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RESEARCH ARTICLE **ENGINEERING MANAGEMENT & OPERATIONS**

Optimizing Project Management Practices in Healthcare Construction: An Evaluative Case Study of Zliten Central Hospital

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ABSTRACT

The study aimed to evaluate project management practices and applications in executing health sector projects, specifically focusing on the maintenance and development project of Zliten Central Hospital as a case study. The research addresses a central problem: despite the significant evolution in mechanisms and techniques used by construction companies and consultancy firms to manage project execution, weaknesses in professional performance may still emerge. This deficiency is often associated with improper planning and a lack of precise understanding of engineering planning, leading to a loss of control over the essential components of project management. The study reached several key findings, most notably: The project management in the case study does not fully recognize the importance of applying engineering methods in project planning and management, which resulted in poor resource allocation, particularly time management. The findings indicate that implementing engineering management techniques leads to a reduction in project duration, as evidenced by the project time being shortened to 18 months instead of 22 months. Furthermore, the application of engineering management methods enhances project cost control through techniques such as Earned Value Management (EVM). The use of these methods shortens completion time without compromising cost or quality. Additionally, the network analysis technique contributed to defining project activities and reducing execution time, while the results highlighted that the Critical Path Method (CPM) remains one of the most successful tools for determining the overall project duration.

تحسين ممارسات إدارة المشاريع في إنشاءات الرعاية الصحية :دراسة حالة تقييمية لمستشفى زليتن المركزي

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الكلمات المفتاحية
الإدارة الهندسية
القيمة المكتسبة
المشروع الإنشائي
تقنية بيرت
طريقة المسار الحرج (CPM)

الملخص

هدفت الدراسة إلى تقييم ممارسات وتطبيقات إدارة المشاريع في تنفيذ مشاريع القطاع الصحي، وذلك بالتركيز على مشروع صيانة وتطوير مستشفى زليتن المركزي بوصفه دراسة حالة. وتتناول الدراسة مشكلة رئيسية تتمثل في أنه، على الرغم من التطور الكبير في الآليات والتقنيات المستخدمة من قبل شركات المقاولات والمكاتب الاستشارية في إدارة تنفيذ المشاريع، إلا أن ضعف الأداء المهني قد يظل ظاهرًا .وغالبًا ما يرتبط هذا الضعف بسوء التخطيط وعدم الفهم الدقيق للتخطيط الهندسي، مما يؤدي إلى فقدان السيطرة على العناصر الأساسية لإدارة المشروع. وقد توصلت الدراسة إلى عدة نتائج رئيسية، من أبرزها أن إدارة المشروع في دراسة الحالة لا تدرك بشكل كامل أهمية تطبيق الأساليب الهندسية في تخطيط وإدارة المشاريع، الأمر الذي أدى إلى ضعف في تخصيص الموارد، وخاصة إدارة الوقت. وتشير النتائج إلى أن تطبيق تقنيات الإدارة الهندسية يؤدي إلى تقليل مدة المشروع، حيث تم تقليص زمن تنفيذ المشروع إلى 18 شهرًا بدلًا من 22 شهرًا .بالإضافة إلى ذلك، فإن تطبيق أساليب الإدارة الهندسية يعزز التحكم في تكاليف المشروع من خلال تقنيات مثل إدارة القيمة المكتسبة (EVM). كما أن استخدام هذه الأساليب يساهم في تقصير مدة الإنجاز دون التأثير على التكلفة أو الجودة .علاوة على ذلك، ساهمت تقنية تحليل الشبكات في تحديد أنشطة المشروع وتقليل زمن التنفيذ، بينما أوضحت النتائج أن أسلوب المسار الحرج (CPM) يُعد من أنجح الأدوات في تحديد المدة الكلية للمشروع.

Introduction

In light of the growing human needs to meet comprehensive development requirements and align with modern technological advancements, there is an increasing demand for expansion in the construction industry. This expansion aims to fulfill essential needs, such as building public

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hospitals, schools, and commercial and industrial facilities. Consequently, official bodies and consultancy offices are required to supervise the management and execution of these projects, addressing technical challenges to ensure completion within the specified time and required quality. Despite the noticeable evolution in the mechanisms, tools, and techniques used by these entities for project management, certain strengths, weaknesses, and professional performance gaps may emerge in the specialized agencies tasked with project execution [1].

The construction industry employs various engineering project management methods, including Network Analysis Technique (NAT), Gantt Chart Technique (GT), Project Evaluation & Review Technique (PERT), Critical Path Method (CPM), Value Engineering (VE), and the Earned Value Method (EVM) for project cost planning and control. Given that a project may involve thousands of diverse tasks—some independent and others interdependent—the execution process requires a sophisticated set of resources. Considering the limitations of these resources and the need for precise cost and time calculations, it becomes essential to apply scientific methods, particularly Operations Research, to allocate and reallocate resources efficiently. This ensures optimal utilization and enhances performance by reducing both execution time and costs [2].

Based on this integrated understanding that every project has specific goals to be achieved with high quality and within a set timeframe, the urgent need for professional construction project management becomes evident. It is a contemporary specialized administrative field that incorporates various elements, managerial expertise, mechanisms, technical structures, and techniques capable of effectively utilizing management principles [3].

Literature Review

(Ghanem, 2011) conducted a study to analyze project management practices in the housing and utilities sector [4]. The study aimed to evaluate practices followed by public administrations in Palestine and explore effective techniques and tools for the public sector. Using a descriptive-analytical approach, a questionnaire was distributed to (35) public sector project managers. The results revealed inefficiencies in Palestine's public sector project management compared to global standards, noting a lack of information feedback and failure to generalize lessons learned, which led to lower project success rates.

(Al-Obaidi, 2009) studied the impact of strategic factors on improving the effectiveness of administrative performance evaluation for projects [5].

Through a descriptive-analytical method, the researcher surveyed (30) individuals across top and executive management levels. The study concluded that strategic factors positively impact performance evaluation. It also noted that project management actively involves target groups throughout the project lifecycle and focuses on alternative means to achieve outputs at lower costs, maximizing value-added from inputs. (Sulaiman, 2005) authored a study titled: "Applying the Critical Path Method to Avoid Delay Problems in Construction Projects" [6]. The objective was to develop a management system using CPM and value-added techniques to prevent delays. Data was collected from (204) engineers and managers in Libya. Results showed a scarcity of scientific research related to time monitoring in
construction and a significant deficiency in using CPM in Libya, primarily due to top management's refusal to adopt such techniques in planning.

(Al-Taie, 2009) in a study titled: "Cost Management and Planning in Construction Projects" [7], emphasized the importance of sound management and precise cost planning from the early stages. The findings revealed a lack of clarity in programming and planning, insufficient cost data, and a decline in the efficiency of planning staff. There was a notable weakness in utilizing the three levels of planning, with an over-reliance on routine planning focused solely on time while neglecting value engineering and quality improvement.

(Al-Jazaeri, 2008) discussed the use of PERT and CPM in balancing time and cost [8]. The study highlighted theimportance of operations research in resource allocation to optimize performance and reduce execution time. Results indicated a clear lack of scientific methods in resource allocation and emphasized that effective project management reflects clearly defined execution responsibilities. Previous studies indicate that most construction projects, locally and globally, suffer from cost overruns due to various factors. The current study differs by focusing on the impact of Engineering Management methods specifically in the Health Sector, drawing on international experiences to evaluate the Libyan context.

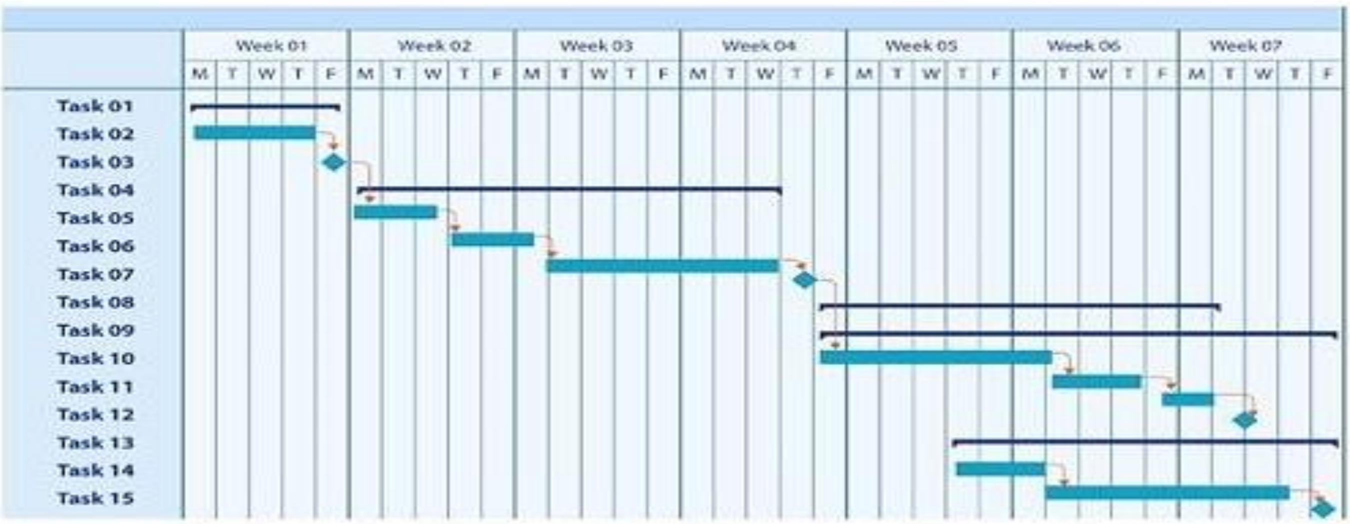

Figure 1: A model illustrating the plotting method of the Gantt Chart technique

Project Management Practices and Application

Gantt Chart Technique (GT)

The Gantt chart is one of the oldest and simplest methods for Scheduling and Loading. Introduced by Henry Ganttpioneer of the scientific movement, it remains in use today in industries and service centers like hospitals and schools. It is considered a traditional descriptive control method that has been widely used since 1900 [9].

Network Analysis Technique

Network analysis is a relatively modern approach in project management, emerging to address the limitations of the Gantt method. In the late 1950s, network techniques like CPM and PERT were developed. Both provide a graphical approach to project scheduling and planning, helping managers visualize required times, expected completion dates, and technical interdependencies. These methods also enable monitoring progress and identifying deviations for corrective action. Another evolved method is GERT (Graphical Evaluation and Review Technique) [10]. (Figure 2 shows a simple project network diagram ending in 32 weeks)

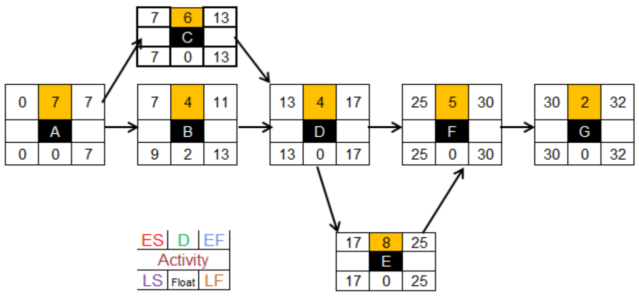

Figure 2: Project scheduling network diagram

Critical Path Method (CPM)

The Critical Path Method (CPM) was notably utilized in 1973 by the Egyptian Armed Forces during the Suez Canal crossing and was first introduced in Iraq in 1975 for the construction of the Hemrin Dam. CPM serves as a vital tool for planning, executing, and monitoring large-scale, complex projects by assigning a single time estimate to each activity. This method identifies a specific set of activities that require intensive focus during planning and execution; the completion of the project within the designated time and budget relies heavily on these activities located on the critical path. The Critical Path is defined as the longest path through the network, representing the maximum duration required to complete the project from the start event to the end event [11].

Project Evaluation and Review Technique (PERT)

The primary objective of this technique was to design a system for planning the Polaris missile production project, ensuring tight control over execution to meet deadlines. Application results showed that PERT reduced the project's duration by approximately two full years—completing the project in four years instead of the initial six-year estimate. Due to this remarkable success, PERT gained widespread recognition in both military and civilian sectors, eventually becoming a standard requirement for all contractors dealing with the U.S. Department of Defense [12].

Value Engineering (VE)

The core of Value Engineering (VE) lies in studying, analyzing, and examining every component of a service and each stage of its production to identify opportunities for achieving real reductions in total costs. Similar to Target Costing (TC), Value Engineering is applied during the design phase. The primary cost concept in the VE approach is "designed cost"—costs that have not yet occurred but are projected for the future based on the chosen design decisions [13].

Earned Value Method (EVM)

This method is used to measure and evaluate the performance of a completed project by comparing the volume of planned work against actual progress to determine if the project is on track. Although Earned Value calculations are typically performed using computers, it is crucial to understand the mathematical foundations and their implications. Earned Value represents the budgeted cost of the work actually performed within a specific timeframe. It is also referred to as the Budgeted Cost of Work Performed (BCWP), which is determined by summing the cost estimates of activities that have been officially completed [14].

Results and Discussion

Case Study

The hospital is located within the boundaries of Zliten City, covering an approximate total area of 12,000 square meters. Classified as a service facility, it initially had a capacity of 480 beds. The hospital has been undergoing maintenance for over 15 years, and its capacity is expected to reach 720 beds upon completion. It comprises various medical, paramedical, and administrative departments. As of 2016, the hospital staff reached approximately 1,700 employees across all specialties. The facility includes 13 administrative offices and 8 departments, each containing several sections to manage hospital operations.

Table (1) provides details regarding the maintenance and development project contract for Zliten Central Hospital, executed by the Organization for Development of Administrative Centres (ODAC) in cooperation with Sama General Contracting Company.

Table 1: Maintenance and Development Contract for Zliten Central Hospital

No.	Item	Contract Data
1.	Contract Number	(106/2007)
2.	Contract Value	29,989,019,000 LYD
3.	Original Duration	22 Months
4.	1st Extension Period	8 Months
5.	2nd Extension Period	9 Months and 15 Days
6.	3rd Extension Period	5 Months and 15 Days
7.	Site Handover Date	July 17, 2007
8.	Work Commencement Date	July 17, 2007
9.	Scheduled Completion Date	May 17, 2009
10	Overall Project Completion Rate	80.50%

Table (2) outlines the project activities, durations, and costs according to the contract, divided into 21 activities required for project completion.

Analysis of Delays

Upon reviewing the contract documents and technical reports, it was noted that the execution period underwent multiple extensions due to variation orders in the project scope. These were based on instructions from the project owner, the Organization for Development of Administrative Centres (ODAC), authorized under the General People's Committee Decree No. [371] of 1989.

Technical reports indicated that time extensions were not only due to scope changes but primarily resulted from poor time estimation, inadequate selection of subcontractors, and a lack of specialized technical expertise in medical equipment.

Consequently, the researchers consulted various construction consultancy firms and reviewed similar regional projects to accurately redefine activity durations

Table 2: Project Activities, Durations, and Costs

No.	Activity Code	Activity Description	Duration (Week)	Cost (LYD)
1.	**A**	Site Mobilization and Preparation	5	35,326.470
2.	**B**	Engineering Design and Mapping	4	25,430.000
3.	**C**	Procurement 1	7	922,325.348
4.	**D**	Excavation and Backfilling	3	15,725.249
5.	**E**	Concrete Works for Surface Structures	3	16,438.475
6.	**F**	Procurement 2	9	1,412,702.725
7.	**G**	Control Room Construction (Battery & Inverter Setup)	5	68,652.000
8.	**H**	Installation of Surface Structures	2	25,794.990
9.	**I**	Installation & Connection of Array Panels	1	45,842.479
10	**J**	Battery Installation and Connection	2	19,304.477
11	**K**	Inverter Installation and Connection	1	15,326.386
12	**L**	Internal Electrical Wiring for Panel Arrays	2	12,328.453
13	**M**	Charge Controller Installation and Connection	2	13,347.614
14	**N**	Automated Measurement & Recording System Setup	1	17,325.487
15	**O**	Diesel Generator Installation (75 kVA)	2	14,513.000
16	**P**	Grounding/Earthing System Installation	2	15,845.847
17	**Q**	Connecting Panels to Control Room via Underground Cables	1	12,947.374
18		Wiring between Panel Arrays and Charge Controllers	2	13,722.535
19		Wiring between Panel Arrays and Charge Controllers	3	14,608.627
20		Street Lighting System Installation	1	70,350.000
21		Connecting Central System to the Village Internal Grid	3	14,254.743

Project Components

The costs of the primary project components have been distributed as illustrated in Table (3), in accordance with project contract No. (106/2007) regarding the maintenance and development of Misrata [or Zliten] Central Hospital

Table 3: Cost Distribution of Project Components

No.	**Description**	**Value (LYD)**	**Percentage of Total Contract Value**
1.	Engineering Design Works	600,266.000	2.00%
2.	Demolition, Removal, and Transport to Public Dumps	3,192,452.550	10.65%
3.	Construction (Masonry) Works	668,328.100	2.22%
4.	Plastering Works	266,700.000	0.22%
5.	Painting Works	567,506.500	0.88%
6.	Floor and Wall Cladding (Tiles + Marble)	2,841,517.00	1.90%
7.	Metalworks, Doors, Windows, and Suspended Ceilings	2,153,604.000	9.50%
8.	Water Supply, Sanitary Works, and Stormwater Drainage	1,098,502.000	7.18%
9.	Insulation and Waterproofing Works	2,410,224.610	3.66%
10	Electrical Works	10,088,842.940	8.03%
11	Miscellaneous and Electromechanical Works (incl. HVAC)	6,101,075.300	33.64%
	Total	**29,989,019.000**	**100%**

Table 4: Activities, Durations, and Float for the Case Study Project

No.	**Activity Name**	**Activity Description**	**Activity Duration (Days)**
1.	**A**	Engineering Design Works	80
2.	**B**	Demolition, Removal, and Transport to Public Dumps	78
3.	**C**	Construction (Masonry) Works	125
4.	**D**	Plastering Works	135
5.	**E**	Painting Works	145
6.	**F**	Floor and Wall Cladding (Tiles + Marble)	95
7.	**G**	Metalworks, Doors, Windows, and Suspended Ceilings	116
8.	**H**	Water Supply, Sanitary Works, and Stormwater Drainage	124
9.	**I**	Insulation and Waterproofing Works	120
10	**J**	Electrical Works	172
11	**K**	Miscellaneous and Electromechanical Works (incl. HVAC)	160
		Total Duration	**1350**

Results &Discussion

Based on Table (4), it is evident that poor planning and inaccurate time estimation for project activities—totaling 1,350 days—led the contractor to repeatedly request time extensions. This reflects a lack of expertise, particularly among local contractors in project management. These factors will be taken into account during data collection and analysis by employing Engineering Management techniques to demonstrate their impact, alongside the use of specialized project management software and Excel.

It is worth noting that other submitted bids proposed durations exceeding 1,000 days. However, the flawed selection process—based solely on the lowest price and an unrealistic completion period of 22 months—was a primary cause for extending the contract three times. Consequently, the project remains incomplete as of the date of this research due to ongoing disputes between the contracting parties. This highlights the critical importance of utilizing engineering methods throughout the project lifecycle, from planning and execution to monitoring and final closure.

Applying Engineering Management Methods in Project Execution

To achieve the study's objectives regarding project management practices at Zliten Central Hospital, several methods will be addressed. This begins with engineering planning using Network Analysis, followed by project monitoring with a focus on cost control using the Earned Value Method (EVM)—one of the most vital engineering management tools for measuring project variance and progress.

Network Analysis Method

To apply this method to the maintenance and development project of the Zliten Central Hospital (the subject of this study), similar projects within the health sector were reviewed. Additionally, interviews were conducted with several consultants and engineers experienced in general project management and healthcare sector projects specifically. These practices were gathered, applied to the case study project, and categorized in Table (5).

Table 5: Activities and Their Time Durations According to the Contract

No.	Activity Name	Activity Description	Duration (Days)	Activity Cost (LYD)
1.	**A**	Engineering Design Works	65	600,266.000
2.	**B**	Demolition, Removal, and Transport to Public Dumps	70	3,192,452.550
3.	**C**	Construction Works	95	668,328.100
4.	**D**	Plastering Works	112	266,700.000
5.	**E**	Painting Works	112	567,506.500
6.	**F**	Floor and Wall Cladding (Tiles + Marble)	88	2,841,517.000
7.	**G**	Metalwork, Doors, Windows, and Suspended Ceilings	102	2,153,604.000
8.	**H**	Water Supply, Sanitary Works, and Rainwater Drainage	124	1,098,502.000
9.	**I**	Insulation Layer Works	114	2,410,224.610
10	**J**	Electrical Works	134	10,088,842.940
11	**K**	Miscellaneous and Electromechanical Works (incl. HVAC)	122	6,101,075.300
Total			**1150**	

The following Figure (3) illustrates the Gantt Chart implemented in accordance with the project contract.

It is observed from Figure (3) that activity planning relied solely on Finish-to-Start (FS) relationships. This reflects a misunderstanding by the project planners, which led to an illogical and unjustified increase in duration. The planning prepared according to the contract does not require such lengthy timeframes to complete the project; this clearly indicates that the failure to apply engineering management tools directly contributed to poor management, planning, and cost control. Furthermore, the engineering management did not adopt the Network Analysis method or apply lead/lag relationships between activities.

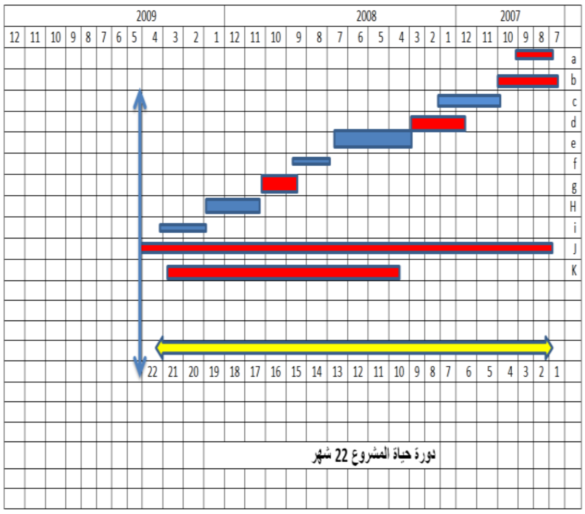

Figure 3: Gantt chart implemented according to the project

By applying engineering management practices to the project, it was possible to reschedule and divide it into (17) activities, each with its allocated time. This resulted in a comprehensive calculation for all project components, totaling 540 days, allowing for day-to- day monitoring and control of each activity.

Project management must focus on the (12) activities located on the Critical Path. This facilitates easier monitoring of resources, labor, subcontractors, and other project management processes, thereby mitigating the risk of cost overruns resulting from unexpected delays. In this context, the time control process is viewed as a comparison between actual performance and the planned schedule to identify deviations, evaluate possible options, and make appropriate decisions.

Accordingly, the project was planned electronically, allowing for the control of activity timings by simply adjusting Early and Late start/finish times—a method proven effective using spreadsheet software (Excel). The activities and their durations, shown in Table (6), were also represented according to a Gantt Chart, as illustrated in Figure (2). Note that eleven main activities were entered to complete four sectors of the project work, effectively representing (44) activities distributed equally (11 activities per sector).

The following Figure (4) illustrates the Network Diagram extracted from the Excel program. The figure indicates the project activities, the Early and Late start/finish times for each, as well as the float (slack) for each activity. The total duration for project completion is 540 days (approx. 18 months). This represents a difference of 4 months when the original contract duration is compared to the project duration after implementing network planning techniques and the Critical Path Method (CPM). This is not to mention the extensions the project underwent for several years due to

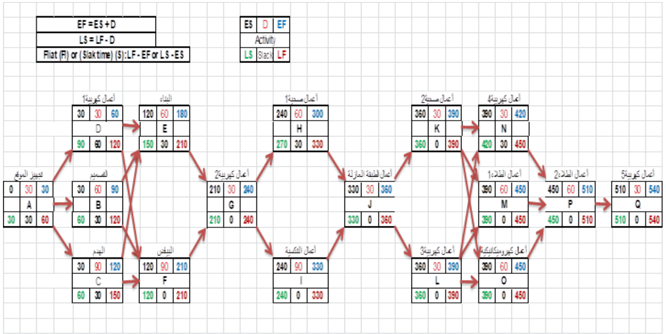

Figure 3: Network Diagram for the Research Project

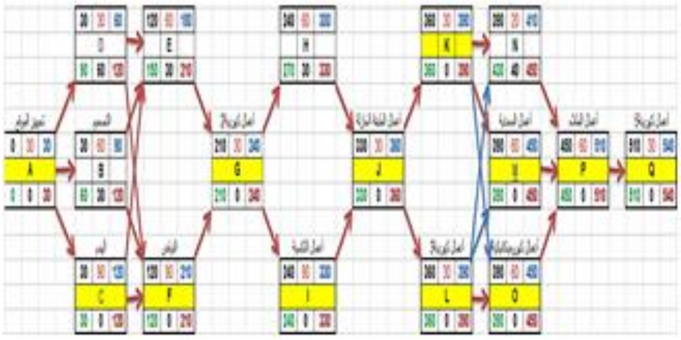

Figure 4: Activities Located on the Critical Path

various reasons, most notably execution methods and the poor utilization of engineering management techniques.

For effective time control, the project manager must ensure that schedule plans include sufficient detail to exercise appropriate control over activities. It is essential to collect schedule performance data systematically, including the following information:

- Actual start time for each activity.
- Estimated remaining time for activities currently in progress.
- Actual completion time for each activity.
- Changes made to time estimates.
- New activities that have been identified or introduced.
- Previously identified activities that are no longer needed.

Subsequently, variances and deviations must be analyzed to determine their impact on the project, whether positive or negative. For instance, an activity might have taken five additional days to execute, or it might have finished five days ahead of schedule. Consequently, not all deviations have a negative impact on the project, and some are so minor that they do not warrant corrective action. Furthermore, the root cause of any significant deviation must be identified to implement corrective measures and prevent recurrence. For ease, speed, and accuracy, Excel was used to calculate the Early and Late times for the project, as shown in Table (7).

Critical Path Method (CPM)

This method serves as a tool for planning, executing, and monitoring large and complex projects using a single time estimate for each activity. It is based on identifying the set of activities that require special attention during planning and execution; completing the project within a specific timeframe and budget depends heavily on the activities located on the Critical Path. In the context of this research, the activities on the Critical Path, as shown in Figure (5), are: (A-C-E-G-I-J-K-L-M-O-P-Q). This represents the longest sequence in the project, estimated at 540 days. The following Table (8) details the activities on the Critical Path for the research project. Table (8): Activities on the Research Project's Critical Path (Note: This table repeats the data from Table 7 to highlight the Critical Path activities where Slack = 0). The following formula was used to calculate the Critical Path: Float (Fl) or Slack time (S) = LF - EF or LS – ES.

Project Evaluation and Review Technique (PERT)

This method is a project management technique known by the acronym PERT. This technique enables managers to plan, schedule, and monitor large and complex projects by employing three time estimates for each activity: Pessimistic Time, Optimistic Time, and Most Likely Time. The time required to execute an activity is estimated probabilistically, based on the Beta probability distribution. This distribution is used because its estimates meet statistical quality criteria more effectively than other distributions, according to research findings by the scientist VANSLYKE regarding the impact of changing probability distributions on project duration.

To apply this method, the time estimates for each activity (Pessimistic, Optimistic, and Most Likely) were scheduled and calculated according to the following formulas, as illustrated in Table (8).

Table 6: Early and Late Times for the Project

Activity No.	Code	Description	Duration (t)	Early Start (ES)	Late Start (LS)	Early Finish (EF)
1	A	Site Mobilization	30	0	30	30
2	B	Design Works	600	30	30	90
3	C	Demolition Works	90	30	0	120
4	D	Electrical Works 1	30	30	64	60
5	E	Plastering	90	120	0	210
6	F	Construction	60	120	30	180
7	G	Electrical Works 2	30	210	0	240
8	H	Sanitary Works 1	60	240	30	300
9	I	Cladding Works	90	240	0	330
10	J	Insulation Works	30	330	0	360
11	K	Sanitary Works 2	30	360	0	390
12	L	Electrical Works 3	30	360	0	390
13	M	Metalworks	60	390	0	450
14	N	Electrical Works 4	30	390	30	420
15	O	Electromechanical	60	390	0	450
16	P	Painting Works	60	450	0	510
17	Q	Electrical Works 5	30	510	0	540

Table 7: Time Estimates for Each Activity (Optimistic, Most Likely, and Pessimistic)

No.	Activity	a (Optimistic)	m (Most Likely)	b (Pessimistic)	t (Mean/ Expected)	Variance (σ2)
1	Site Mobilization	25	30	35	30	2.778
2	Design Works	50	60	70	60	11.111
3	Demolition Works	85	90	95	90	2.778
4	Electrical Works 1	25	30	35	30	2.778
5	Plastering	85	90	95	90	2.778
6	Construction	50	60	70	60	11.111
7	Electrical Works 2	25	30	35	30	2.778
8	Sanitary Works 1	50	60	70	60	11.111
9	Cladding Works	85	90	95	90	2.778
10	Insulation Works	25	30	35	30	2.778
11	Sanitary Works 2	25	30	35	30	2.778
12	Electrical Works 3	25	30	35	30	2.778
13	Metalworks	50	60	70	60	11.111
14	Electrical Works 4	25	30	35	30	2.778
15	Electromechanical	50	60	70	60	11.111
16	Painting Works	50	60	70	60	11.111
17	Electrical Works 5	25	30	35	30	2.778
Sum of Variances on Critical Path						55.556

In PERT applications, the mean duration for activity completion was estimated, in addition to the standard deviation that may occur during the execution of the activity.

$$ExpectedTime(t) = \frac{(a + 4m + b)}{6} \quad (1)$$

As for the calculation of the Variance, it can be found using the following Equation (2):

$$\sigma = \sqrt{\sum \sigma_{ij}{}^2} = \sqrt{\sum (55.556)} = 7.454 days \quad (2)$$

As for the calculation of the Variance, it can be found using the following Equation (3):

$$\text{Variance } \sigma^2 = \left(\frac{b-a}{6}\right)^2 \quad (3)$$

The equation for the Standard Deviation is:
Standard Deviation

$$\sigma = \sqrt{\sum \sigma_{ij}{}^2} \quad (4)$$

To apply this in practice:
From Table (9), it is evident that the sum of variances reached 55.58, and the value of the Standard Deviation (σ) is 7.457 days.
To calculate the Z-value, we apply the following equation:

$$Z = \frac{X-\mu}{\delta} \quad (5)$$

Where: X: is the target value (duration) at which you wish the project to be completed, μ: is the value of the project's Critical Path, which equals 540 days.
To speed up the execution of equations and obtain accurate results, spreadsheet software (Excel) was used, yielding a calculated standard deviation of 7.454 days. Table (10) below illustrates the probability percentages for the durations at which the project aims to be completed.
For instance, the probability of completing the project according to the critical path (540 days) was only 50%. This demonstrates, beyond a reasonable doubt, that poor temporal planning led to this percentage—a fact that would remain unknown without the application of the PERT engineering method. As the value decreases below 540 days (the critical path duration), the probability of completion also decreases, which is evident when calculating the Z value corresponding to the values from Equation (4).
The result of this equation is compared to the value in the Standard Normal Distribution Table (Z-Table). By applying the equation in Excel, a Z value of 1.34 was obtained for a 550-day duration. The corresponding value in the Z-Table is 0.9099, representing a 91% completion probability. A project manager should rely heavily on this result, even though there is only a ten-day difference between this target duration and the planned critical path duration (540 days). Therefore, project management must optimize this period, especially regarding potential risks, whether apparent or hidden.

Table 8: Project Completion Probabilities According to the Normal Distribution Table

Z-Score (z)	Target Duration (X)	Critical Path (μ)	Probability (m)	% Completion
-3.3541	515	540	0.0004	**0%**
-2.01246	525	540	0.0174	**2%**
-1.34164	530	540	0.1075	**11%**
-0.67082	535	540	0.2514	**25%**
0	540	540	0.5000	**50%**
0.67082	545	540	0.7486	**75%**

Project Completion Probabilities According to the Normal Distribution Table

To control the project effectively, an electronic framework—similar to a data entry and processing system—must be designed to determine completion rates and the variance between planned and actual progress. This is achieved through the Earned Value method and its ability to measure project progress variance and its impact on project success within the allocated budget.
Using this method, the total amount allocated for the Misrata Central Hospital maintenance and development project, totaling 29,989,019 LYD, was distributed across all activities. This allows us to monitor actual expenditures and compare them with the plan. This requires high precision and consistent follow-up to track where we stand relative to the daily planned expenditures (or monthly, per technical reports) according to the budget distribution during the execution phase.
Excel was used to analyze the earned values for all activities by designing an electronic framework that simulates real-world project cost control. All project activity costs were entered, and the expenditure value for each month was determined according to the planning sequence.

The first step in Earned Value Analysis (EVA) is identifying the following three values:

- Planned Value (PV): Also known as the Budgeted Cost of Work Scheduled (BCWS).
- Earned Value (EV): Also known as the Budgeted Cost of Work Performed (BCWP).
- Actual Cost (AC): Also known as the Actual Cost of Work Performed (ACWP).

Accordingly, all values will be calculated as follows:

- Budgeted Cost Work Performed
- BCWP = Actual Time × Budgeted Cost
- Budgeted Cost Work Scheduled
- BCWS = Scheduled Time × Budgeted Cost
- Actual Cost Work Performed
- ACWP = Actual Time × Actual Cost

Once these values are determined, they can be used in various mathematical equations as metrics to determine whether the work is being completed as planned.

Schedule Variance (SV) (5)

Cost Variance:

Schedule Performance Index

SPI = EV/PV (6)

CPI = EV/AC (7)

Value (EV) for project activities at the six-month mark

To calculate these indicators using the equations mentioned above, the Earned Value method was applied at the six- For instance, upon controlling costs in the sixth month, it was found that the Cumulative Total Planned Value (PV) reached 3,792,721.55 LYD, the Cumulative Total Actual Cost (AC) reached 3,922,262 LYD, and the Cumulative Total Earned Value (EV) reached 3,480,. This aims to control a specific time period to understand the reality of the earned value and other costs. The Cost Variance (CV) at the sixth month was -441,677.45 LYD, which means the project is operating over budget. The Schedule Variance (SV) was -312,136 LYD, indicating the project is behind schedule. Furthermore, the Cost Performance Index (CPI) was 0.89, which means the project costs more than estimated; specifically, for every one Dinar spent, only 0.89 of value is produced. The Schedule Performance Index (SPI) was 0.92, which signifies that the project has exceeded its planned timeframe and is behind schedule. Additionally, the Estimate at Completion (EAC) for the project at the end of the sixth month reached 33,794,549.2 LYD.

Conclusions

The most significant results achieved in this research can be summarized as follows:

1. Results indicated that project management does not realize the importance of applying engineering methods in project management and planning, which led to poor planning of project resources, most notably the time resource.
2. The results showed that applying engineering management methods leads to a reduction in project duration; it became clear that the project duration was reduced to 18 months instead of 22 months.
3. Applying engineering management methods, such as the Earned Value (EV) technique, leads to effective control over project costs.
4. Utilizing engineering management methods leads to shortening the project completion time without affecting the cost or the quality of the project.

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-1546176	-1285528	-1085030	-1036135	-1013910	-1018355.01	-312136	-684588	-578172	-312133	-226593.1	-27000	تباين الجدولة=القيمة المكتسبة -التكلفة المخططة			
0.75	0.78	0.80	0.81	0.81	0.80	0.92	0.75	0.65	0.48	0.28	0.1	مؤشر إداء الجدولة=تكلفة القيمة المكتسبة/التكلفة المخططة			
0.72	0.74	0.76	0.77	0.77	0.77	0.89	0.70	0.60	0.41	0.24	0.06	مؤشر أداء التكلفة = تكلفة القيمة المكتسبة /التكلفة الفعلية			
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Figure 5: illustrates the control history of planned

5. The Network Analysis method contributed to defining project activities and reducing the overall completion time based on the Standard Normal Distribution (Z).
6. Apply the Project Evaluation and Review Technique (PERT) to estimate the probability of project completion
7. Results also indicated that the Critical Path Method (CPM) is one of the most important techniques that proved successful in determining the total project duration.
8. The Project Evaluation and Review Technique (PERT) contributed to estimating the probability percentage of project completion using a probabilistic approach based on the Standard Normal Distribution (Z) table.
9. The Earned Value method is considered an effective tool for measuring deviation and determining various types of costs.
10. Pre-qualification is one of the modern scientific methods used to qualify suppliers or contractors before contracting with them, which assists decision-makers in choosing the best alternative among suppliers or contractors undertaking the project

Recommendations

1. Work on encouraging and training project management on the importance of applying engineering methods in project management and planning.
2. Apply engineering management methods to reduce project duration and improve overall performance.
3. Implement Earned Value Engineering to improve project performance, reduce costs, and avoid unnecessary maintenance expenses.
4. Encourage and train project management on Pre-qualification methods due to their role in selecting the best alternative for suppliers or contractors.
5. Apply Network Analysis techniques for their role in defining project activities and reducing completion time.
6. 585.55 Encourage and train personnel in the construction industry on engineering methods like the Critical Path

Method (CPM), which has proven successful in determining total project duration

7. Provide high-quality training and qualification for cadres in health sector project management on modern planning methods, engineering management tools, and cost-control/budgeting systems.
8. The research also recommends the necessity of raising awareness among project managers regarding the importance of providing a comprehensive database for engineering projects.

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