal duration for activity D.
dvar float+ xe; : The linear value of normal duration for activity E.
dvar float+ xf; : The linear value of normal duration for activity F.
dvar float+ xg; : The linear value of normal duration for activity Q.
dvar float+ xh; : The linear value of normal duration for activity H.
dvar float+ xi; : The linear value of normal duration for activity I.
dvar float+ xj; : The linear value of normal duration for activity J.
dvar float+ xk; : The linear value of normal duration for activity K.
dvar float+ xl; : The linear value of normal duration for activity L.
dvar float+ xm; : The linear value of normal duration for activity M.
dvar float+ xn; : The linear value of normal duration for activity N.
dvar float+ xo; : The linear value of normal duration for activity O.
```

```

dvar float+ xp; : The linear value of normal duration for activity P.
dvar float+ xq; : The linear value of normal duration for activity Q.
dvar float+ xr; : The linear value of normal duration for activity R.
dvar float+ xs; : The linear value of normal duration for activity S.
dvar float+ xt; : The linear value of normal duration for activity T.
dvar float+ xu; : The linear value of normal duration for activity U.
dvar float+ xv; : The linear value of the end event (the termination of the
project)
dvar float+ yb; : The linear value of normal duration for activity B.
dvar float+ yc; : The linear value of normal duration for activity C.
dvar float+ ye; : The linear value of normal duration for activity E.
dvar float+ yh; : The linear value of normal duration for activity H.
dvar float+ ym; : The linear value of normal duration for activity M.
dvar float+ yn; : The linear value of normal duration for activity N.
dvar float+ yo; : The linear value of normal duration for activity O.
dvar float+ yq; : The linear value of normal duration for activity Q.
dvar int+ p1 in 0..1; : The first integer value of normal duration for
activity P which will be selected or ignored by the solver
dvar int+ p2 in 0..1; : The second integer value of normal duration for
activity P which will be selected or ignored by the solver
dvar int+ p3 in 0..1; : The third integer value of normal duration for
activity P which will be selected or ignored by the solver
dvar int+ r1 in 0..1; : The first integer value of normal duration for
activity R which will be selected or ignored by the solver
dvar int+ r2 in 0..1; : The second integer value of normal duration for
activity R which will be selected or ignored by the solver
dvar float+ p_duration;
dvar float+ r_duration;

// the model

```

minimize

$$450000*y_b+700000*y_c+483333*y_e+1200000*y_h+320000*y_m+2400000*y_n+1920000*y_o+800025*y_q+127500000*p_1+154000000*p_2+185000000*p_3+21000000*r_1+23000000*r_2;$$

Minimize

450000 (cost for crash per unit of B)* y_b (number of crash unit for B)+ 700000 (cost for crash per unit of C)* y_c (number of crash unit for C)+ 483333 (cost for crash per unit of E)* y_e (number of crash unit for E) + 1200000 (cost for crash per unit of H) * y_h (number of crash unit for H) + 320000 (cost for crash per unit of M) * y_m (number of crash unit for M) + 2400000 (cost for crash per unit of N) * y_n (number of crash unit for N) + 1920000(cost for crash per unit of O) * y_o (number of crash unit for O) + 800025 (cost for crash per unit of Q) * y_q (number of crash unit for Q) + 127500000 (cost for the first alternative of P) * p_1 + 154000000 (cost for the second alternative of P) * p_2 +185000000 (cost for the third alternative of P) * p_3 + 21000000 (cost for the first alternative of R) * r_1 + 23000000 (cost for the second alternative of R) * r_2 .

subject to {

$$x_c-x_b+y_b \geq 10;$$

The start time for activity C – The normal time for activity B + The crash time for activity B. should be greater than or equal to 10.

$$x_d-x_c+y_c \geq 10;$$

The start time for activity D – The normal time for activity C + The crash time for activity C should be greater than or equal to 10.

$$x_e-x_d \geq 20;$$

The start time for activity E – The normal time for activity D should be greater than or equal to 20.

$$x_f-x_e+y_e \geq 10;$$

The start time for activity F – The normal time for activity E + The crash time for activity E should be greater than or equal to 10.

$$x_g-x_f \geq 5;$$

The start time for activity Q – The normal time for activity F should be greater than or equal to 5.

$$x_h - x_g \geq 7;$$

The start time for activity Q – The normal time for activity F should be greater than or equal to 7.

$$x_i - x_h + y_h \geq 15;$$

The start time for activity I – The normal time for activity H + The crash time for activity H should be greater than or equal to 15.

$$x_j - x_i \geq 30;$$

The start time for activity J – The normal time for activity I should be greater than or equal to 30.

$$x_k - x_j \geq 8;$$

The start time for activity K – The normal time for activity J should be greater than or equal to 8.

$$x_l - x_k \geq 30;$$

The start time for activity L – The normal time for activity K should be greater than or equal to 30.

$$x_m - x_k \geq 30;$$

The start time for activity M – The normal time for activity K should be greater than or equal to 30.

$$x_n - x_s \geq 20;$$

The start time for activity N – The normal time for activity S should be greater than or equal to 20.

$$x_o - x_j \geq 8;$$

The start time for activity O – The normal time for activity J should be greater than or equal to 8.

$$x_o - x_s \geq 20;$$

The start time for activity O – The normal time for activity S should be greater than or equal to 20.

$$x_p - x_n + y_n \geq 60;$$

The start time for activity P – The normal time for activity N + The crash time for activity N should be greater than or equal to 60.

$$x_p - x_s \geq 20;$$

The start time for activity P – The normal time for activity S should be greater than or equal to 20.

$$x_q - x_o + y_o \geq 100;$$

The start time for activity Q – The normal time for activity O + The crash time for activity O should be greater than or equal to 100.

$$x_q - x_s \geq 20;$$

The start time for activity Q – The normal time for activity S should be greater than or equal to 20.

$$x_r - x_i \geq 30;$$

The start time for activity R – The normal time for activity I should be greater than or equal to 30.

$$x_r - x_s \geq 20;$$

The start time for activity R – The normal time for activity S should be greater than or equal to 20.

$$x_s - x_h + y_h \geq 15;$$

The start time for activity S – The normal time for activity H + The crash time for activity H should be greater than or equal to 15.

$$x_s - x_f \geq 5;$$

The start time for activity S – The normal time for activity F should be greater than or equal to 5.

$$x_t - x_k \geq 30;$$

The start time for activity T – The normal time for activity K should be greater than or equal to 30.

$$x_u - x_o + y_o \geq 100;$$

The start time for activity U – The normal time for activity O + The crash time for activity O should be greater than or equal to 100.

$$x_u - x_f \geq 5;$$

The start time for activity U – The normal time for activity F should be greater than or equal to 5.

$$x_u - x_s \geq 20;$$

The start time for activity U – The normal time for activity S should be greater than or equal to 20.

$$xv - xl \geq 12;$$

The start time for activity V – The normal time for activity L should be greater than or equal to 12.

$$xv - xm + ym \geq 18;$$

The end event for the project – The normal time for activity M + The crash time for activity M should be greater than or equal to 18.

$$xv - xn + yn \geq 60;$$

The end event for the project – The normal time for activity N + The crash time for activity N should be greater than or equal to 60.

$$xv - xs \geq 20;$$

The end event for the project – The normal time for activity S should be greater than or equal to 20.

$$xv - xp \geq p_duration;$$

The end event for the project – The normal time for activity P should be greater than or equal to one of the alternatives of activity P.

$$xv - xt \geq 100;$$

The end event for the project – The normal time for activity T should be greater than or equal to 100.

$$xv - xr \geq r_duration;$$

The end event for the project – The normal time for activity R should be greater than or equal to one of the alternatives for activity R.

$$xv - xu \geq 30;$$

The end event for the project – The normal time for activity U should be greater than or equal to 30.

$$xv - xq + yq \geq 70;$$

The end event for the project – The normal time for activity Q + The crash time for activity Q should be greater than or equal to 70.

$$xv \leq 230;$$

The end event for the project should be less than or equal to 230.

```
yb<=4;
```

The crash time for activity B should be less than or equal to 4.

```
yc<=3;
```

The crash time for activity C should be less than or equal to 3.

```
ye<=3;
```

The crash time for activity E should be less than or equal to 3.

```
yh<=5;
```

The crash time for activity H should be less than or equal to 5.

```
ym<=5;
```

The crash time for activity M should be less than or equal to 5.

```
yn<=10;
```

The crash time for activity N should be less than or equal to 10.

```
yo<=20;
```

The crash time for activity O should be less than or equal to 20.

```
yq<=20;
```

The crash time for activity Q should be less than or equal to 20.

```
p1+p2+p3==1;
```

Only one should be selected from the alternatives of the duration of activity P, when one of the alternatives selected then the value of others are 0.

```
p_duration==60*p1+50*p2+35*p3;
```

```
r1+r2==1;
```

Only one should be selected from the alternatives of the duration of activity R, when one of the alternatives selected then the value of others are 0.

```
r_duration==125*r1+114+r2;
```

```
}
```

CURRICLUM VITAE

PERSONAL INFORMATION

Surname, Name: Abd, Ibrahim

Nationality: Iraqi

Date and Place of Birth: 01/04/1993 – Baghdad

Marital Status: Single

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EDUCATION

DEGREE	INSTITUTION	GRADUATION
BA	AL-Iraqia University - Baghdad / Faculty of Administration and Economics	2016
High School	AL-Aqsa High School - Baghdad	2012

BUSINESS EXPERIENCE

YEAR	INSTITUTION	POSITION
2011-now	Ministry of Suni Endowment	Assistant Department Manager
2013-2014	Caterpillar Company	Marketing

FOREIGN LANGUAGES: English

AREAS OF INTEREST: Literature, Sport, History.