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The Role of Scheduling in Reducing Delays in Infrastructure Projects

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Abstract. *Large delays in infrastructure projects may lead to budget overruns, worse quality, and stakeholder dissatisfaction. This study examines scheduling tools and methods to decrease delays in large infrastructure projects. It compared Primavera P6 and MS Project projects with traditional scheduling methods. Detailed case studies indicate that improved scheduling improves project timetables, resource allocation, and cost management. Results demonstrate that advanced scheduling may boost project productivity and save delays by 50%. At the study's conclusion, risk management, real-time tracking, and critical path analysis were suggested for scheduling.*

Keywords: *Critical Path Method, MS Project, Infrastructure Delays, Primavera P6, Project Scheduling*

1. INTRODUCTION

Infrastructure projects are crucial to sustainable growth and national economic and social advancement. Strong roads, bridges, buildings, and public facilities increase people's quality of life. Due to their many moving elements and detailed nuances, these projects are notoriously difficult to manage.

Many governments squander time and money on infrastructure projects that never start. This hurts the economy and society. To solve this problem, effective strategies and tools are needed.

Planning is essential for reducing project delays. Time is only one of many elements that may help forecast risk, coordinate stakeholders, and manage resources.

There are many methods, including traditional ones such as the Bar Chart (Gantt Chart), Network Analysis Technique or Critical Path Method (CPM), which consists of the Arrow Diagram Method (ADM) and the Procedure or Node Diagram Method (PDM or NDM), Program Evaluation & Review Technique (PERT), and Line of Balanced Technique (LOB). Each of these methods will be discussed in detail in the research.

Modern scheduling tools like Primavera and MS Project make scheduling more precise and productive.

This research aims to explore the role of scheduling in reducing delays in infrastructure projects by analyzing the main causes of delays and providing practical solutions based on scheduling applications. It also highlights the importance of using advanced tools for project planning and execution to achieve the desired efficiency and quality. (Heldman, 2018; Lock, 2020)

Basic Concepts

Definition of a Project

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A project is an activity or a set of activities that has a specific timeframe, meaning it has a start date and an end date. It utilizes certain resources like labor and equipment, and money is spent to achieve expected benefits during a certain timeframe. A project can be commercial, agricultural, industrial, tourist, or service-oriented. It may be large, small, or medium-sized and can be local, national, or international.

Definition of Management

Management is the process of planning, organizing, employing, directing, and controlling resources (human or material) in order to achieve the project's objectives.

The five functions of management include planning, which involves anticipating the time required for the project and identifying the best ways to accomplish it; organizing, which defines the tasks and authorities of each person involved in the project; employing, which focuses on selecting, appointing, training, and placing the right person in the appropriate role within the project; directing, which guides and motivates individuals towards achieving the project's goals; and controlling, which monitors the project's performance to evaluate whether the objectives have been achieved or not.

Engineering management of the project is considered one of the most important elements contributing to the success of the work and avoiding its failure. It's well-known that management is crucial in any field for the success of the work, especially in construction projects, which are more complex administratively and practically than most other management areas. A simple comparison to highlight its importance is that in a car factory, for instance, if a car is produced and tested, it can easily be modified until the desired product is achieved and then mass-produced without significant losses in time or costs. On the other hand, in construction projects, you can't build a project that has been completely modified; you must anticipate all flaws in advance and eliminate them. This is where good management, skilled leadership, and the genius of finding solutions and alternatives become essential.

Engineering Project Management

It is the process of coordinating between the project owner, the contractor, and the engineer to control the execution of the project in a way that ensures a balance between the project's essential elements: time, cost, and quality, aiming to achieve good construction quality.

2. METHODS AND TECHNIQUES OF PROJECT MANAGEMENT

Delivery: The project is handed over to a design engineer for project design, and then it's handed over to the contractor for execution. The owner appoints an engineer to supervise the execution, and the project is handed over to the owner after the construction is completed.

Design and Construction: The design, execution, and supervision work are carried out within a single contracting company.

The owner or consulting manager delegates the management of the project to a consulting engineer who takes on the responsibility of selecting the designer, the contractor, and the supervisor.

Phases of an engineering project lifecycle

There are four main phases that engineering projects go through, which are as follows:

Phase One: Project Feasibility Study - The project idea

Phase Two: Project Documentation Preparation (Design Phase)

Phase Three: Project Execution

Phase Four: Project Handover, Maintenance, and Operation

Project Feasibility Study

When the owner or project holder contemplates any project, the first step to initiate is the feasibility study, which is carried out by a specialized consulting firm in this type of study. In this phase, an initial study and project feasibility study is conducted, which is the economic analysis of the project to determine its costs and estimate the returns at various stages of the project, meaning estimating the project budget according to standards and specifications, understanding the time frame for completion, and assessing the future benefits of the project.

Preparing Project Documentation (Design Phase)

In this phase, the project owner commissions a consulting firm, which may be the same firm that previously conducted the feasibility study, to prepare project documents for bidding. The consultant prepares various documents, including project studies covering its needs, nature, and size; initial designs and visual proposals based on preliminary ideas; final designs that further develop the proposed concept; detailed execution designs necessary for implementation; technical specifications aligned with standard regulations; tables detailing material quantities; and the terms and format of contracting.

After that, the project works are put out to public tender, in what's known as the bidding announcement phase, which occurs in an open or limited announcement in media outlets. The bids are analyzed and decided upon with the participation of the consulting firm that previously prepared the project documents. Then, the bid envelopes are opened by a committee representing the project owner and the consultant as a third party, in the presence of representatives or delegates from the competing entities that have applied to execute the project.

Project Implementation

This phase begins after the tender is awarded by selecting a contractor to carry out the project under the supervision of the oversight entity chosen by the owner (the consultant). Thus, the contractor becomes responsible for the project execution, and they may enlist subcontractors who specialize in certain areas (if the size and type of the project require it). This involves dividing the project into several specializations and trades, where the execution stages for the different designs are distributed according to those specializations, making the contractor a general contractor overseeing the project execution.

Project Planning

Controlling project time involves scheduling the construction project using various planning methods, such as the Bar Chart (Gantt Chart), Network Analysis Technique or Critical Path Method (CPM) – which includes the Arrow Diagram Method (ADM) and the Procedure or Node Diagram Method (PDM or NDM) – Program Evaluation & Review Technique (PERT), and the Line of Balanced Technique (LOB). The scheduling process follows several steps: first, the project is divided into multiple activities, items, and events; second, the relationships between these events are determined; third, the required time for each event is defined; fourth, the events and their relationships are represented using one of the planning methods; and finally, the project's execution time is calculated after establishing the start and end dates, incorporating allowances for each event while considering overlaps to achieve the shortest possible execution time.

Event Duration

It is determined after knowing the productivity rates and the quantity or volume of work as follows:

Event Duration D = Work Quantity (Q) × Productivity Rate (R)

$D = QR$

D = Event Duration

Q = Quantity of work for the event

R = Productivity Rate for the event (there are tables used for estimating it)

An example of productivity estimation tables is as follows.

	Description of work	Productivity	Unit
1	Manual digging in clay soil above the groundwater level at a depth of 1.5 m	0.2	M^3 /hr
2	Unreinforced concrete for site foundations	0.8	M^3 /hr
3	Brick construction with a 1:3 cement mix	0.05	M^3 /hr
4	Leveling floors with broken bricks, thickness 8cm	1.9	M^3 /hr
5	Pouring unreinforced concrete floors, thickness 12cm	1.9	M^3 /hr

Time scheduling is defined as the process of organizing activities and tasks related to a project in a way that ensures achieving the goals within the specified time and resources. Time scheduling is a fundamental element in project management, especially in infrastructure projects, where they tend to be complex and involve multiple parties.

Time scheduling includes various tools and methods, such as:

- Network scheduling: like the Critical Path Method (CPM) and PERT analysis techniques, which are used to identify critical activities that cannot be delayed without impacting the overall project schedule.
- Traditional time scheduling: which uses timeframes and weekly schedules for minor tasks or activities.
- Dynamic scheduling: Which adjusts to project changes and is necessary for addressing crises or unforeseen work environment changes.

Challenges in time scheduling management

Infrastructure projects often face multiple challenges leading to delays, as seen in several major cases. The **Third Bosphorus Bridge Project in Turkey** suffered from a lack of preliminary planning, resulting in substantial redesigns and delays. Similarly, issues with collaboration between Saudi Arabian and foreign contractors prolonged the completion of the **Haramain High-Speed Railway Project**. The **Panama Canal Expansion Project** encountered unexpected design changes, requiring multiple schedule revisions to accommodate new needs. Additionally, the **Grand Ethiopian Renaissance Dam Project** faced timeline setbacks primarily due to insufficient financial support in certain phases (Mubarak, 2015; Nicholas & Steyn, 2020; Smith & Brown, 2020).

Previous Studies

Numerous studies have shown that scheduling reduces engineering project delays, including:

-A recent research found that utilizing Primavera and MS Project in the Al Maktoum International Airport project reduced execution time by 20%.

- Global project success stories:
- Dubai Metro: The project was finished quickly due to thorough planning and prior scheduling.
- Millau Viaduct in France: Following a rigid timetable utilizing PERT technology helped the project succeed without delays.
- Challenges in local contexts: A research on Indian infrastructure projects found that paper timetables caused delays compared to modern software. (Johnson, P., & Lee, 2018; Kerzner, 2017).

Research Gap

Despite advances in scheduling technologies, their application is still lacking, particularly in developing country infrastructure projects.

- Studies show that African projects like the Ethiopia-Djibouti railway project were delayed owing to a lack of skilled workers to use current scheduling methods.
- To schedule major projects effectively, time management strategies must be combined with hands-on training and capacity development.(Johnson, P., & Lee, 2018; Nicholas & Steyn, 2020).

Scheduling Programs

- Primavera P6:
  - Helps analyze complex schedules and identify critical paths.
  - Provides detailed reports on project progress, making it easy to compare actual performance with what's planned.
- Microsoft Project:
  - A flexible tool for creating easy-to-understand timelines.
  - Used to experiment with alternative scenarios and predict their impact on the project timeline.(Mubarak, 2015; Nicholas & Steyn, 2020; Smith, J., & Brown, 2020).

Graphs and Illustrative Tables:

- Charts:
  - Gantt charts to illustrate the original schedule and the improved schedule.
  - Critical path method (CPM) charts to identify critical activities.
  - Program evaluation and review technique (PERT).
  - Line of balanced technique (LOB) for repetitive projects like housing.

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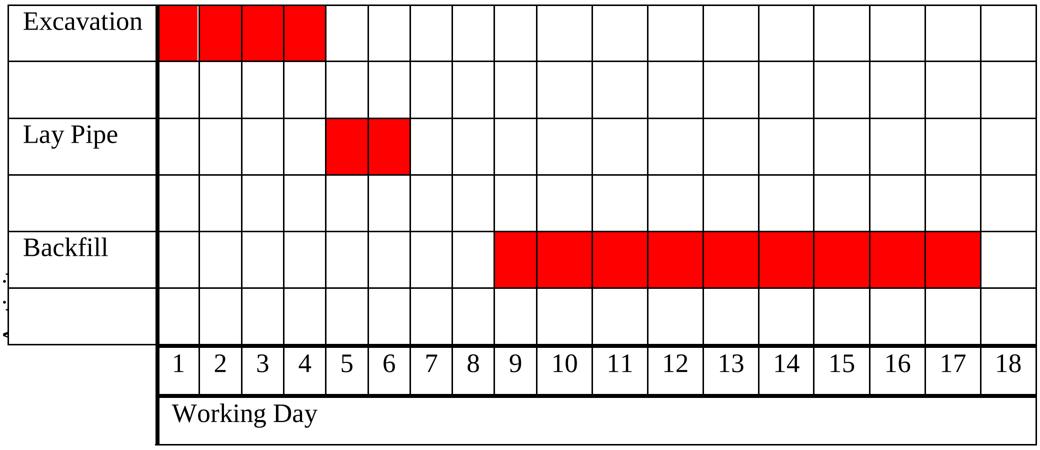
Bar Chart Method

One of the oldest planning methods since 1900, where activities are represented as rectangles whose lengths correspond to the duration of the activity. The project is divided into a number of activities, each with its duration and relationships, and then these activities are represented as horizontal rectangles on a graph, with the vertical axis showing the activity name and the horizontal axis representing the time of the activity.

Example 1: A project to lay a water and sewage pipe of 400m in length, involving the activities detailed in the table below. A timeline needs to be prepared using the Bar Chart method, based on the available equipment and labor represented by the productivity listed next to each activity in the table below. Working conditions include a two-day wait after laying the pipe for pressure testing before burial.

Activity	Productivity	Duration = Amount of work ÷ Productivity = 400 ÷ Productivity
Excavating the trench	100m/day	4
Laying or placing the pipe	200m/day	2
Burial of the pipe	50m/day	8

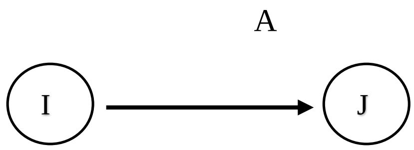


Bar Chart timeline

Network Analysis Technique or Critical Bath Method (CPM)

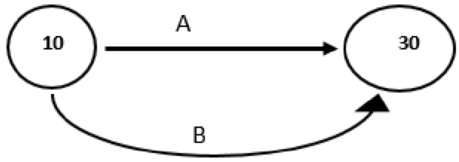
- Arrow diagram method (ADM)
- Procedure or Node diagram method (PDM or NDM)
- The arrow diagram method

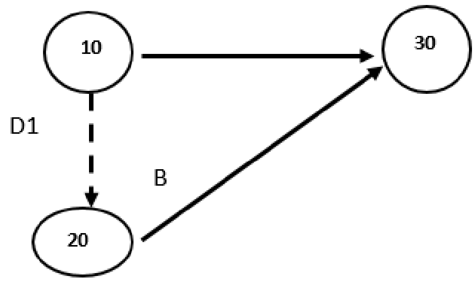
Has been in use since 1950. In this type of network diagram, each activity is represented as a single arrow that points from left to right, connecting two events: the starting event of the activity I and the ending event of the activity J.



The event

An event is defined as a point in time where the construction activity starts and ends. The event is represented as a small circle, and the arrow typically describes the





activity and its duration in time units. Events are marked with ascending numbers, which helps indicate the activities.

Duration

This is the estimated time in any time unit to complete a specific activity.

Steps to Draw the Network Diagram

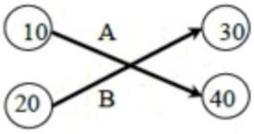
- Each arrow represents one phase of the project.
- The circles (events) must be numbered according to the natural sequence of preparation and the order of the project's phases.
- The arrow should point from the lower number to the higher number.
- More than one activity can share either the start or the end, but not both at once.
- It's not permissible to have more than one activity at both the start and the end at the same time, so a dummy activity is used to resolve this issue or glitch in the drawing.

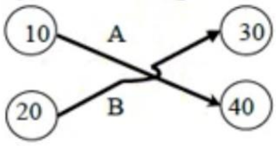
The fake activity

It is the activity that does not require a time duration, does not consume any resources, and is used solely for the purpose of achieving the logical sequence of project activities, represented as a dashed line in the flowchart.

Examples of using the fake activity

Activities that share both the beginning and the end together Activities should not overlap in drawing.



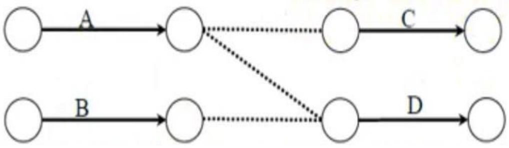


Example: Planning the next project using the arrow diagram method

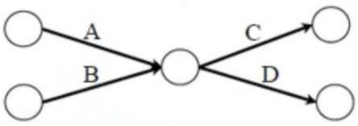
Activity	Dependency
A	-
B	-
C	A
D	A.B

-Drawing activities at several levels according to reliability

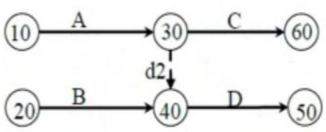
- Link the activities based on dependencies with intersecting lines.



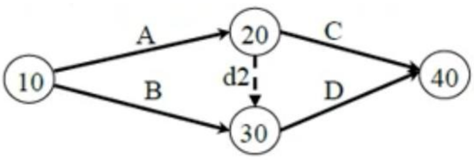
- Delete and draw the arrows and adjust the relationships between the activities based on dependencies, using a fake activity if needed.



- Use the fake activity d3 to achieve the required sequence.



- Group the beginnings into one start and the endings into one end.



Method of Rectangles Node (Precedence) Diagram

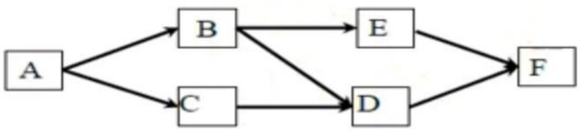
In this method, rectangles are used to represent activities, while arrows are used to link these activities together to represent their dependency relationships.

Steps to Draw the Rectangles

- Draw the activities at different levels based on their dependencies.
- Connect the activities with arrows according to their dependencies, linking an activity to the activity it depends on.

Example: Draw the network diagram using the rectangle method for the project whose activities and their sequence are shown in the following table.

Activity	Dependency
A	-
B	A
C	A
D	B, C
E	B
F	D, E



Network calculations based on the Critical Path Method

Early Start (ES): This is the earliest time the activity can start.

Early Finish (EF): This is the time the activity finishes if it starts at the early start.

EF = ES + D

D = Duration of Activity

Late Start (LS): This is the latest time the activity can start.

Late Finish (LF): This is the time the activity finishes if it starts at the late start.

LF = LS + D

Total Float of Activity (TF): This is the amount of time the activity can be delayed without affecting the project's timeline.

TF = LS – ES = LF – EF

Free Float of Activity (FF): This is the amount of time the activity can be delayed without affecting the start of the following activity.

FF = ES of Succeeding Activity – EF

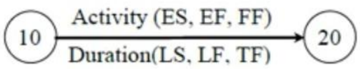
Critical Activity: This is an activity that has no total float or has a total float equal to zero (TF = FF = 0)

Critical Path: This is the path that goes through the critical activities and is the longest path in the network, from which the project's duration can be determined.

Representing calculations on network diagrams:

- Node Diagram

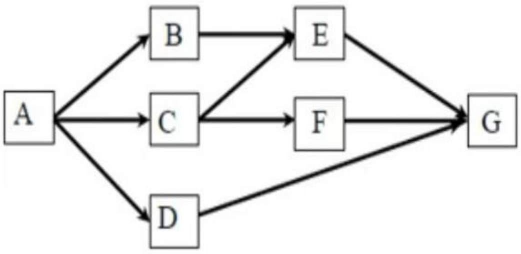
ES	FF	EF
Activity	Duration	
LS	TF	LF

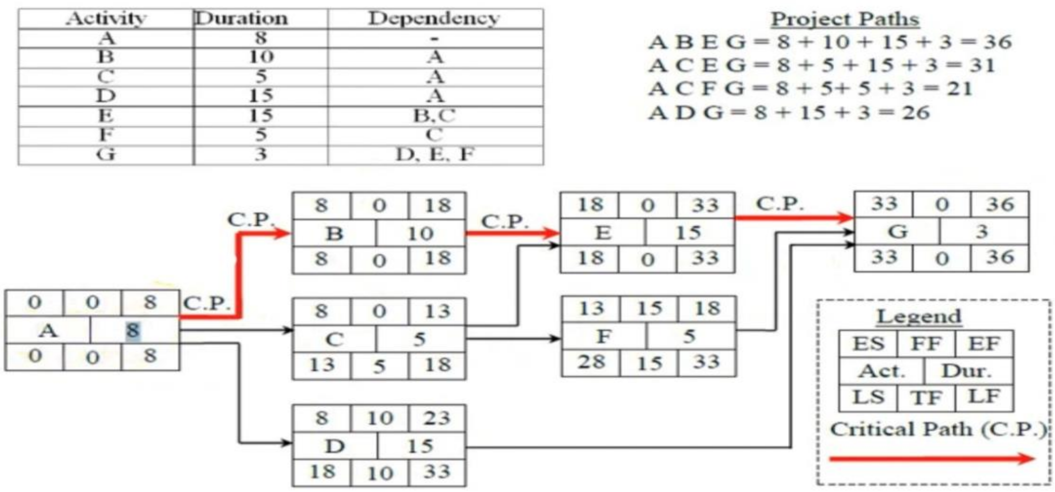


- Arrow Diagram

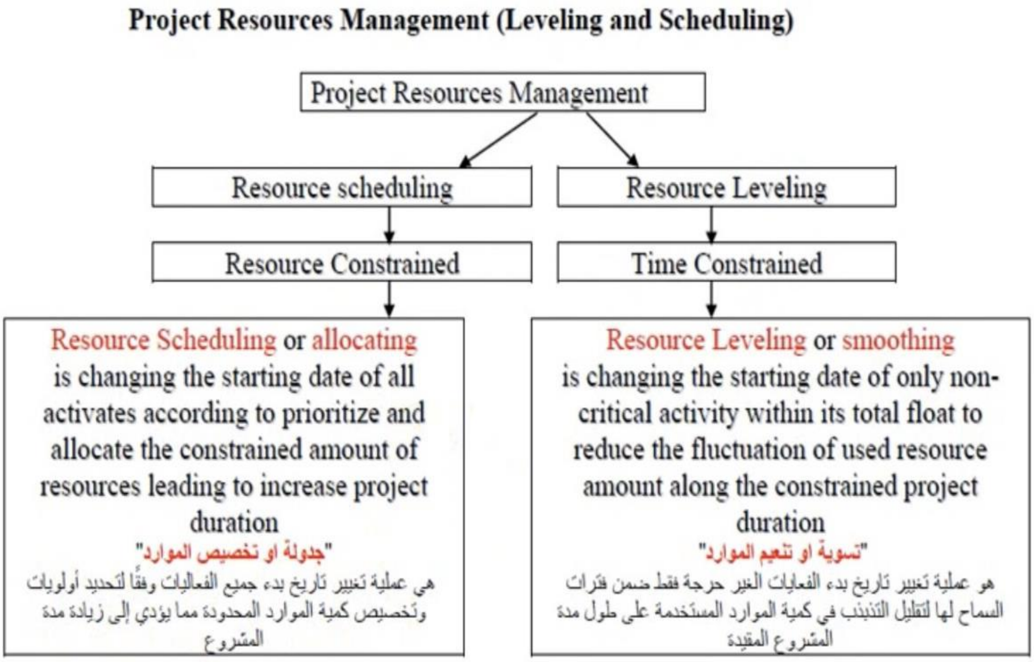
Activity	Duration	Dependency
A	8	-
B	10	A
C	5	A
D	15	A
E	15	B,C
F	5	C
G	3	D, E, F

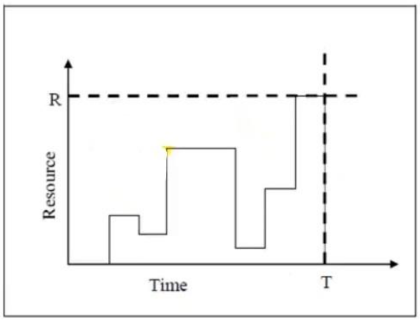
For example: To create a network diagram using rectangles for the project detailed in the table below, then calculate the early and late start and finish times, the total float and slack for the activities, and then identify the critical activities, the critical path, and the project's completion time. (Al-Attar, n.d.; Pilcher, 1992)

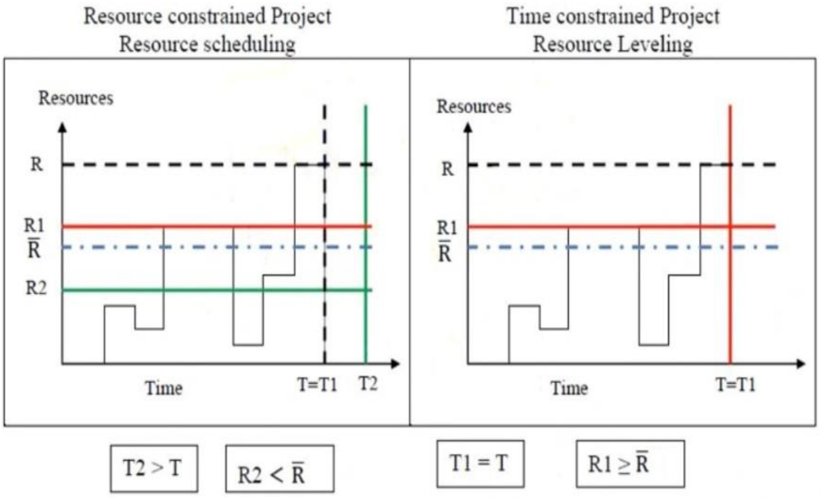




Project Resources Management (Leveling and Scheduling)







If $\overline{R}_{av.} < R$ ∴ Project will be delay (Resource Scheduling)

If $\overline{R}_{av.} \geq R$ ∴ Project on time (Resource Levelling)

Where:

$$R = \frac{\sum R}{T}$$

$\overline{R}$ = Average Resource Required Per Unit Time of Project = $\frac{\sum R}{T}$

$R_{av.}$ = Resource Available

R = Resource at any Unit time of project

T = Comlection Time pf Project

Resource Leveling (Smoothing)

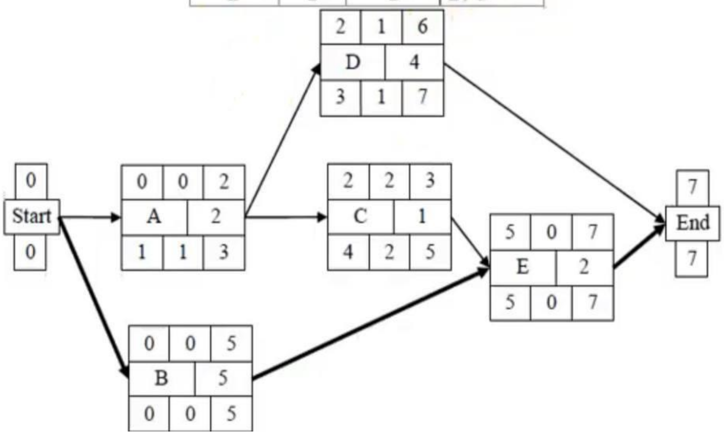
- Resource unconstrained; no limits on resources and use average resource
- Project duration constrained: project duration not allowed to be delayed
- Reduce the difference between the peaks and the valleys to avoid the resource fluctuation
- Change the starting date of some the non-critical activities

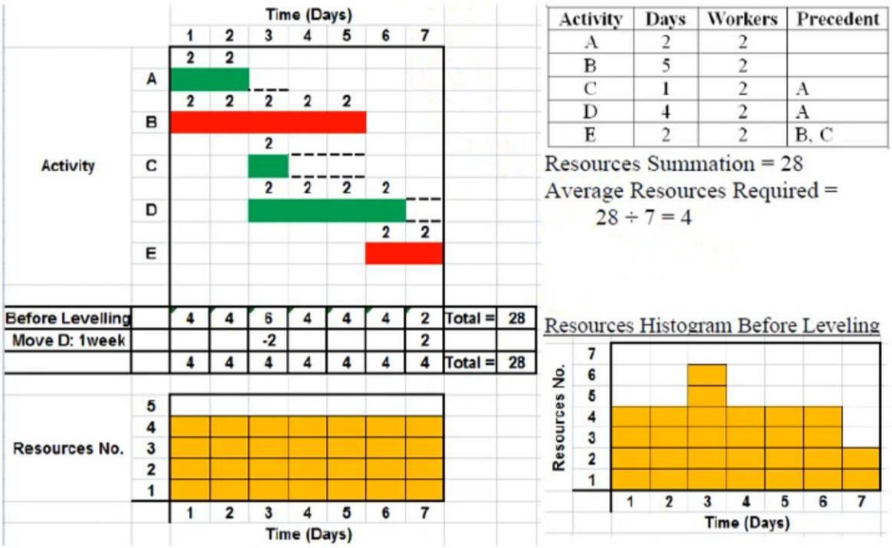
Example 1: A company has taken a contract involve the following activities. Each activity required two workers. Can we complete the job with only 4 workers?

Activity	Days	Workers	Precedent
A	2	2	
B	5	2	
C	1	2	A
D	4	2	A
E	2	2	B, C

Solution

Activity	Days	Workers	Precedent
A	2	2	
B	5	2	
C	1	2	A
D	4	2	A
E	2	2	B, C



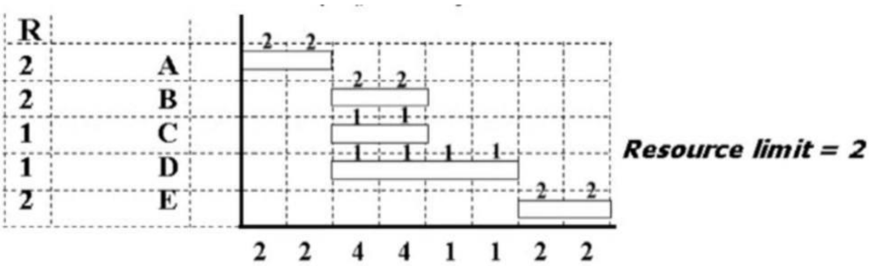


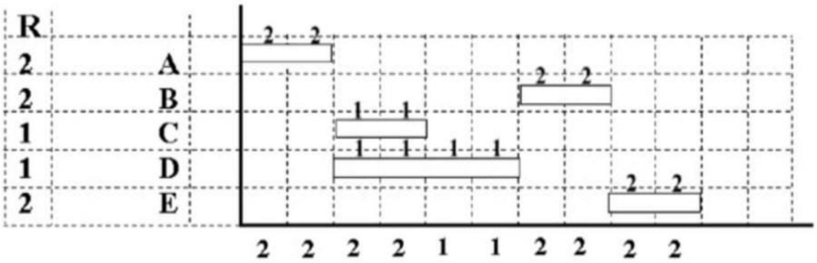
Resource Leveling Procedure

- Draw a node diagram for the project
- Draw a bar chart for the project
- Resource Loading: put the resource usage in each bar of the related activity
- Resource Aggregate; summation the resources in each time period
- Calculate the total resources required = ∑ resource required for all unit time of project
- Calculate the average resource required = ∑ Total Resources Required / Project duration
- Draw the FF as dashed line beside the upper side of the bar of activity
- Draw the TF as dashed line beside the lower side of the bar of activity
- Critical activities to be drawn first (do not move them)
- Shift non-critical activities within their FF first, then their TF
- Revise the schedule of activities
- Aggregate the resources in each time period

Resource Scheduling

- Reduce the resource usage to be less than the average resource required
- Constrained Resources; available resources are less than the average resource required
- Unconstrained project duration; project time may be delayed
- The objective is calculating a minimum project time delay to meet the resources limits
- Resource Scheduling: Is there is a way to prioritize activities that compete for the limited resources so that the net project delay is minimized?





Act.	Dep.	Dur.	R
A	-	2	2
B	A	2	2
C	A	2	1
D	A	4	1
E	B,C,D	2	2

Resource Scheduling (Example) or Scheduling Limited Resource

Example 1:

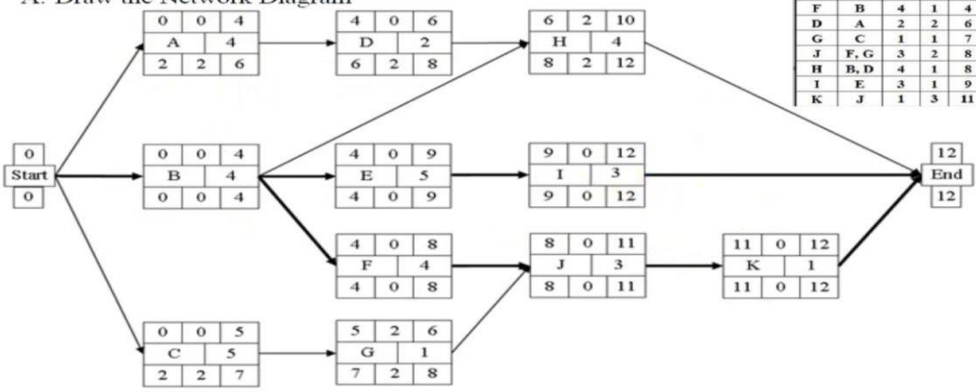
The activities involved in the construction of a certain project are given in the table below. One resource type will be used during the contract. It is required to schedule the project above so that the weekly resource requirements do not exceed 3 machine

Activity	Dependency	Duration (Weeks)	Number of machines (Units/Week)
A	-	4	1
B	-	4	1
C	-	5	2
D	A	2	2
E	B	5	1
F	B	4	1
G	C	1	1
H	B, D	4	1
I	E	3	1
J	F, G	3	2
K	J	1	3

Act.	Dep.	Dur.	R	LS	TF
B	-	4	1	0	0
A	-	4	1	2	2
C	-	5	2	2	2
E	B	5	1	4	0
F	B	4	1	4	0
D	A	2	2	6	2
G	C	1	1	7	2
J	F, G	3	2	8	0
H	B, D	4	1	8	2
I	E	3	1	9	0
K	J	1	3	11	0

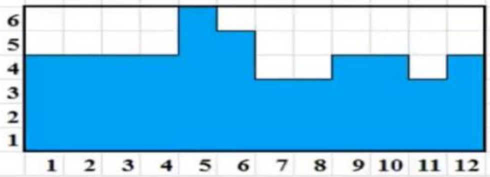
Solution:-

A. Draw the Network Diagram



B. Drawing the Bar Chart of the project

Act.	Dep.	Dur.	R	1	2	3	4	5	6	7	8	9	10	11	12
A	-	4	1	1	1	1	1								
B	-	4	1	1	1	1	1								
C	-	5	2	2	2	2	2	2							
D	A	2	2					2	2						
E	B	5	1					1	1	1	1	1			
F	B	4	1					1	1	1	1				
G	C	1	1						1						
H	B, D	4	1							1	1	1	1		
I	E	3	1										1	1	1
J	F, G	3	2									2	2	2	
K	J	1	3												3
		ΣR=	48	4	4	4	4	6	5	3	3	4	4	3	4

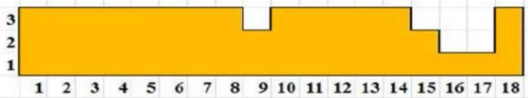


C. Priorities activities according to the following rules, priority goes to the activity that has:

a. Earliest Late Start (LS)
b. If a tie, Lowest Total Float (TF)
c. If a tie, consider sequence

D. Draw the Bar chart (Gantt chart) so that the weekly resource requirement does not exceed the limit available. As illustrated in the following Chart:

Act.	Dep.	Dur.	R	LS	TF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
B	-	4	1	0	0	1	1	1	1														
A	-	4	1	2	2					1	1	1	1										
C	-	5	2	2	2	2	2	2	2	2													
E	B	5	1	4	0						1	1	1	1	1								
F	B	4	1	4	0						1	1	1	1									
D	A	2	2	6	2										2	2							
G	C	1	1	7	2											1							
J	F, G	3	2	8	0												2	2	2				
H	B, D	4	1	8	2												1	1	1	1			
I	E	3	1	9	0															1	1	1	
K	J	1	3	11	0																		3
				ΣR=	48	3	3	3	3	3	3	3	3	2	3	3	3	3	3	2	1	1	3
				ΣR²=	136	9	9	9	9	9	9	9	9	4	9	9	9	9	9	4	1	1	9



Programme Evaluation and Review Technique (PERT)

Planning using PERT Method

-The PERT method is one of the techniques that relies on network diagrams for programming construction projects.

- It is considered a modern technique that was developed in 1959 when it was successfully used to program activities for a missile project by the U.S. Navy.

- This method differs in that it relies on statistical probability theory to choose three values for the durations of activities, which are as follows:

- Optimistic Time (a): the shortest time to complete the activity.
- Pessimistic Time (b): the longest time to complete the activity.

- Most Likely Time (m): the most probable value between the two.

- The assumptions of the PERT method are as follows:

- Activity durations are estimated using values that follow a normal distribution and have a mean (T), variance (V), and standard deviation (S).
- Using the average time values (T) and variance values (V), the most probable distribution of the project's critical path duration can be calculated.

Steps to solve:

Calculate the expected time or average value (t) for all activities.

Identify the critical path and calculate the average project duration (T).

Calculate the standard deviation (S) and the variance (V) for each critical activity.

Calculate the variance for the critical path (Vep).

Calculate the standard deviation for the critical path (Scp).

Find the project's probability at a specific time as follows:

• Calculate the Z value for the time (Ts) for which you want to find the probability.

• Extract the corresponding probability value from the probability table.

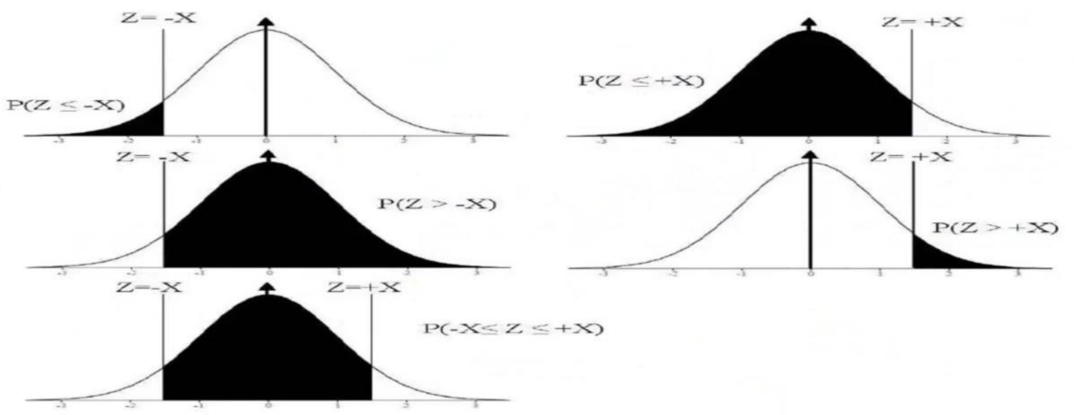
The corresponding value for Z is (P): the probability of completing the activity in the required time.

Laws:

$$t = \frac{a + 4m + b}{6} \quad , \quad S = \frac{(b - a)}{6}, \quad V = (S)^2$$

$$T = \sum t \text{ critical} \; , \quad V_{cp} = \sum V \; , S_{cp} = \sqrt{\sum V}, \quad Z = \frac{T_s - T}{S_{cp}},$$

Z	P	Z	P	Z	P	Z	P
-3	0	-0.9	0.18	0.1	0.54	1	0.84
-2.5	0.01	-0.8	0.21	0.2	0.58	1.1	0.86
-2	0.02	-0.7	0.24	0.3	0.63	1.2	0.88
-1.5	0.07	-0.6	0.27	0.4	0.66	1.3	0.9
-1.4	0.08	-0.5	0.31	0.5	0.69	1.4	0.92
-1.3	0.1	-0.4	0.34	0.6	0.73	1.5	0.93
-1.2	0.12	-0.3	0.38	0.7	0.76	2	0.98
-1.1	0.14	-0.2	0.42	0.8	0.79	2.5	0.99
-1	0.16	-0.1	0.46	0.9	0.82	3	1
		0	0.5				



Example: The table below shows the number of activities for a construction project and the relationship of each with other activities along with the values of a, m, b.
The task is to plan the project using PERT.

Activity	a	m	b	Preceded by
A	6	8	10	-
B	1	7	12	A
C	5	6	7	A
D	5	5	12	B
E	2	4	8	B
F	1	5	7	D
G	6	7	7	F

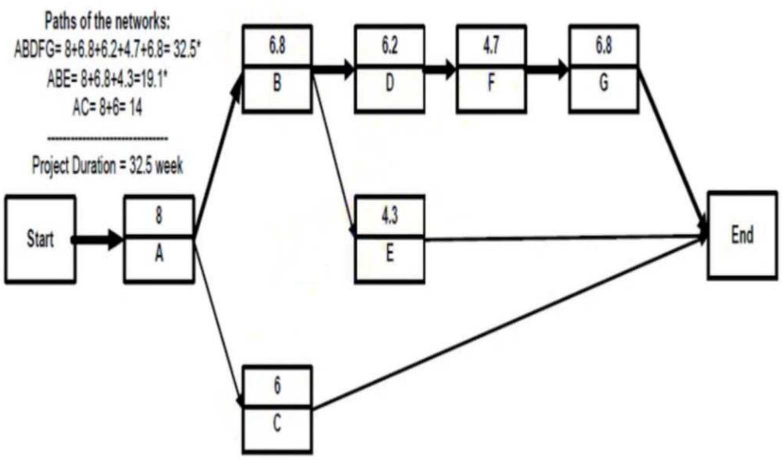
- What is the probability of finishing the project in 32.5 weeks?
- What is the probability of finishing the project in 33 weeks?
- What is the probability of finishing the project in 38 weeks?
- What is the probability of finishing the project in 36 weeks?
- What is the completion time of the project with a probability of 93%?

3. SOLUTION

We calculate t for all activities where:

Activity	a	m	b	t
A	6	8	10	8.00
B	1	7	12	6.83
C	5	6	7	6.00
D	5	5	12	6.17
E	2	4	8	4.33
F	1	5	7	4.67
G	6	7	7	6.83

Identifying the critical activities.



calculating S and V for the critical activities where:

$$S = \frac{(b-a)}{6}, \qquad V = (S)^2$$

Critical Activity	a	m	b	t	S	V
A	6	8	10	8.00	0.67	0.44
B	1	7	12	6.83	1.83	3.36
D	5	5	12	6.17	1.17	1.36
F	1	5	7	4.67	1.00	1.00
G	6	7	7	6.83	0.17	0.03
المجموع				32.50		6.19

$$T = \sum t = 32.5, \qquad S_{cp} = \sqrt{\sum V\,\text{critical}} = \sqrt{6.19} = 2.49$$

The probability of finishing the project in 32.5 weeks:

$$Z_{32.5} = \frac{Ts - T}{Scp} = \frac{32.5 - 32.5}{2.49} = 0$$

$$P_{32.5} = 50\ \%\ \text{from the Table}$$

The probability of finishing the project in 33 weeks:

$$Z_{33} = \frac{Ts - T}{Scp} = \frac{33 - 32.5}{2.49} = 0.2$$

$$P_{33} = 58\ \%\ \text{from the Table}$$

The probability of finishing the project in 38 weeks:

إيجاد احتماليه إنهاء المشروع في زمن 38 أسبوع ؟

$$Z_{38} = \frac{Ts - T}{Scp} = \frac{38 - 32.5}{2.49} = 2.21$$

Find P for Z= 2.21 (from the Z-Table)

Z	P	
2	0.98	$\frac{0.98 - 0.99}{2.5 - 2} = \frac{x - 0.98}{2.21 - 2} \Rightarrow x = 0.984$
2.21	x	
2.5	0.99	

P_{38} = 0.984 = 98.4% from the Z-Table

The probability of finishing the project in 36 weeks:

$$Z_{36} = \frac{Ts - T}{Scp} = \frac{36 - 32.5}{2.49} = 1.41$$

Find P for Z= 1.41 (from the Z-Table)

Z	P	
1.4	0.92	$\frac{0.93 - 0.92}{1.5 - 1.4} = \frac{x - 0.92}{1.41 - 1.4} \Rightarrow x = 0.921$
1.41	x	
1.5	0.93	

P_{36} = 0.921 = 92.1 % from the Z-Table

Finding the time at which the project will finish with a probability of 93%.

From the table, we find that the value of Z at 0.93 → Z = 1.5

$$Z_{P=0.93} = \frac{Ts - T}{Scp} = 1.5 \rightarrow 1.5 = \frac{\text{Ts} - 32.5}{2.49} \rightarrow \text{Ts} = 36.24 = 37 \text{ weeks}$$

(Hares, n.d.; Pilcher, 1992)

4. RESULTS

Analysis of the root causes of the delay

By analyzing the data extracted from the studied projects, several key factors contributing to delays have been identified, namely:

Inadequate Planning:

- In many projects, the scheduling was insufficient or inaccurate, leading to unexpected changes in the timeline during execution.
- For example, in the **Third Bosphorus Bridge Project in Turkey**, the project's start was without a detailed enough timeline, resulting in the redesign of parts of the bridge after execution began, causing delays estimated at 15% of the overall project time.

- Proposed solutions: ensure a detailed timeline is in place from the outset using tools like Primavera to accurately identify critical activities and allocate time precisely.

Poor Coordination Among Parties:

- Some projects were delayed due to poor contractor, consultant, and government collaboration.
- Some administrative procedures took longer than planned in the **Haramain High-Speed Railway Project** due to delays in securing clearances from appropriate agencies.
- Stakeholder coordination may be improved by utilizing flexible collaboration platforms like Trello and Basecamp to share project progress in real time.

Sudden Changes in Design:

- Continuous design changes or execution revisions disrupted the timeline, requiring continual work plan adjustments.
- The Panama Canal Expansion Project deadline was delayed by design changes due to changing water and topographical circumstances. This caused frequent re-evaluation, prolonging execution.
- Proposed solutions: correctly employ change management methodologies, setting explicit criteria to analyze early design changes' possible implications.

Lack of resources:

- Some projects were delayed due to staffing or equipment shortages.
- The Ethiopian Grand Renaissance Dam project was delayed by financial and heavy machinery concerns.
- Proposed solutions: Resource management software like Primavera P6 helps identify and distribute resources across tasks to avoid shortages and maintain the schedule. (O'brien, 1993; Williams, 2019)

Evaluation of the role of scheduling in reducing delays

When comparing projects that relied on modern scheduling techniques like Primavera and **MS Project** (*MS Project Documentation*, 2020) with those that used traditional methods, it was found that:

- Projects using Primavera:

- In the **Dubai Metro project**, using **Primavera P6** (Management, 2019), critical activities were accurately identified early on, and the project's progress was monitored regularly, helping to ensure that the project was completed on time despite challenges related to efficiency and resources.

- The **King Abdullah Economic City project**, which employed advanced scheduling, clearly demonstrated the ability to reduce delays to less than 5% compared to traditional projects that did not use these tools.
- Projects without advanced tools:
- The **road construction project in India**, which relied on traditional methods such as paper schedules, experienced a delay of 12% from the planned schedule due to a lack of adequate tools to adapt to changes in resources. (O'brien, 1993; Williams, 2019)

Proposed Solutions

Improve time management using advanced scheduling software:

- Software like Primavera and MS Project should be adopted for all large and complex projects. These tools provide high capabilities for identifying critical activities, analyzing schedules, and offering detailed reports on project progress, which significantly helps reduce delays.
- For instance, projects that face coordination or resource issues can benefit from the flexible planning these programs offer through Gantt charts and multi-scenario planning.

Enhance coordination among parties:

- It is recommended to use digital collaboration platforms like Basecamp and Slack to improve communication between multiple teams (contractors, consultants, and government entities).
- Specific time should be allocated at the beginning of each project to clarify roles and responsibilities to ensure smooth workflow, and a **collaborative project management system** can help reduce delays caused by poor coordination.

Implement thoughtful change policies in design:

- Design changes should occur in well-considered phases, taking into account the analysis of potential impacts on the timeline, and applying a flexible mechanism to track modifications and understand their actual effects on the project in real-time. (Heagney, 2016; Leach, 2014)

Presenting results using tables and graphs

To present results more clearly, the following will be used:

Gantt charts: showing a comparison between the original and modified timelines of the studied projects.

Comparative tables: displaying projects that used advanced scheduling tools compared to traditional projects in terms of delivery delays and costs.

Graphs: illustrating the difference in delays between projects that relied on advanced scheduling techniques (Management, 2019) (like Primavera) and traditional projects.

Table 1: Comparison of Expected vs Actual Delays

Project	Tools Used	Expected Delay (%)	Actual Delay (%)	Improvement (%)
Bosphorus Bridge	Traditional	10%	15%	-
Haramain Train	Traditional	12%	18%	-
Dubai Metro	Primavera P6	5%	3%	40%
KAEC	MS Project	8%	4%	50%
Panama Canal	Primavera P6	15%	8%	47%

- The table shows that projects using traditional methods experienced significant delays compared to those that used advanced software. (Mubarak, 2015; Smith, J., & Brown, 2020)

Project	Planned Cost (Million USD)	Actual Cost (Million USD)	Cost Increase Due to Delays (Million USD)
Bosphorus Bridge	500	575	75
Haramain Train	3000	3600	600
Dubai Metro	2000	2100	100
KAEC	1500	1800	300
Panama Canal	6000	6300	300

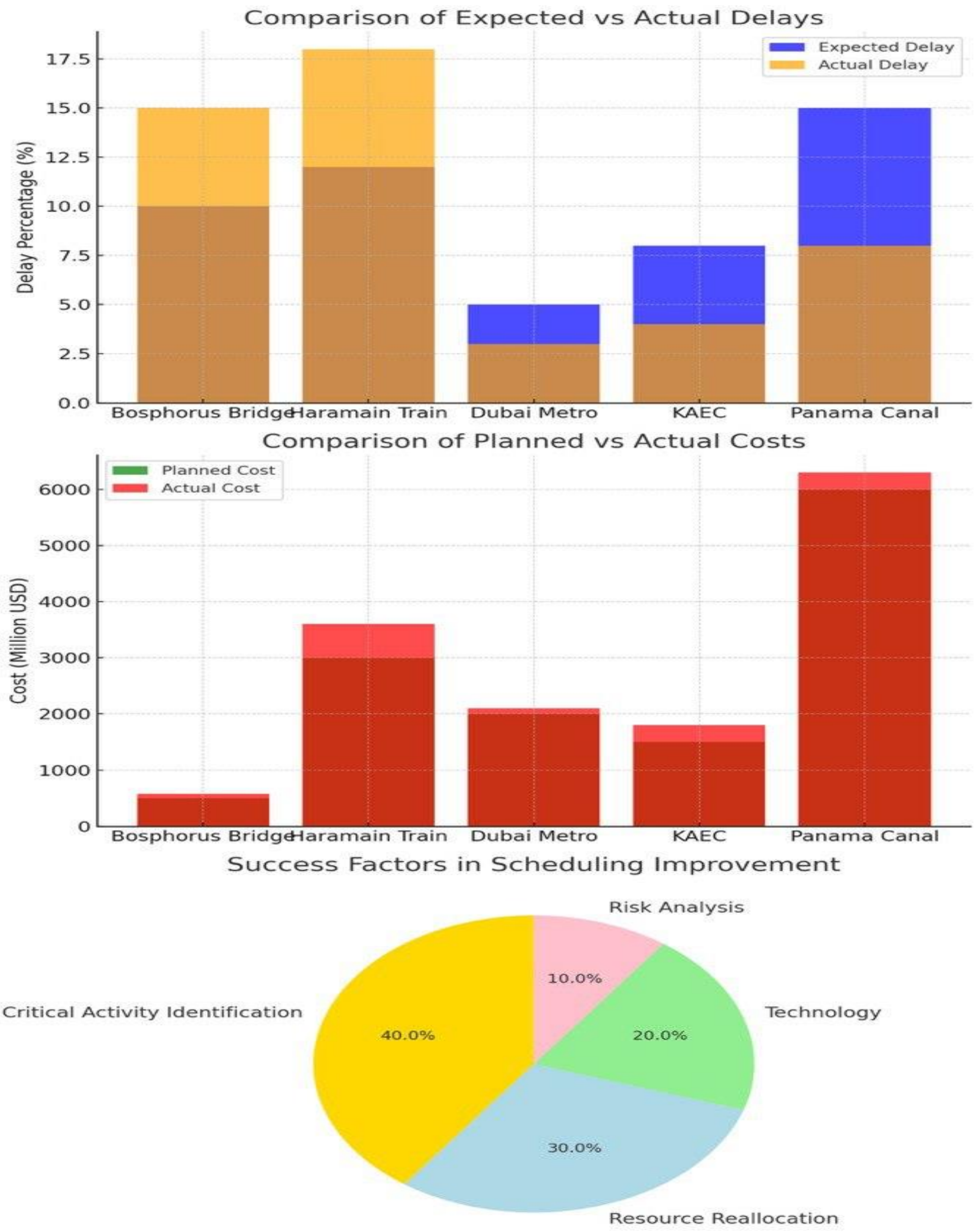
Analysis:

- Projects that faced major delays due to poor scheduling or a lack of coordination among parties saw substantial increases in costs.

- Projects using conventional approaches saw a larger spike in costs. (Lock, 2020; O'brien, 1993)

Table 3: Key Factors Leading to Success

Factor	Contribution (%)
Critical Activity Identification	40%
Resource Reallocation	30%
Technology Usage	20%
Risk Analysis	10%



(Johnson, P., & Lee, 2018; Kerzner, 2017)

5. CONCLUSION

Focusing on identifying the root causes of infrastructure project delays and evaluating the efficacy of scheduling improvement methods, this study examined the role of scheduling in minimizing such delays. The findings highlight that delays in infrastructure projects are often caused by inadequate planning, communication, cooperation, design modifications, and financial constraints, as seen in the **Grand Ethiopian Renaissance Dam** and the **Haramain**

High-Speed Railway Project. Advanced scheduling tools such as **Primavera P6** and **MS Project** play a crucial role in reducing delays and improving execution efficiency by enhancing task organization, assignment, critical path identification, and delay assessment. Delays also significantly impact project costs, with the **Haramain High-Speed Railway Project** experiencing approximately $600 million in cost overruns. However, projects with better scheduling, such as the **Dubai Metro**, faced lower cost increases. The use of advanced software improved resource allocation, minimized resource-related delays, and enhanced schedule management by emphasizing critical activities.

6. RECOMMENDATIONS:

In order to guarantee proper scheduling and minimize delays, the findings suggest that all significant projects should use modern software. Furthermore, it is crucial to focus on training project management staff to use these technologies efficiently.

Last but not least, when it comes to infrastructure projects in particular, timing is a game-changer. To accomplish project objectives within the allotted time, careful preparation and the efficient use of modern scheduling tools must be given top priority. (Heagney, 2016; Leach, 2014)

REFERENCES

Al-Attar, I. (n.d.). *Construction project management and professional relationships*.

Hares, R. H., & Hares, F. (n.d.). *Construction management*.

Heagney, J. (2016). *Fundamentals of project management*. Amacom.

Heldman, K. (2018). *Project management jumpstart*. John Wiley & Sons.

Johnson, P., & Lee, K. (2018). Integration of risk management and scheduling in large infrastructure projects. *Procedia Engineering*, *212*, 123–130.

Kerzner, H. (2017). *Project management: A systems approach to planning, scheduling, and controlling*. John Wiley & Sons.

Leach, L. P. (2014). *Critical chain project management*. Artech House.

Lock, D. (2020). *The essentials of project management*.

Microsoft Corporation. (2020). *MS Project documentation*.

Mubarak, S. A. (2015). *Construction project scheduling and control*. John Wiley & Sons.

Nicholas, J. M., & Steyn, H. (2020). *Project management for engineering, business and technology*. Routledge.

O'Brien, J. J. (1993). *CPM in construction management*.

Oracle Corporation. (2019). *Primavera P6 Professional Project Management*.

Pilcher, R. (1992). *Principles of construction management*.

Smith, J., & Brown, L. (2020). A comparative analysis of project scheduling techniques. *International Journal of Project Management, 38(4)*, 567–580. https://doi.org/10.xxxx/ijpm.2020.xxxx

Williams, R. (2019). Impact of delays on construction projects and mitigation strategies. *Journal of Construction Engineering and Management, 145(6)*, 04019045.