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Techniques of construction delay analysis – A study of application and enhancement criteria

Master Thesis

Master of Science and Engineering in Construction and Real Estate Management

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Conceptual Formulation

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Techniques of construction delay analysis – A study of application and enhancement criteria

Introduction

The project's completion time is basically the essence for the employer and the contractor. For the purposes of taking the correct decision on future time and/or costs compensation claims, it was very imperative for the contracting parties to analyse project delays. Over the years, current methods of delay analysis (DAT) have been beneficial, but the high incidence of litigation associated with delay claim resolution has not been curbed (Al-Momani, 2000). The limitations and capabilities of the technologies in their practical application are a major source of controversy. The existing methods of analysis of delays (DAT) have been beneficial over the years, however, the high level of disputes associated with the settlement of delays have been not limited. There is some debate about the limitations and the capacity of the technologies to implement them (Arditi and Pattanakitchamroon, 2006). It is crucial to learn about these aspects of techniques to understand the genuine issues and their improvement needs. Furthermore, avoiding construction claims and disputes requires an understanding of the contractual terms and causes of claims (Iyer, Chaphalkar and Joshi, 2008).

Methodology

The study will be conducted using a mixture of quantitative and qualitative methods. In understanding the real problems involved and their enhancement needs, it is important to gain good knowledge about these aspects of techniques. This paper is intended to expand this expertise through:

- Part 1 will study the major differences between the delay techniques.
- Part 2 will explore the impact of the project delays on all the parties in terms of time and/or cost.
- Part 3 will collect, and analyse data related to project delays based on previous studies.
- Part 4 will be an evaluation of the most popular DATs based on a case study; an evaluation and enhancement of the main related issues frequently not dealt with by the techniques.
- Part 5 will conduct a claim preparation using Primavera P6 or one of the BIM tools.

The evaluation confirmed that, due mainly to their implementation procedures, the different methods provide different results for evaluating the same delay claim scenario. The problems frequently overlooked in the study, but which also influence the outcomes of the delay analyses, include the functionality of the software used for the analysis, the loading of resources and elevation requirements, the resolution of concurrent delays and the timing of the strategy. The key study suggestions are the need to strengthen the way these problems are integrated in the report and reflected on in future studies.

Research questions or objectives

- To study the different process between delay analysis techniques
- To propose the easiest procedure which leads to solving claims with no efforts and before reaching the disputation level
- To calculate the project delay and work to try to identify how much of it is attributable to each party (contractor, owner, or neither) so that time and/or cost compensation can be decided.
- To elaborate the main causes of delay in construction.
- To construct a claim preparation using Primavera P6 or one of the BIM tools.

Time Scale

Project key dates	Start date	End date
(Research Proposal) **Submit final topic to HTW & Metropolia UAS**	**06/2021**	**07/2021**
Research Master Plan and strategy	**07/2021**	**08/2021**
Literature Review	**08/2021**	**10/2021**
Collecting and analyzing data for the case study	**10/2021**	**02/2022**
1st Draft for the thesis	**02/2022**	**03/2022**
2nd Draft for the thesis	**03/2022**	**05/2022**
Final Draft for the thesis	**05/2022**	**06/2022**

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Abstract

Both the employer and the contractor place a high value on project completion time. Analysis of project delays was critical for contractual parties in order to make informed decisions about future compensation claims. Even if delay analysis techniques (DAT) have proven useful over the years, the high number of disagreements around the resolution of delays has not decreased. Concerns concerning the limits and capabilities of current technology have been raised.

Construction delays, the causes and types of delays, and methods for analyzing timetable delays are all explored. The article discusses two case studies in order to get to the bottom of the research question. Case studies on the Berlin-Brandenburg airport and a hypothetical restaurant storage facility are presented here. The paper details the implementation of the delay analysis technique. Time overruns and cost overruns might result from delays in construction, according to one of the case studies. Inconvenient delays in a project's construction timetable may cause significant problems for the project's contractors and owners, leading to costly disputes, contentious issues, and strained relationships among all parties.

There are a variety of reasons why projects go behind schedule, but this thesis focuses on two case studies and examines the approaches used in the past. A wide-ranging examination of delays. Various methods were used to determine the length of the construction delays and who was to blame. Final results include an examination of two delay analysis approaches' limits, which shows that each technique has a distinct set of drawbacks that may require a certain delay technique to be used by the project team.

Keywords: time extensions; delay analysis, construction planning, scheduling

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List of Abbreviations

AC: Actual Cost

ACWP: the actual cost of work performed

APM: Association for Project Management

ASCE: American Society of Civil Engineers

BCWP: the budgeted cost of work performed

BCWS: the budgeted cost of work scheduled

BFF: Berlin Flughafen Brandenburg

CPM: Critical Path Method

DAT: Delay Analysis Techniques

ED: Excusable Delays

EOT: Extension of Time

EF: Early Finish

ES: Early Start

EV: Earned Value

LF: Late Finish

LS: Late Start

LOB: Line of Balance

NED: Non-excusable Delays

PERT: Program Evaluation Review Technique

PM: Project Management

PV: Planned Value

TIA: Time Impact Analysis

WBS: Work breakdown structure

1. Introduction

Construction management is primarily concerned with resource planning and control within the context of a project. Construction management processes help project managers understand how to effectively use their resources throughout the construction process, and they attempt to ensure that the resources are employed in a timely and efficient manner. Only a small portion of the whole construction process is spent on the actual building site itself. The first section is mostly devoted to office tasks. To ensure a high-quality project that is completed on time and under budget, it is critical that all of these tasks be completed in the office prior to beginning work on the site.

In most construction projects, delays are commonplace. The preconstruction phase is defined as the time between conceptualization and signature of the contract between owner and contractor. However, delays may also occur during construction, which is the time during which the project is really being built. There is a constant flux in project timetables. Project delays may be caused by a variety of circumstances, both controlled and uncontrollable. These setbacks have a direct influence on the timeliness and quality of the project. One of the most challenging aspects of a construction project is staying on schedule. This may lead to expensive disagreements and poor working relationships amongst the many parties involved in the project. How to precisely calculate the total cost of construction delays might be difficult. Otherwise, any parties participating in the building process may file claims for delay. The schedule delay analysis approach should be acceptable to all of the project's stakeholders.

The topic of building schedule delays has been extensively researched, and a variety of methods for doing so have been put forward. An analysis of schedule delays is used to discover delays and quantify the overall effect they have on a project's schedule. Bar chart and critical path method (CPM) schedules are two of the most basic techniques used in schedule analysis. The construction business has been given with several publications outlining typical approaches to schedule analysis, as well as innovative ideas. Since each strategy has benefits and limitations, no one way is appropriate for all kinds of projects when it comes to dealing with different kinds of delay claims..

Construction project delays are almost always an unfortunate fact of life. At the beginning of a project, the timetable is prone to being reworked several times, which results in delays. Contractors as well as owners may face substantial challenges due to timetable delays, which may lead to expensive conflicts as well as contentious situations and strained relationships between all parties involved. Because of this, the detection, measurement, and analysis of delays are critical. Contractors tend to blame the owner for delays, but owners prefer to place the blame on the contractor or a third-party provider. To prevent or reduce the negative effect on the project and its participants, it is vital to examine schedule delays and discover the most significant reasons of delay in building projects.

1.1 Research Objectives

Delays in construction may have a significant influence on a project's completion time, and this research was aimed at determining who is responsible for these delays and how they affect the overall project time. By answering the following questions, we were able to arrive at the following additional research questions:

- Is there delay in Construction? (1st Hypothesis) How to prove it?

- Explain the delay Consequences in construction? How to minimize construction delay consequences?

- What is the current compensation of the project delays on all the parties in terms of time and/or cost? How to minimize it?

1.2 Research Scope

Only Delay Analysis Techniques will be the subject of this investigation. This study's analysis is based on the work of construction industry specialists and prior research. What are the consequences of building delays, and how may they be reduced? To conclude, a second case study was carried out to determine the cause of the project's delay and to assign a monetary value to each party's share of the blame. In addition, the examination of this case study yields a list of the limits of each strategy.

1.3 Research Procedure

A primary goal of the investigation was to identify the best effective method for analyzing construction-related timetable delay. On the basis of theses, books in the library, scientific papers, articles and online sources, a literature survey was conducted on a variety of issues. Research on construction schedule delays, their causes, classifications, and analytical tools was conducted as part of this study, which was used to better understand the difference between project planning and project scheduling and to identify the goals of project scheduling.

1.4 Research structure

The research is organized into five sections, the first of which is this introductory chapter. In the first chapter, the study's goals and methods are laid out in full detail. The structure and substance of the chapters are also included. Chapter 2 provides a short literature review on construction project planning and scheduling methodologies. After that, information on construction schedule delays, the reasons and kinds of construction delays, and the techniques of schedule delay analysis are discussed. In order to address the research topic, two case studies are discussed in the third chapter. The airport in Berlin-Brandenburg is the subject of the first case study, while a hypothetical storage facility for a restaurant is the subject of the second. The implementation of the delay analysis approach is discussed in detail in the fourth chapter. A summary of the study's results and conclusions can be found in the study's fifth and final chapter.

2. Literature Review

2.1 Construction Project Planning

2.1.1 Definition

Project planning is characterized as an output-driven approach..It is concerned with determining what, when, how, and who will take the essential steps to achieve stated objectives (Lester, 2014).

The term “planning” encompasses all construction phases, It necessitates a continuous approach, all the way from feasibility through completion or commissioning. Neale, Neale, and Stephenson (2016).

2.1.2 Objectives

Planning, according to Arkan and Dikmen (2004), is "the process through which efforts and decisions are made to achieve the intended goals at the desired time and in the desired way." A construction project's goal is to achieve these things, according to them.

1. To fulfill the stipulated deadline for the project's completion (duration)
2. To ensure that the deadline is met and the budget is not exceeded (with a profit)
3. Ensure that it meets all requirements for both technical and administrative aspects.

According to long-time construction specialists, planning is at the heart of a building project’s life cycle. The planning phase essentially directs everyone on a construction project to their destination. The construction plan is created by the project’s significant stakeholders (usually using Project Management (PM) software today), who compile all the scheduled activities into a single document. Before the timetable of all activities is drawn, the project objectives and requirements are defined. The usage of materials, tools, machines, and equipment and the timing of tasks are all planned. Following are the objectives of construction project planning (Engineering et al., 2014).

1. Each activity's planning
2. Construction Techniques
3. Construction Equipment and Machinery Planning
4. Materials procurement
5. Employee skill development planning
6. Document and drawing requirements planning
7. Financial Management

The basic purpose of planning, according to Arkan and Dikmen (2004), is to fulfill the manager's primary roles: The ability to guide and control oneself. In order to achieve the second purpose of project planning, all contacts and data management must be organized. According to the writers, the third role of planning is to allow project management and forecasting. Furthermore, according to Smith (2002), the actions of designers, manufacturers, suppliers, employees, contractors, and their capabilities must be integrated and connected with the contractor's goals.

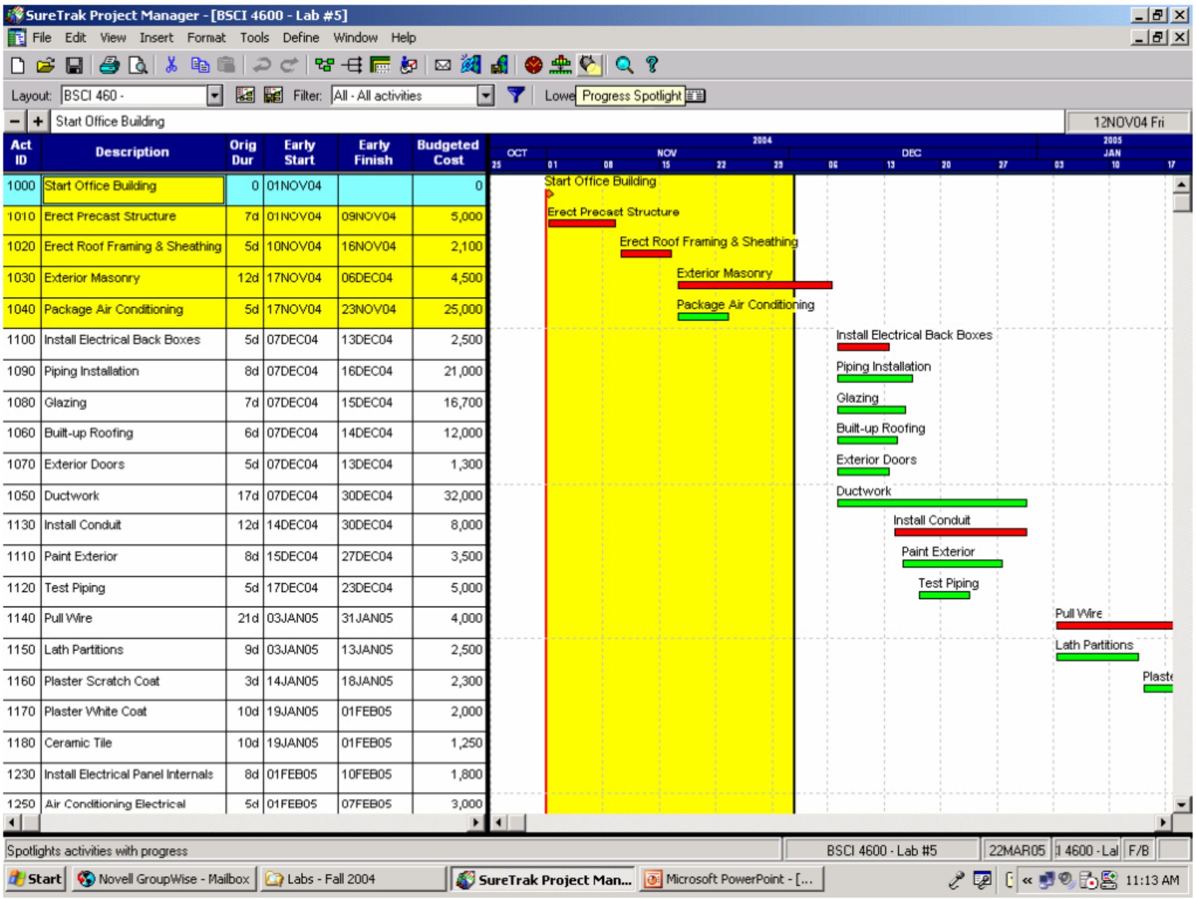
2.2 Methods of Project Planning

The construction planning process is considered the most substantial part of construction management (Najjar et al., 2004). To estimate the time required for projects before they begin, project managers use different project scheduling methods. Before, during, and after construction, a project’s duration can be divided into three parts. Planning and estimating project duration, cost, materials, workers, and sequence of activities are included in the first part of the project, which occurs before planning. It is essential to plan out a project’s start and finish dates, how much it will cost, and what materials, machines, and equipment will be used. There are many methods to schedule projects, such as the following:

2.2.1 Critical Path method

The Critical Path Method is defined in the Project Management Body of Knowledge (Project Management Institute, 2013): "The Critical Path Method is the sequence of scheduled activities that determines the project's duration."

The critical path method (CPM), also known as critical path analysis (CPA), is a scheduling approach that illustrates a project and the sequences of activities necessary to accomplish it using a network diagram. After the pathways have been identified, an algorithm is used to compute the length of each path to find the crucial path, which defines the project's overall duration. The critical path of a project could also be identified with tools such as "Primavera P6" or "Microsoft Project," which can help evaluate the critical activities of a project with large numbers of activities, as demonstrated in (Fig.1).



Act ID	Description	Orig Dur	Early Start	Early Finish	Budgeted Cost
1000	Start Office Building	0	01NOV04		0
1010	Erect Precast Structure	7d	01NOV04	09NOV04	5,000
1020	Erect Roof Framing & Sheathing	5d	10NOV04	16NOV04	2,100
1030	Exterior Masonry	12d	17NOV04	06DEC04	4,500
1040	Package Air Conditioning	5d	17NOV04	23NOV04	25,000
1100	Install Electrical Back Boxes	5d	07DEC04	13DEC04	2,500
1090	Piping Installation	8d	07DEC04	16DEC04	21,000
1080	Glazing	7d	07DEC04	15DEC04	16,700
1060	Built-up Roofing	6d	07DEC04	14DEC04	12,000
1070	Exterior Doors	5d	07DEC04	13DEC04	1,300
1050	Ductwork	17d	07DEC04	30DEC04	32,000
1130	Install Conduit	12d	14DEC04	30DEC04	8,000
1110	Paint Exterior	8d	15DEC04	27DEC04	3,500
1120	Test Piping	5d	17DEC04	23DEC04	5,000
1140	Pull Wire	21d	03JAN05	31JAN05	4,000
1150	Lath Partitions	9d	03JAN05	13JAN05	2,500
1160	Plaster Scratch Coat	3d	14JAN05	18JAN05	2,300
1170	Plaster White Coat	10d	19JAN05	01FEB05	2,000
1180	Ceramic Tile	10d	19JAN05	01FEB05	1,250
1230	Install Electrical Panel Internals	8d	01FEB05	10FEB05	1,800
1250	Air Conditioning Electrical	5d	01FEB05	07FEB05	3,000

Figure 1 Example of a computer-generated CPM schedule (Kramer and Jenkins, 2006)

Activities should be classified according to which one comes first and comes second. This technique will tell us how long the project will take to finish in months, weeks, or days and clarify the construction process for employees, contractors, engineers, and supervisors to understand the procedure and deadlines for each project activity. This technique displays the earliest starts (E.S.), earliest finishes (E.F.), latest starts (L.S.), and latest finishes (L.F.) of each project activity.

To fully understand the principle of the critical path, you must comprehend the terminology utilized in this technique (Project Management Institute, 2013).

Earliest start time (E.S.): Earliest date the activity can start.

Latest start time (L.S.): The latest date that the activity can start without causing a delay to the project completion date.

Earliest finish time (E.F.): The earliest date the activity can finish.

Latest finish time (L.F.): The latest date that the activity can finish without causing a delay to the project completion date.

Float. The amount of time an activity can be delayed without delaying the overall project duration.

To calculate the critical path in project management, these are the principal steps planner need to follow as described in (Fig.2):

Collect Activities

Identify Dependencies

Create a Network Diagram

Estimate Timeline

Use the Critical Path Algorithm

Forward Pass

Backward Pass:

Identify the Float of Each Activity

Identify the Critical Path

Revise During Execution

Figure 2 Critical path steps (Own work)

The procedure of implanting CPM is explained by (Project Manager 2020) as follows:

You are using a work breakdown structure to collect all the project activities that contribute to the final product. Firstly, before you begin, figure out which activities are dependent on others. Then A critical path analysis chart, often known as a network diagram, illustrates the series of events. Next, figure out how long each task will take. After that, the algorithm has two components: a forward pass and a backwards pass.

Consequently, Determine the earliest start (E.S.) and earliest finish (E.F.) of each activity using the network diagram and the length of each activity (E.F.). An activity's E.S. is equal to its predecessor's E.F., and its E.F. is calculated using the formula E.F. = E.S. + t. (t is the activity duration). The E.F. of the previous activity determines the estimated time to finish the whole project. Then assigns the latest finish to the last activity's earliest finish. The formula for determining the L.S. is L.S. = L.F. – t. (t is the activity duration). The L.F. is the earliest start times for the activity that immediately follows the preceding activities. This is why the float is the length of time that an activity may be postponed without delaying the project's overall completion timetable. The float formula shows the critical path since the critical path has no float: Float = L.S. – E.S. The critical route is then made up of actions with 0 float. Finally, Modify Throughout Execution: Keep updating the critical path network diagram as you progress through the execution stage.

2.2.2 Gantt Chart

Gantt charts are used as a visual aid when it comes to project schedules. For example, the bar chart shows the start and end dates of many project aspects, including resources and milestones and task and dependency relationships.

“Most project managers are familiar with the Gantt chart—but there is more to Henry Laurence Gantt’s work than his useful document” (Bourne, 2012). One of the most straightforward techniques for preparing a project schedule is Its actions are displayed as bars, with the length of each bar indicating the time of the activity. Each action's start and finish dates are indicated at the beginning and end of the bar. As a result, these bars could run parallel based on the project’s implementation schedule and availability of resources (Maltz, 2018).

A Gantt chart identifies which activities may be completed in parallel and which must be completed in order. This information may be used to investigate the trade-offs between scope (performing more or less work) and cost (using more or fewer resources) and the project’s timeline. The project manager can examine the impact of adding or lowering resources or scope on the end date. A basic Excel Template may be used to create a Gantt Chart and change it at any moment. Gantt Charts may be created using an Excel template for scheduling and planning construction projects. Each activity in a project must be estimated in terms of time, and each task must be reliant on other activities to build a chart. It lets a project manager focus on the most critical aspects of a project and create a realistic timeline for completion only by gathering this information. Additionally, with tools such as “Primavera P6” or “Microsoft Project,” a Gantt chart could be created.

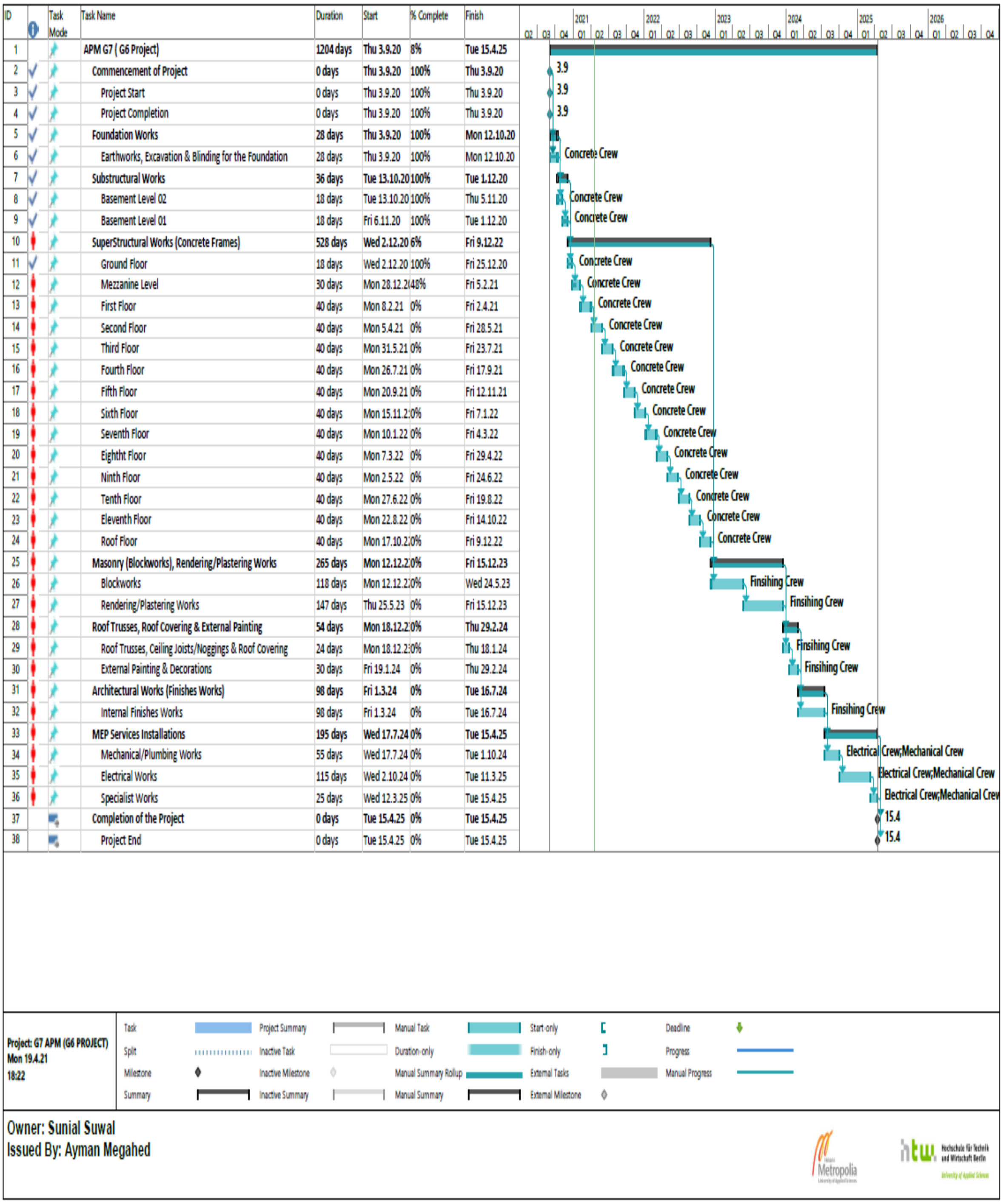


Figure 3 Gantt chart (Own work)

The Association for Project Management (APM) answered the question Why use a Gantt chart?

- Set out a preliminary timetable for the project.
- Determine the allocation of funds and resources.
- Make changes to the project.
- Observe and report on the progress of the project.
- Organize and convey the timetable.
- Display milestones
- Identify and report problems

2.2.3 Program Evaluation and Review Techniques (Pert)

Program Evaluation and Review Technique (PERT) is a version that includes a statistical approach for determining the chance that a project will be finished on a particular date.(Neale, Neale and Stephenson, 2016).

Researchers and project management practitioners have utilized PERT (program evaluation review technique) to run a growing number of varied applications since its introduction in the late 1950s. When project managers plan and estimate their projects, for example, they may use these tools to help them evaluate essential routes and establish both early- and late-start and completion dates., many computer programmes include PERT (Green and Zigli, 1984). To apply the PERT Method Implementation, these are the main steps that planners need to follow:

- List the activities and milestones
- Determine the order in which the activities will be carried out.
- Generate a network diagram.
- Calculate the length of each activity.
- Establish the critical path

The PERT technique relies on basic statistical computations to arrive at its results. Three-time estimates are used:

Optimistic Estimate: The least amount of time needed to finish the job.

Pessimistic Estimate: The amount of time needed to finish the work in the most time.

Most Likely Estimate: The amount of time that it will take to finish the work in the best-case scenario.

Like all techniques, Pert has significant advantages that planners noticed (Aljebori, 2013) stated as follows:

- Timeframe for project completion
- The likelihood that a given work will be finished by a certain date.
- The completion of time-sensitive tasks (critical route activities)
- Slack-time and resource-contributing activities
- Dates of the start and finish of the activity.

2.2.4 Work Breakdown Structure

All three project criteria - quality, money, and time - are planned to use a work break-down structure. It’s breaking down a project into tasks or work packages (Fig.4). This reduces the chance of missing or skipping an important stage because all elements necessary to finish the project are defined (R Keith Mobley, 2001).

Project Risks			
Organization	**Environment**	**Technical**	**Financial**
Management	Legislation	Technology	Financing
Resources	Political	Contracts	Exchange rates
Planning	Pressure groups	Design	Escalation
Labour	Local customs	Manufacture	Financial stability of
Health and safety	Weather	Construction	(a) project
Claims	Emissions	Commissioning	(b) client
Policy	Security	Testing	(c) suppliers

Figure 4 Work breakdown structure (WBS) (Project Management Institute, 2013)

To ensure efficient project management, a detailed planning process is required. An effective Work Breakdown Structure (WBS) creates the basis for defining and managing the project's objectives (Sheng, 2019). The WBS is a significant way to achieve the project deliverables (Sheng, 2019). The usage of WBS starts with Establishing the project's scope of work in terms of deliverables, then breaking them down further into components. Then Set up a structure for the project management team's status and progress reporting. The project manager and stakeholders should be able to communicate with each other throughout the project's duration. As well as communicating information about project scope, dependencies, and risk, the WBS may also be used to communicate progress and performance information about budgets and schedules. Finally, Other project management procedures and deliverables may require your input.

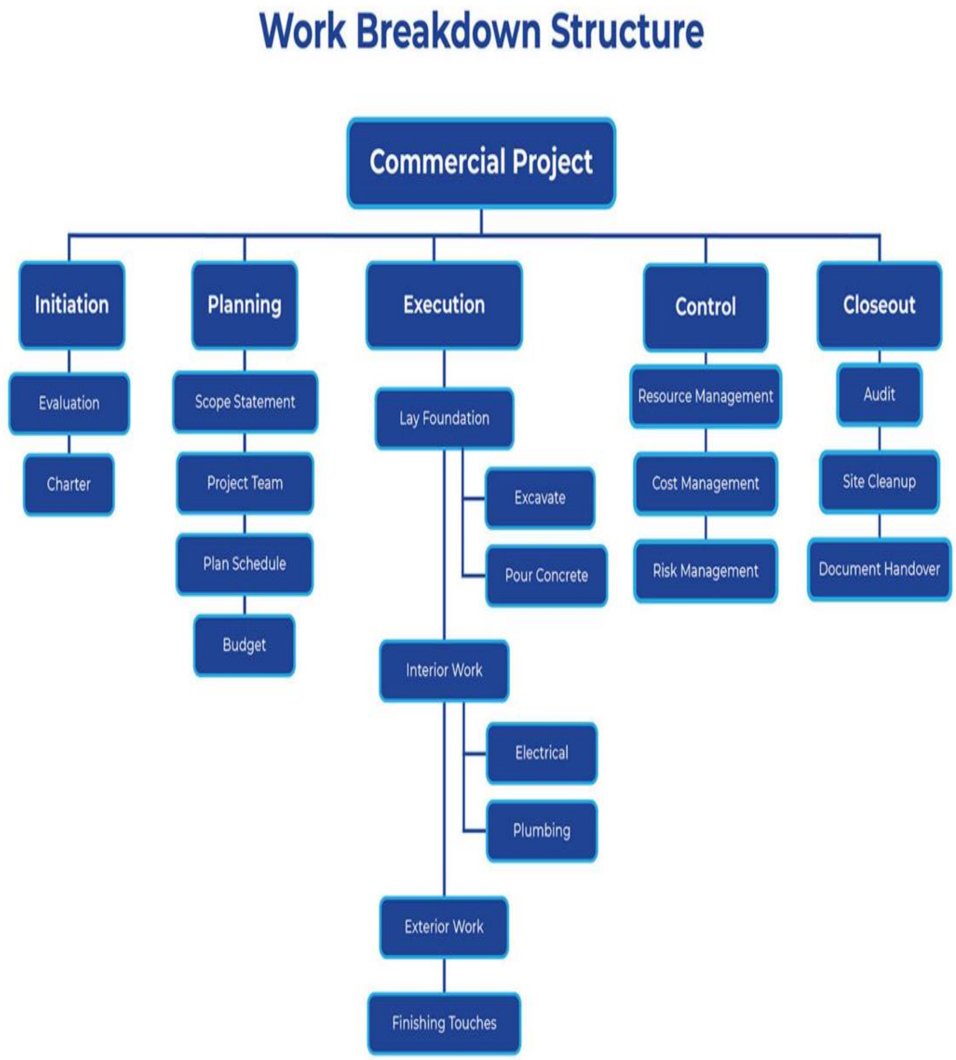


Figure 5 Work breakdown structure for commercial project (ProjectManager.com, 2019)

2.2.5 Resource Allocation Chart

This method is Beneficial in projects when there is a competition for project resources among the activities. Materials, certain forms of labour, transportation resources, etc., are all examples of resources. There are three columns for each activity in this method's table (Start date, Duration and End date). However, like previous techniques, this one does not provide as much detail. While the Gantt chart shows both planned and actual work, the Resource Allocation Chart shows just scheduled work. The act of allocating or loading resources is nothing more than allocating the needed resources to each operation in the appropriate amount and time. Construction resources are divided into four primary groups, known as 4Ms (Manpower, money, material, and machinery) (Eirgash, 2020).

Act.	Cem. Bags																								TF	Tot Res
A	0	0	0	0	0																				0	0
B	5	5	5	5	x	x	x	X	x	x															6	15
C	7										7	7	7	7											0	28
D	10					10	10	10	10	10															0	50
E	6					6	6	6	6	6	6	x	x	X	x	x	x	x	x						8	36
F	12														12	12	12								0	36
G	8																	8	8						0	16
H	6														6	6	6	6	6	6	6	x	x	x	3	42
I	0																		0	0	0	0	0	0	0	0
Days		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23		223
Cement bags Per-day		5	5	5	0	16	16	16	16	16	13	7	7	7	18	18	18	14	14	6	6	0	0	0	Max	18

Figure 6 Resource histogram with Bar chart (Eirgash, 2020)

2.2.6 Line of balance chart (Linear Scheduling Method)

When a construction project comprises blocks of repeated work activities, such as roads, pipelines, tunnels, railroads, and high-rise buildings (LOB), it is utilized as a management control method. Information on time, cost and completion is collected, measured, and presented against a specified plan by LOB (Project Management Institute, 2013). Plan and manage workflows with the use of Line-of-Balance, a visual method. The high degree of repetition makes it ideal for building projects. Despite its advantages, Line of Balance has not been widely adopted in the international building sector. However, since the 1980s, it has been utilized as Finland’s primary scheduling tool (Seppänen & Aalto, 2005).

Line-of-Balance studies from the past provide algorithms and heuristics to optimize resource usage continuity, reduce time, and model learning curves (Kang et al. 2001, Arditi et al. 2001, Harris & Ioannou 1998).

When scheduling multi-story buildings, Line of Balance (LOB) is one scheduling and management approach that attempts to overcome CPM's multi-story scheduling limitations. Although the LOB method is most suited for repeated projects, such as residential building construction, it may also be used for other projects. In addition to their visual presentation, LOB schedules are easy to grasp and have specific planning objectives. (Hafez, 2004).

(Badukale and Sabihuddin, 2014) Stated the advantages of Line of Balance as follows: Work in progress in a particular region is visible at any one point during a project. Additionally, being capable of tracking and optimizing a vast number of repetitive operations performed in several zones or locations. Moreover, Cost and time optimization analyses are more manageable due to the abundance of information accessible for each project activity. This technique is quite popular because of its ease of installation, improved presentation, and visualisation. (Badukale and Sabihuddin, 2014) Also added that Scheduling is easier to adjust and update, better management of the project's subcontractors. Finally, Resource management and resource optimization functions are simplified and transparent. Consequently, it helps project managers to assess whether they can achieve the timeline if they keep working as they have been in the middle of a project.

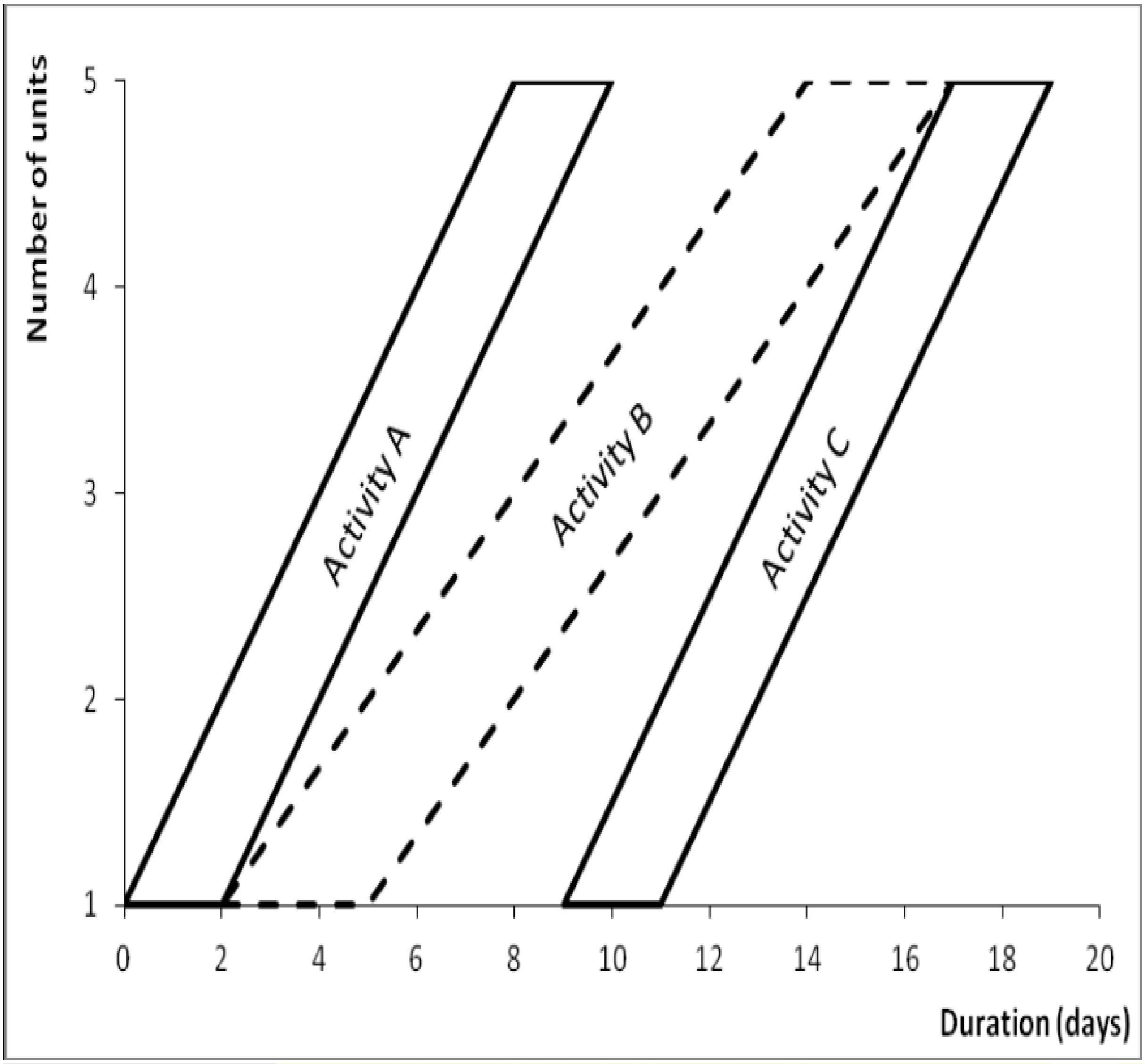


Figure 7 LINE OF BALANCE SCHEDULING TECHNIQUE LOB (Zahran, Nour and Hosny, 2016)

2.2.7 S-curve (cumulative progress chart)

One way to visualize an S-curve is to compare it to a time-based data field, such as the number of person-hours or the cost. When used in project management, the S-curve may track project progress by comparing the predicted and actual shapes (Project Management Institute, 2013).

There are two curves in this S-curve envelope. The top curve represents the curve from the beginning of time, while the lower curve represents the curve from the end of time. If the S-curve obtained from correct progress data is suitable or has to be altered, this warning envelope may be utilized as an early warning system. Consider the case when actual progress is being compared to a scheduled-based S-curve envelope and the project is found to be outside the envelope. As a result, the appropriate course of action depends on whether or not the real S-curve falls inside or outside the envelope.

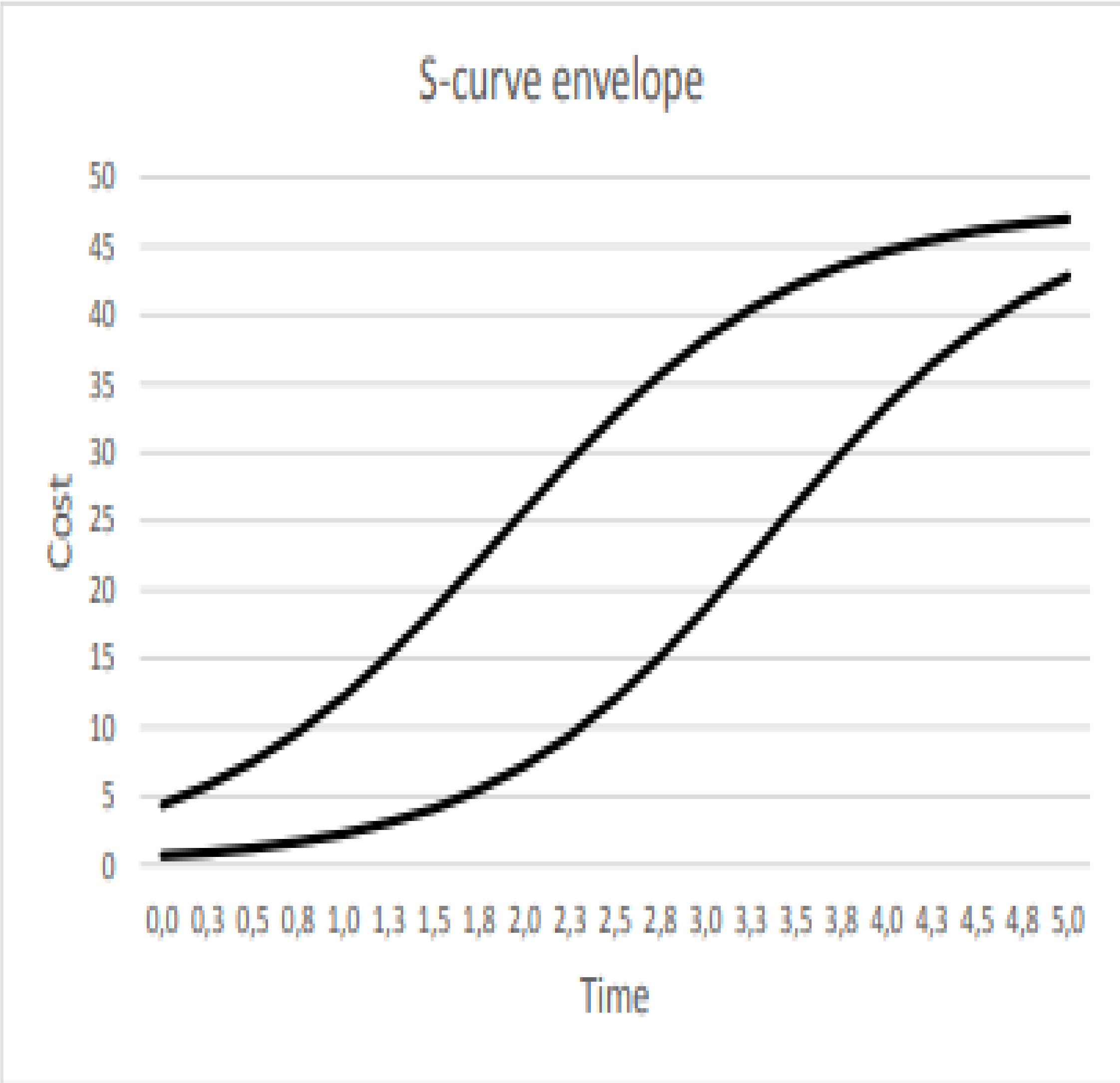


Figure 8 S curve (Cristóbal, 2017)

The abbreviations for the fundamental earned-value values were derived straight from the initials of the defining nomenclature before the current version of PMI's Handbook of Project Management Theory and Practice (PMBOK® Guide — Project Management Institute Standards Committee, 2000).

- BCWP.: the budgeted cost of work performed
- ACWP.: the actual cost of work performed
- BCWS.: the budgeted cost of work scheduled

In the current version of the PMBOK® Guide, the Project Management Institute sought to enhance this terminology by decreasing the number of words per cost phrase to two:

- E.V.: Earned Value (BCWP)
- A.C.: Actual Cost (ACWP)
- P.V.: Planned Value (BCWS)

2.3 Construction Schedule Delays

2.3.1 Construction Delays: What Causes Them?

Over the years, several research studies have been performed to investigate the causes and impacts of building delays. Much research on construction delays exists, yet there is still an issue with many projects not finishing on schedule. (Durdyev and Hosseini, 2019) made an investigation on the causes of delays in construction projects by searching for the most significant delays mentioned in previous studies.

Climate/weather conditions (C1) have been identified as a significant source of delay in seventy-four research studies. However, these delays are excused because the contractor has no control over the weather/climate situations (Nguyen et al., 2010). In 63 studies, "poor communication, coordination, and disagreements among stakeholders" (C2) was listed as the second most common cause for delays. 59 studies found that "ineffective/inadequate planning" (C3) was the third most common cause of failure. C4 (material scarcity) was mentioned 58 times in the studied articles. 'Financial troubles' (C5) and 'Payment delays' (C6) were cited by 58 and 56 people, respectively, making them the 5th and 6th most prevalent causes.

"Equipment/plant shortage" was found in 54 of the studies that were evaluated (Durdyev and Hosseini, 2019), with the bulk of the research coming from nations with weak economies that are import-based or nations that are suffering political unrest (C7)

(Enshassi et al., 2010; Kadry et al., 2017). According to the findings of a number of research, project timelines are negatively impacted when there is a "lack of stakeholder experience, credentials, or competence" (C8) (Durdyev et al., 2018).

Despite the proliferation of new building technology, the construction industry continues to rely heavily on manual labor (Durdyev and Ismail, 2016). It should come as no surprise that there is a labor shortage in the construction industry (C9), since this deficit has been documented (in 47 studies). Although off-site planning and management are very important, the great bulk of construction operations are carried out on the actual building site itself. As a consequence of this, the management of the project site is essential (Durdyev and Mbachu, 2011). The article titled "Poor Site Administration" (C10) had the tenth most citations out of all the ones that we looked at (47).

Label	Causes of delay	References
C1	Weather/climate conditions (74)	1, 2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 34, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 59, 63, 64, 65, 66, 68, 69, 70, 71, 73, 74, 75, 77, 78, 79, 82, 83, 84, 85, 87, 89, 93, 95, 96
C2	Poor communication, coordination and conflicts among stakeholders (63)	1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 14, 15, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31, 32, 35, 36, 37, 39, 40, 42, 43, 45, 46, 47, 49, 50, 51, 56, 57, 59, 61, 63, 64, 65, 66, 68, 69, 70, 71, 73, 74, 75, 76, 82, 83, 85, 86, 87, 89, 96, 97
C3	Ineffective/improper planning (59)	1, 2, 4, 6, 7, 8, 9, 11, 13, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, 26, 27, 28, 30, 32, 33, 34, 35, 37, 38, 39, 40, 41, 42, 43, 45, 47, 49, 55, 56, 57, 59, 61, 64, 65, 68, 71, 73, 75, 76, 78, 82, 83, 85, 86, 87, 88, 90, 91, 92, 95, 96, 97
C4	Material shortage (58)	1, 2, 6, 7, 8, 9, 10, 11, 14, 15, 17, 18, 19, 20, 22, 23, 27, 28, 29, 30, 33, 34, 35, 36, 39, 40, 42, 45, 51, 55, 56, 57, 59, 61, 63, 64, 65, 66, 68, 69, 71, 73, 75, 76, 77, 78, 79, 82, 83, 85, 86, 87, 90, 91, 92, 93, 95, 96
C5	Financial problems (58)	1, 2, 4, 7, 8, 9, 12, 13, 14, 15, 16, 18, 19, 21, 22, 23, 24, 25, 28, 29, 31, 35, 36, 37, 38, 40, 41, 42, 45, 47, 48, 49, 50, 51, 55, 60, 61, 62, 63, 64, 65, 66, 69, 71, 73, 74, 75, 76, 77, 78, 79, 82, 85, 87, 91, 92, 95, 96
C6	Payments delay (56)	1, 2, 4, 7, 8, 9, 11, 12, 13, 14, 15, 16, 18, 19, 21, 22, 25, 27, 29, 30, 35, 36, 38, 39, 40, 41, 42, 43, 47, 48, 49, 50, 51, 56, 57, 59, 60, 61, 63, 64, 65, 68, 69, 71, 75, 76, 79, 83, 85, 86, 87, 89, 92, 93, 95, 96
C7	Equipment/plant shortage (54)	1, 2, 4, 6, 7, 8, 9, 10, 12, 15, 17, 18, 19, 21, 25, 27, 28, 30, 32, 34, 35, 38, 39, 41, 42, 43, 45, 47, 50, 56, 57, 59, 60, 61, 63, 64, 65, 66, 68, 69, 71, 73, 75, 76, 83, 85, 86, 87, 88, 90, 91, 92, 93, 96, 97
C8	Lack of project stakeholders' experience/ qualification/competence (48)	1, 3, 4, 7, 10, 12, 16, 18, 19, 21, 23, 24, 25, 27, 28, 29, 30, 31, 32, 39, 42, 46, 47, 48, 49, 50, 55, 56, 57, 59, 61, 63, 65, 66, 68, 69, 70, 71, 72, 74, 75, 77, 78, 80, 83, 88, 89, 96, 97
C9	Construction labour shortage (47)	1, 2, 3, 7, 12, 15, 18, 19, 25, 27, 28, 33, 34, 35, 36, 39, 41, 42, 43, 45, 47, 50, 51, 55, 56, 57, 59, 60, 63, 64, 65, 68, 69, 71, 73, 75, 76, 77, 78, 79, 82, 83, 85, 86, 91, 92, 96, 97
C10	Poor site management (47)	3, 4, 6, 8, 10, 11, 12, 13, 16, 18, 19, 22, 24, 25, 27, 28, 30, 32, 37, 38, 39, 41, 42, 45, 46, 47, 48, 49, 50, 56, 57, 59, 60, 65, 68, 69, 71, 74, 75, 76, 82, 83, 87, 88, 89, 91, 96

Notes: 1 = Hussain *et al.* (2018); 2 = Mahamid (2017); 3 = Chiu and Lai (2017); 4 = Chen *et al.* (2017); 5 = Arditi *et al.* (2017); 6 = Kadry *et al.* (2017); 7 = Jalal and Shoar (2017); 8 = Mpofu *et al.* (2017); 9 = Agyekum-Mensah and Knight (2017); 10 = Sambasivan *et al.* (2017); 11 = Durdyev *et al.* (2017); 12 = Oyegoke and Al Kiyumi (2017); 13 = Vu *et al.* (2017); 14 = Wang and Yuan (2017); 15 = El-Maaty *et al.* (2017); 16 = Amoatey and Ankrah (2017); 17 = Venkateswaran and Murugasan (2017); 18 = Santoso and Soeng (2016); 19 = Bagaya and Song (2016); 20 = Vilventhan and Kalidindi (2016); 21 = Kim *et al.* (2016); 22 = Asiedu and Alfen (2016); 23 = Larsen *et al.* (2016); 24 = Samarghandi *et al.* (2016); 25 = Ruqaishi and Bashir (2015); 26 = Ballesteros-Pérez *et al.* (2015); 27 = Gunduz *et al.* (2015); 28 = McCord *et al.* (2015); 29 = Amoatey *et al.* (2015); 30 = Bekr (2015); 31 = Wang *et al.* (2014); 32 = Russell *et al.* (2014); 33 = González *et al.* (2014); 34 = Lindhard and Wandahl (2014); 35 = Shehu *et al.* (2014); 36 = Mahamid (2013); 37 = Alsehaimi *et al.* (2013); 38 = Akogbe *et al.* (2013); 39 = Gündüz *et al.* (2013); 40 = Fallahnejad (2013); 41 = Muya *et al.* (2013); 42 = Ibironke *et al.* (2013); 43 = Alinaitwe *et al.* (2013); 44 = Anastasopoulos *et al.* (2012); 45 = Shebob *et al.* (2012); 46 = Doloi, Sawhney and Iyer (2012) and Doloi, Sawhney, Iyer and Rentala (2012); 47 = Mahamid *et al.* (2012); 48 = Kazaz *et al.* (2012); 49 = Doloi, Sawhney and Iyer (2012) and Doloi, Sawhney, Iyer and Rentala (2012); 50 = Hampton *et al.* (2012); 51 = Mahamid (2011); 52 = Bhargava *et al.* (2010); 53 = Nguyen *et al.* (2010); 54 = Apipattanavis *et al.* (2010); 55 = Yang *et al.* (2010); 56 = Khoshgoftar *et al.* (2010); 57 = Enshassi *et al.* (2010); 58 = Ahsan and Gunawan (2010); 59 = Enshassi *et al.* (2009); 60 = Kaliba *et al.* (2009); 61 = Al-Kharashi and Skitmore (2009); 62 = Han *et al.* (2009); 63 = Abd El-Razek *et al.* (2008); 64 = Sweis *et al.* (2008); 65 = Toor and Ogunlana (2008); 66 = Yang and Ou (2008); 67 = Iyer *et al.* (2008); 68 = Sambasivan and Soon (2007); 69 = Alaghbari *et al.* (2007); 70 = Iyer and Jha (2006); 71 = Faridi and El-Sayegh (2006); 72 = Othman *et al.* (2006); 73 = Aibinu and Odeyinka (2006); 74 = Lo *et al.* (2006); 75 = Assaf and Al-Hejji (2006); 76 = Abdul-Rahman *et al.* (2006); 77 = Koushki *et al.* (2005); 78 = Koushki and Kartam (2004); 79 = Frimpong *et al.* (2003); 80 = Chang (2002); 81 = Manavazhi and Adhikari (2002); 82 = Elinwa and Joshua (2001); 83 = Odeh and Battaineh (2001); 84 = Al-Momani (2000); 85 = Al-Khalil and Al-Ghafly (1999); 86 = Abd. Majid and McCaffer (1998); 87 = Mezher and Tawil (1998); 88 = Kumaraswamy and Chan (1998); 89 = Chan and Kumaraswamy (1998); 90 = Kaming *et al.* (1997); 91 = Ogunlana *et al.* (1996); 92 = Assaf *et al.* (1995); 93 = Mansfield *et al.* (1994); 94 = Dlakwa and Culpin (1990); 95 = Arditi *et al.* (1985); 96 = Gunduz and AbuHassan (2017); 97 = Zidane and Andersen (2018)

Figure 9 Top 10 causes of delay mentioned in construction (Durdyev and Hosseini, 2019)

(Arditi, Nayak and Damci, 2016) They compared the American and Indian construction industries for equipment shortages, equipment failures, and inappropriate equipment. According to their findings, there was a minor delay in American building projects than in Indian construction projects. A significant amount of study was done to determine delays in different nations, and the results were impressive. It was shown that delays in projects are caused mainly by labour-related factors, such as unskilled labour and low labour productivity (Marzouk and El-Rasas, 2013)

Another study showed that the causes of delays related to client approval issues in construction projects are many and varied; Shop Drawings and Samples approvals from clients, approval of Completed Work by Clients, financial issues regarding Payments of Running Bills are the most prominent issue in each project. (Kaczoreka, 2016) investigated and concluded the Shop Drawings and Samples approval at the passing stage.

Construction delays can be categorized into six different types by (Mubarak 2005), irrespective of who is at fault:

1. Sites with varying conditions
2. Omissions or Mistakes in the Design
3. Requirements of the Owner
4. Extremely Unfortunate Weather
5. Some Other Factors
6. Unforeseeable Circumstances

Research on the reasons and importance of time extensions in the Turkish construction sector (Kazaz, Ulubeyli and Tuncbilekli, 2012). Surveys were performed with 71 construction businesses in Turkey using questionnaires, and the results were analyzed using statistical analysis. In addition, a study done by (Akan & Gurdamar, 1985) looked at many public projects in Turkey to identify what factors contributed to construction delays. In their investigation, the most important causes for these delays were as follows: Construction materials and equipment, as well as skilled workers, technicians, and other resources, are in short supply (31%); contractors and government agencies are having financial troubles (21%); government agencies and contracting businesses have organizational problems, such as institutional barriers and a slow decision-making process (19%); and design work is being delayed (12 %).

In Egypt, a survey that was made by (Marzouk and El-Rasas, 2014) was carried out in order to demonstrate the demographic information about the respondents that was included in the survey, as well as 43 delay causes that were divided into seven categories: owner related, consultant related, contractor related, material related, labor and equipment related, project related, and externally related. The results of the survey were presented in order to demonstrate that the demographic information about the respondents was included in the survey. The survey results were presented in the form of an infographic (see Table 1). There was a choice of rarely, sometimes, frequently, or continuously for each delay cause. According to the study, respondents were also prompted to choose a severity level that fell under one of the following categories: low, moderate, high, or extreme. As a direct consequence of this, we invited only owners who are representatives of significant investment projects and who are affiliated with first-rate experts to fill out the questionnaire.

Table 1 Delay causes of construction projects (Marzouk and El-Rasas, 2014)

Delay group	Causes
1. Owner related	1.1 Slow decision making 1.2 Suspension of work 1.3 Late in revising and approving design documents by owner 1.4 Delay to furnish and deliver the site to the contractor 1.5 Delay in finance and payments of completed work by owner 1.6 Variation orders/changes of scope by owner during construction 1.7 Type of project bidding and award (negotiation, lowest bidder) 1.8 Unrealistic contract duration 1.9 Ineffective delay penalties 1.10 Owner interference
2. Consultant related	2.1 Inadequate experience of consultant 2.2 Delay in approving shop drawings and sample materials 2.3 Mistakes and discrepancies in design documents 2.4 Unclear and inadequate details in drawings 2.5 Quality assurance/control
3. Contractor related	3.1 Difficulties in financing project by contractor 3.2 Poor site management and supervision 3.3 Ineffective planning and scheduling of project 3.4 Rework due to errors during construction 3.5 Delays in sub-contractors work 3.6 Inadequate contractor experience 3.7 Delay in site mobilization 3.8 Delay in preparation of shop drawings and material samples
4. Material related	4.1 Shortage of construction materials in market 4.2 Delay in material delivery 4.3 Changes in material types and specifications during construction
5. Labor & equipment related	5.1 Shortage of labors 5.2 Unqualified workforce 5.3 Low productivity level of labors 5.4 Equipment availability and failure
6. Project related	6.1 Effects of subsurface conditions (e.g., soil, high water table, etc.) 6.2 Traffic control and restriction at job site 6.3 Unavailability of utilities in site or Delay in providing services from utilities such as (water, etc.) 6.4 Accident during construction 6.5 Problem with neighbors
7. External related	7.1 Weather effect (hot, rain, etc.) 7.2 Environmental restrictions 7.3 Changes in government regulations and laws 7.4 Slow permit by government/municipality 7.5 Delay in performing final inspection and certification by a third party 7.6 Lack of communication between the parties 7.7 Fluctuations in cost/ currency 7.8 Force Majeure as war, revolution, riot, strike, and earthquake, etc.

There have been several investigations into the reasons for building delays and the consequences they have on the bottom line. As a whole, these studies focus on the country's economic and development status at the national level and on large-scale projects. Late payments and inflation are the most typical reasons of delays in under-developed nations. When it comes to delays in industrialized nations, the most typical culprits are customer requests for changes, faults in planning and programming, and the incapacity of clients to make timely decisions (Assaf and Al-Hejji 2006, Pourrostam et al. 2011, Kumar 2016, Samarghandi et al. 2016, Tafazzoli and Shrestha 2017).

2.3.2 How many projects are delayed?

Finance, Economics, and Urban Division of the World Bank's Sustainable Development Department said in March 2010 that a rationale for more openness and supervision in the publicly financed building should begin with a detailed description of the problem. Problematic outcomes in a significant sector critical to development are at issue here. The construction sector generates $1.7 trillion in revenue worldwide, with a large portion coming from publicly financed projects. Investments by governments in road transportation alone may account for up to 3.5% of the GDP (Kenny, 2011).

Most of the time, the results of this funding are suboptimal. India, for example, has cost overruns of more than 25% on road projects, and over half suffer delays of 50% or more on completion dates (see Fig.8.). Moreover, the construction of infrastructure can sometimes be substandard. For example, according to news sources, one-fifth of a recent rural road project in India was unsatisfactory. Worldwide, cost escalation is the norm rather than the exception for infrastructure projects. For example, one global assessment estimates that average costs have risen by 35% (Kenny, 2011).

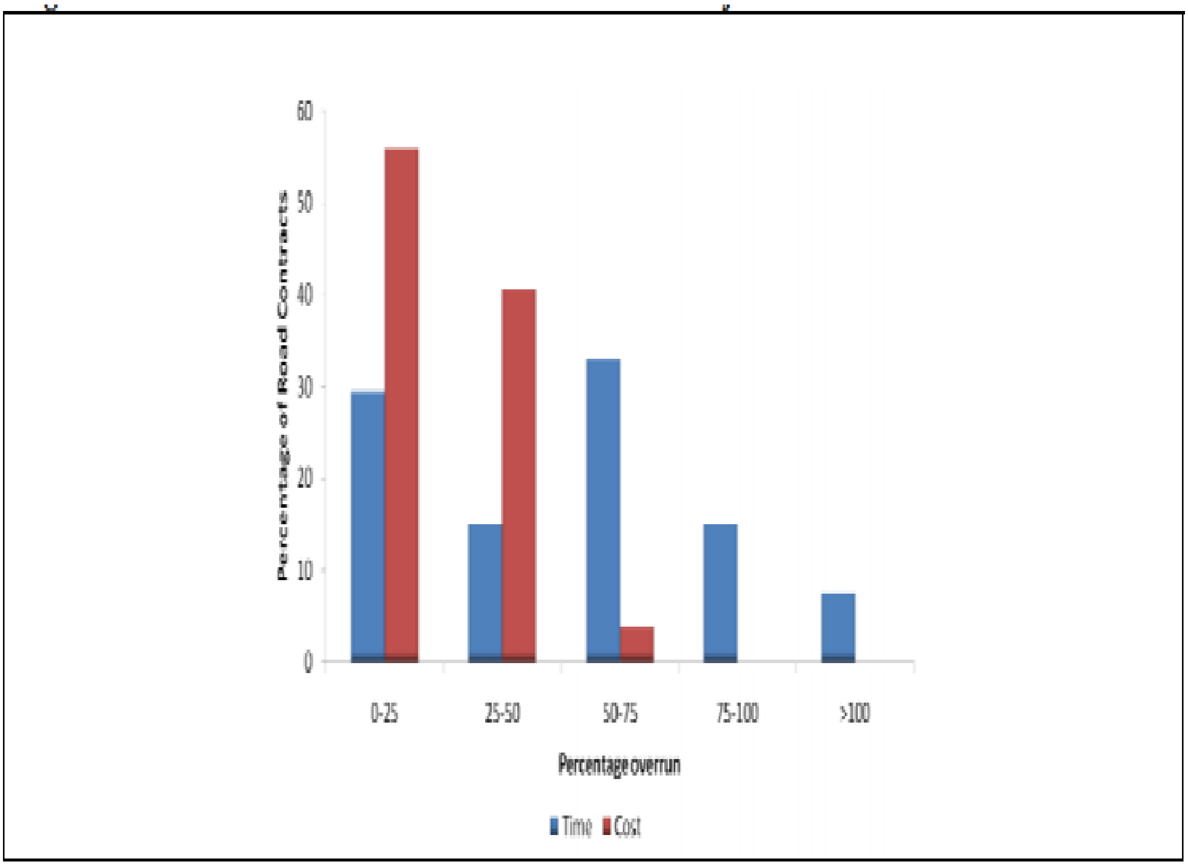


Figure 10 Time and Cost Overruns in Indian Roads Projects (Kenny, 2011)

Furthermore, The Associated General Contractors of America found that 60% of construction firms have cancelled or postponed projects in the future (AGC). According to the latest KPIs provided by the Department for Business, Innovation and Skills, three out of five construction projects are completed late (BIS). Constructing Excellence and Glenigan's data reveal that the industry's ability to deliver on time decreased from 45% in 2014 to 40%. In 2007, the survey's highest point was 58%. Over half (52%) of non-housing projects had their design phase finished on time, but just 45% of construction projects were completed on time.

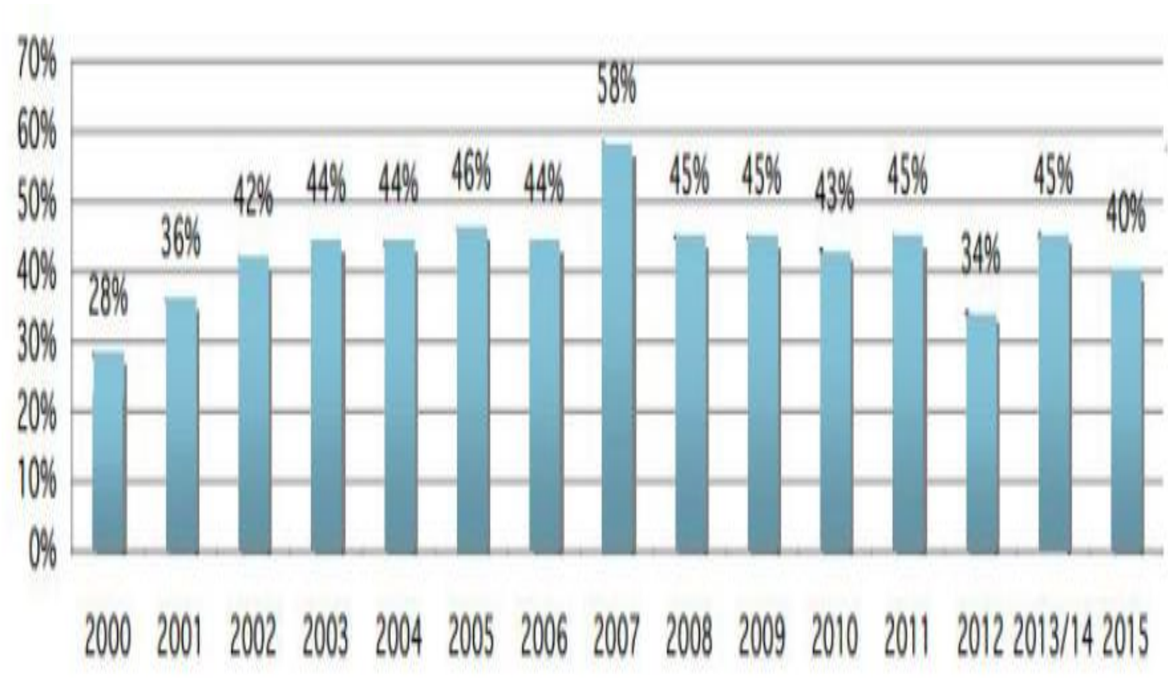


Figure 11 (U.K. Industry Performance Report, 2015)

Since 1981, around 45 percent of the money for national development plans in Egypt has been allocated to the construction industry. As a result, the building sector is one of the most active sectors in the Egyptian economy. (Ahmed, 2003). (Mobarak, 2004) discussed the significance of consultation in preventing significant delays in the completion of a project and illustrated possible classifications of the factors that contributed to the delays, including internal and external, financial and nonfinancial. Issues about construction delays in Egypt were addressed in (Amer, 1994). These concerns were addressed by examining and assessing the causes for construction delays in order to improve the ability to finish construction projects on time.

2.3.3 Construction Delay Types

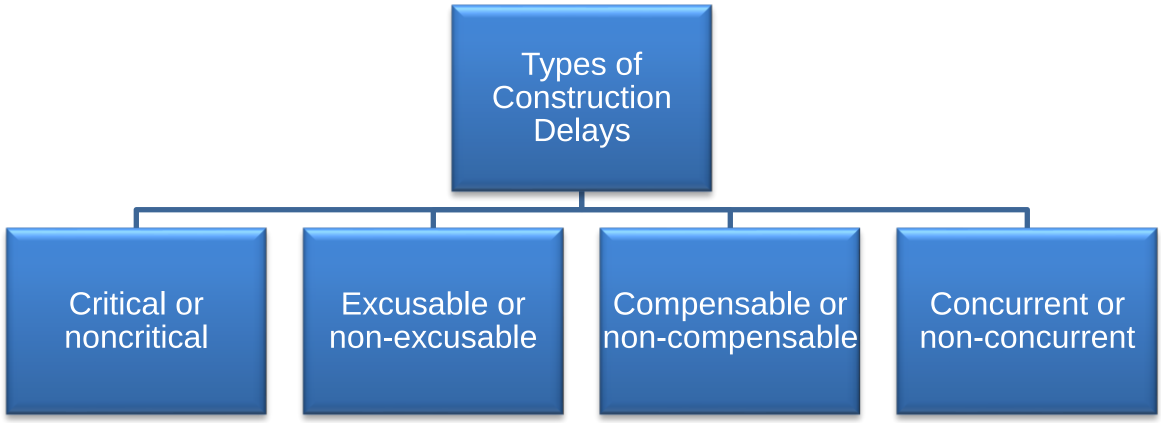


Figure 12 Types of construction delays (Own work)

In Figure Fig.12, you can see how construction delays might be classified. The first step is to identify whether the delay is critical or non-critical and whether it is concurrent or nonconcurrent as part of the delay impacts on the project. As indicated in the image, all construction delays are either excusable or not. It is then classed as a compensated or non-compensable delay when a delay is deemed excused. However, this statistic only provides one interpretation, as the excusable and compensable delays might vary per contract.

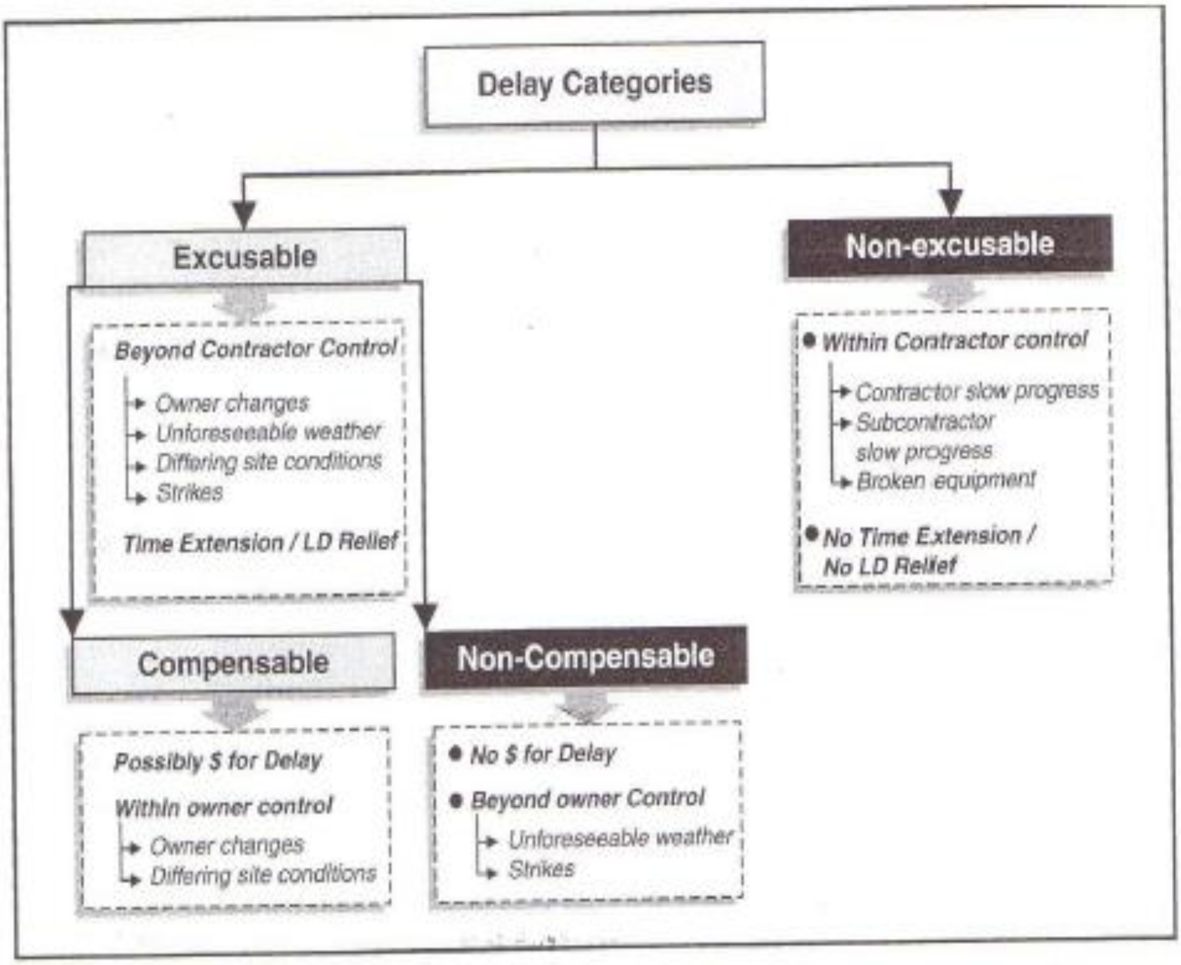


Figure 13 Delay Categories (Trauner, 2009)

2.3.3.1 Delays: Critical vs Non-critical

There are two types of delays: critical and non-critical. Critical delays influence the project's completion or a milestone date. The project completion date or a milestone date will be postponed if these tasks are delayed (Parbat, Attarde and Gajare, 2014).

When studying delays in a project (Trauner, 2009), the primary goal is to determine whether the delay impacts overall project progress or project completion date. According to the authors, significant delays result in a longer project completion time, whereas non-critical delays do not influence the project completion date. In addition, it is stated that the Critical Path Method scheduling causes considerable delays (Trauner, 2009). Key activities on all projects must be completed on time, or the project's completion date will be pushed back as a result.

Project deadlines are as follows:

- The actual project by itself
- The strategy and schedule of the contractor
- The contract's criteria for sequencing and phasing
- The project's physical constraints
- How to construct the work from a practical standpoint

2.3.3.2 Excusable vs Non-excusable Delays

An excusable delay is caused by an unexpected incident outside the contractor’s or subcontractor’s control. For example, strikes by large groups of workers, wildfires, and other unforeseen events are not; excused delays occur when the contractor can’t be held responsible for them or can be predicted. Finally, unacceptable (non-Excusable) delays are caused exclusively by the contractor or its suppliers (Parbat, Attarde and Gajare, 2014).

According to (Trauner, 2009), standard construction contracts include the many sorts of delays that will allow the contractor to get a time extension. Under some contracts, for instance, unforeseen or extreme weather conditions are not considered to be excusable, and as a result, no time extensions are granted.To put it another way: Excusable delays occur when an unanticipated event happens that is beyond of a construction company or subcontractor's control (Trauner 2009).

According to the authors, the following issues justify delays:

- Strikes by the whole working class
- Acts of nature (fires, floods, etc.)
- Changes initiated by the property owner
- Plans and specifications with errors and omissions
- Unknown or changing circumstances on the location.
- Interference by external organizations Official authorities, such as building inspections, have failed to act.
- Unusually harsh weather.

According to (Trauner 2009), some non-excusable delays include:

- Failure of suppliers to meet deadlines
- lateness of subcontractors
- poor construction
- contractor or subcontractor refusal to meet with labor representatives
- strike pertaining to a certain project
- a refusal on the part of the contractor to meet with representatives of the workforce
- practices of unfair labor that are being used.

2.3.3.2 Compensable vs Non-compensable Delays

Contractors that experience compensation delays are eligible for time extensions and extra pay. The owner is liable for compensable delays. For instance, the owner's architect may have released designs late. A delay that is considered to be non-compensable occurs when the contractor is not eligible for further payment as a result of the delay being justified. It is not the responsibility of the owner or the contractor to compensate a contractor for delays that are caused by a third party or an event that is beyond their control.Typical examples include unexpected weather, strikes, government actions, etc. (Parbat, Attarde and Gajare, 2014).

a) Extension of time (EOT)

An Extension of Time claim is a request to extend the original contract duration in construction. For example, the contractor often submits a Request for Extension of Time claim to request more time owing to client changes. A claim for an extension of time is also made when a delay occurs that could not have been reasonably anticipated at signing the contract. The contractor is relieved of obligation for damages such as liquidated damages from the original completion date for the term of the claim if an Extension of Time is granted.

Due to a variety of Factors, many projects get delayed (Rana, 2018). The author also added that due to the complexity of integrated environments resulting in internal and external dependencies, large enterprise high value and high-risk projects tend to run late. Consequently, project management needs to play a crucial part in the detection of the delays but also the reason for the delays to calculate the time of extension and logic of the delay.

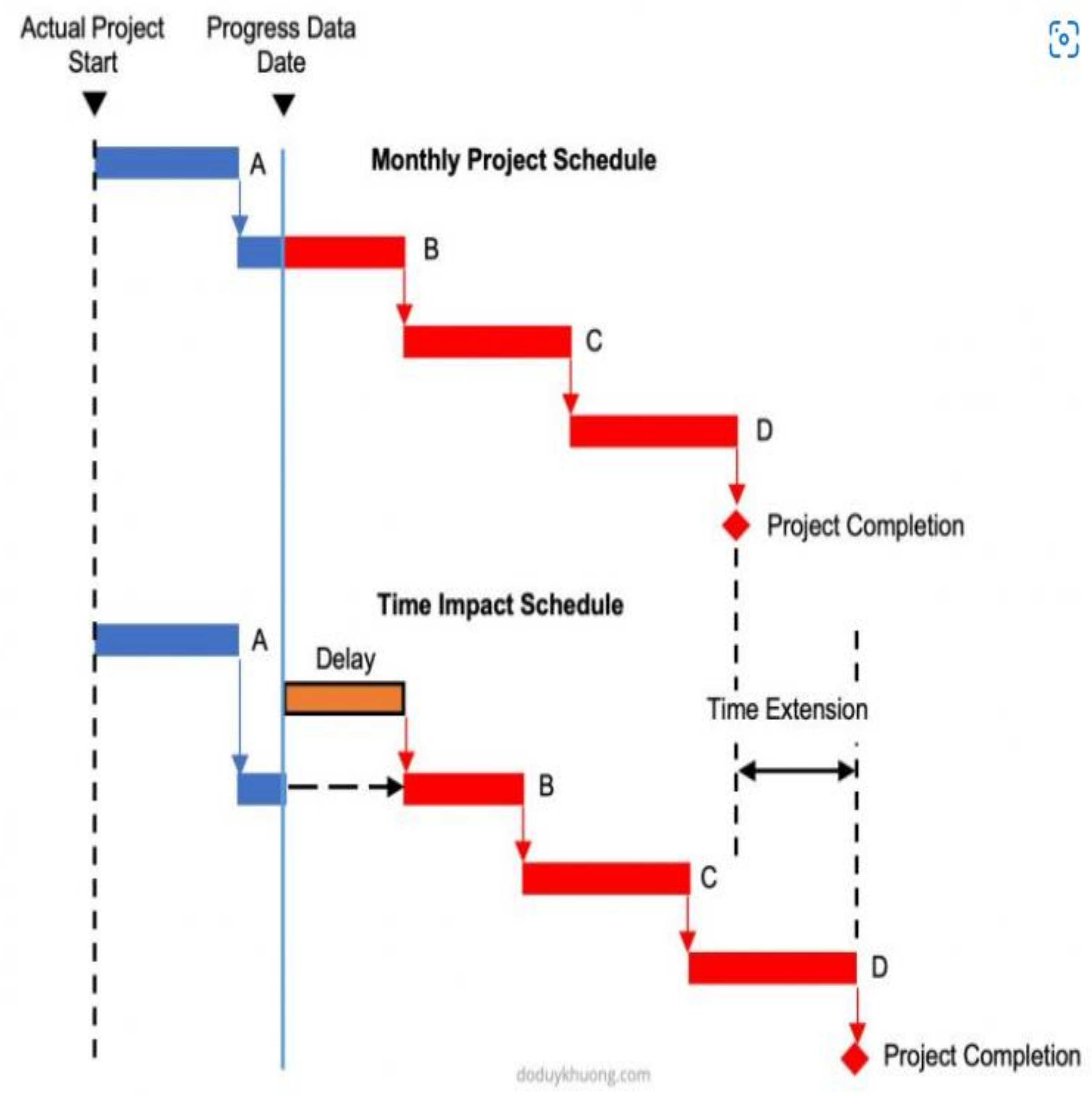


Figure 14 Construction Contract Extension of Time (EOT) (StreetwiseSubbie.com Ltd, n.d.)

Therefore, the below stated things act as the pre-requisite to submission of Extension of Time (EOT) requests:

- Prepare baseline project schedules
- Seek approval of baseline project schedules
- Prepare and disseminate project progress report
- Serve notices
- Prepare claim for extension of time (eot) claim

b) Liquidated damages

In the event that a contract is broken, liquidated damages are a predetermined amount of money that was agreed upon by both parties prior to the signing of the deal (Benarroche, 2019). The author further highlighted that this number need to take into account each party's most accurate assessment of the losses that were incurred. In the realm of construction, one of the most common types of violations that come under this umbrella is a failure to finish work within the allotted amount of time.

In most cases, they are presented in the form of a formula, such as the following:

The total cost of the contract is equal to [(X amount of $ per day) x (number of days late] multiplied together.

Liquidated damages clauses are frequent when a project is delayed beyond the contract completion date. Both public and private building contracts have these clauses. In addition, construction project owners often add liquidated damages provisions in the prime contract with the general contractor to protect themselves (Tompkins, 2020).

2.3.3.4 Concurrent delays

A too concurrent delay occurs when there are several delays contributing to the project's delay, according to (Callahan 1992). When two or more different delays co-occur, according to (Mubarak 2005), it is called a concurrent delay. If you're talking about overlapping delays, (Levy 2006) calls it that.

What is a concurrent delay, and how does it work? The concurrent delay has no universally accepted definition. Concurrent delay can be further defined as "real concurrency." As a result of the employer and contractor's delay events co-occurring, the project's progress will be held up by an equal amount of time. Likewise, the project's completion will be held up by the same amount if they were absent. Fig.12. shows a true concurrency (Furst, 2019). For example, in true concurrency, the author explained that employer and contractor delays co-occur and produce a delay that starts at once and ends at another time.

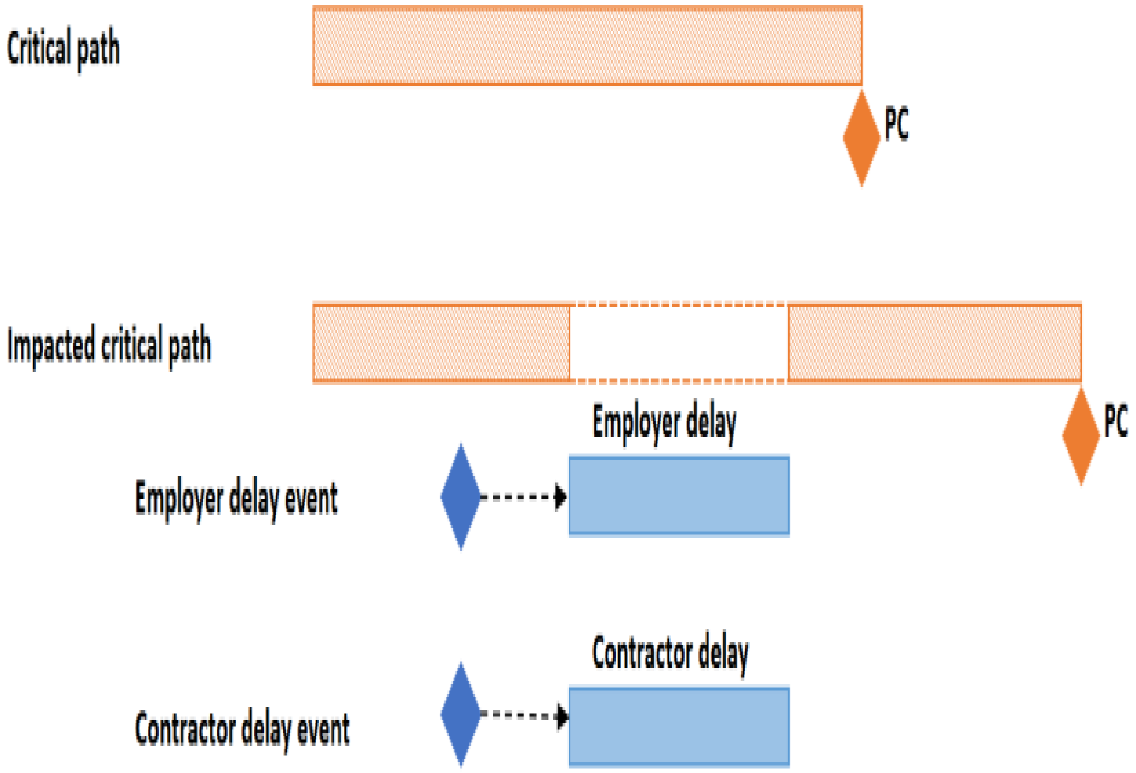


Figure 15 True concurrency (Furst, 2019)

The author also explained that another case might happen. The concurrent delay occurs when the employer and contractor delays begin at different periods but overlap. Fig.16. shows this.

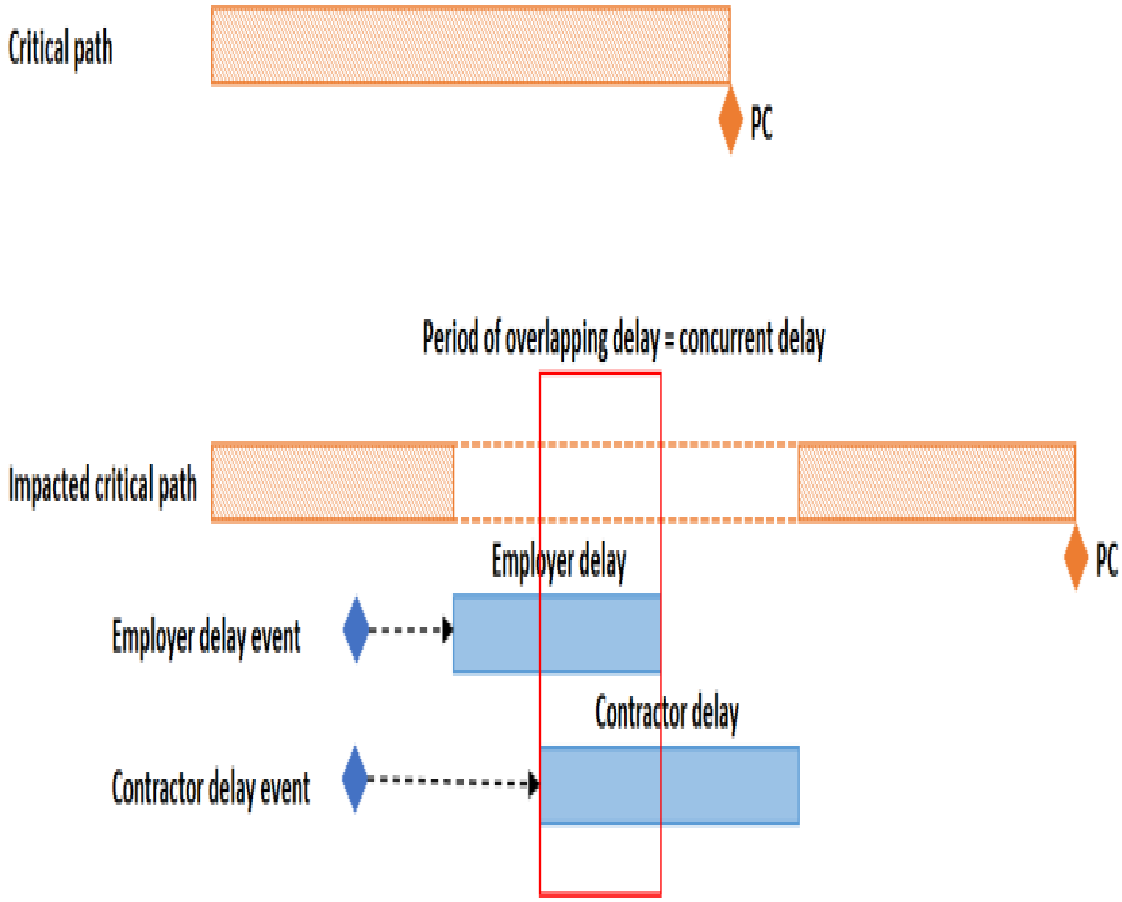


Figure 16 Keating's 'overlapping' concurrent delay (Furst, 2019)

2.3.4 Methods for Analysing Schedule Delays

2.3.4.1 As-planned versus as-built method

With this approach, you can see how long it will take to complete two projects, which is why you may hear it referred to as "total time" or "net effect." The owner (owner) causes all delays, but a contractor (contractor) causes none. It demonstrates how each and every delay impacts the project's scheduled completion date (Nguyen, 2007). Figure 14 shows that the as-planned program takes 10 days, whereas the as-built schedule takes 15 days. That's a 5-day difference in total delays that can be reclaimed. The difference is five days between the two, which is the entire amount of delays that may be recovered. This means that a contractor can get an extension of time for the difference between the two as an excused delay activity.

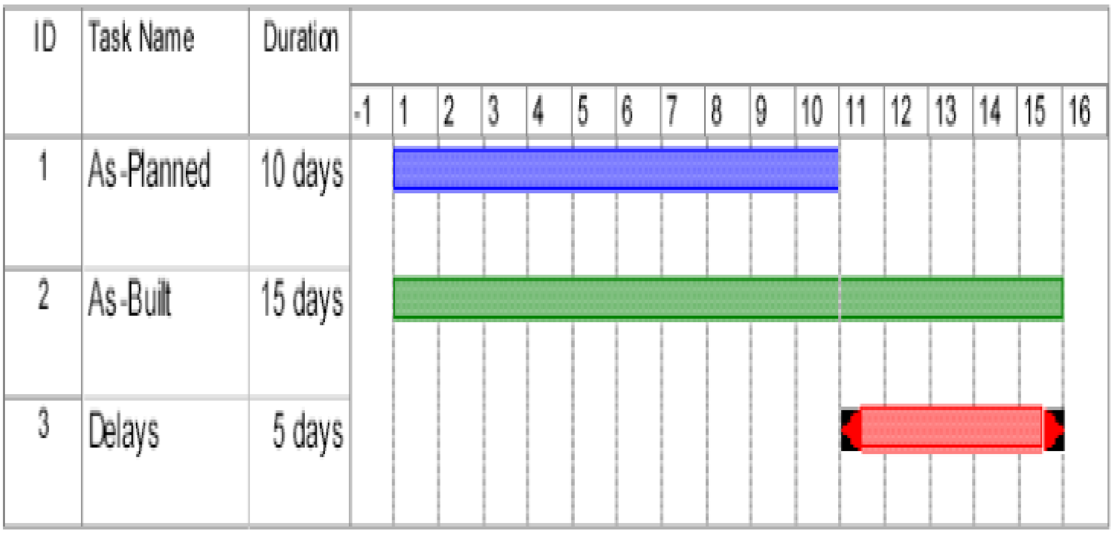


Figure 17 Diagram of As-Planned versus As-Built Method (Nguyen, 2007)

Observation of the discrepancy between a planned and an actual timetable is called planned vs built. As-built vital activities are identified compared to those on the as-planned schedule, delays are assessed, project duration sequences are identified, and the cause and responsibility of delays that influence project completion are determined. (Fruchtman, 2000).

According to Ndekugri et al. (2008), On the one hand, this technique has the benefit of being affordable, while on the other, it has the disadvantage of not considering changes in the critical route and of not being capable of handling complicated construction delays.

a) As-planned vs. as-built approach advantages

For those presenting to a non-technical audience, the method's ease of understanding makes it an excellent choice. As a result of the method's simplicity, it requires fewer resources. It takes less time to prepare the analysis since the approach is less intensive than other methods. The client saves money by using an outside consultant. For many claimants, the method's simplicity and convenience are the key reasons for its overwhelming popularity (Ndekugri, Braimah and Gameson, 2008).

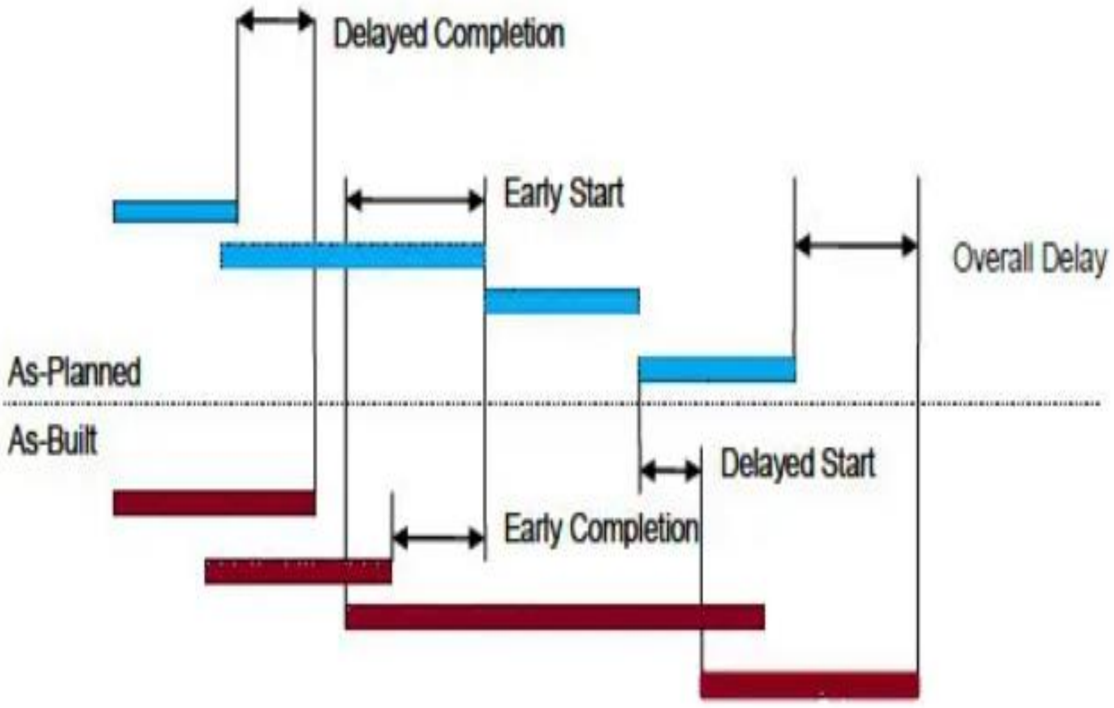


Figure 18 Symbolic Representation of an As Planned vs As-Built Analysis (AACE International,2011)

A delay should be examined as soon as it happens in order to minimize its impact, according to the author. There must be periodic updates to the project schedule so that it accurately reflects the start and end dates, the length of reassessment activities, the revised activity connections, and so on. Due to a lack of timely scheduling updates, specialist delay analysis methods are not possible. We propose using the as planned vs. built method since it removes the need for ongoing improvements.

b) Deficiencies that exist in the approach as-Planned versus As-Built Method

There are certain drawbacks to the simple and affordable implementation of the "As Planned vs. As Built" strategy. For example, suppose a project is challenging, long-term or created in a way that is substantially different from the desired order of events. In that case, the method might not be appropriate to discover the reason for delays. Furthermore, this approach cannot be used for projects with delays in near-critical routes, as critical path changes are not considered over time (Ndekugri, Braimah and Gameson, 2008).

While the As-Planned vs. As-Built Method may be straightforward and affordable to apply and overcome limits with readily available documentation, there are several drawbacks to take into account while considering its applicability. The author's claim that Techniques like these are not well-suited to finding the root reasons of delays when a project is complex, long-lasting and/or created in a fashion that deviates considerably from the anticipated order of events. It is also inadequate for projects with near-critical pathways that have suffered delays since the strategy does not account for changes in the critical path over time.

2.3.4.2 Impacted as-planned method

The only schedule used for delay analysis in the affected as-planned method is the as-planned or baseline one. According to this theory, it is possible to estimate when a project will conclude by taking into account any delays that may occur. Project completion was more than a month behind schedule due to the addition of new operations that reflect delays, disruptions, and suspensions. Owner-induced delays must be added to the as-planned schedule sequentially by contractors submitting claims for time extensions, so that they may establish the total project delay caused by the owner (Wickwire, Driscoll and Hurlbut, 1991).

The Impacted As-Planned technique provides a more sophisticated delay analysis method than the As-Planned and As-Built procedures (Trauner,1990). According to the author, it also examines all real-time delay/acceleration events right before they occur. However, because the approach only analyses the delays/acceleration of the As-Planned critical path(s), it fails to address the critical path to non-critical path shift. As a result, the method does not appropriately handle the real-time state of the delayed event. Furthermore, the approach does not consider concurrent delays since it overlooks other essential paths (s).

According to Trauner (2009), this technique has the following flaws: Since it is impossible to know exactly which modifications or effects should be included into the affected schedule and because of this, the finalized schedule is a deception. It also fails to take into account the project's dynamic character and the critical route. Some analysts like this approach, however it's faulty, according to the authors, due to its simplicity. In the authors' opinion, locking down the critical pathways at the beginning of the project with a first timetable prevents any genuine modifications to the critical path from occurring.

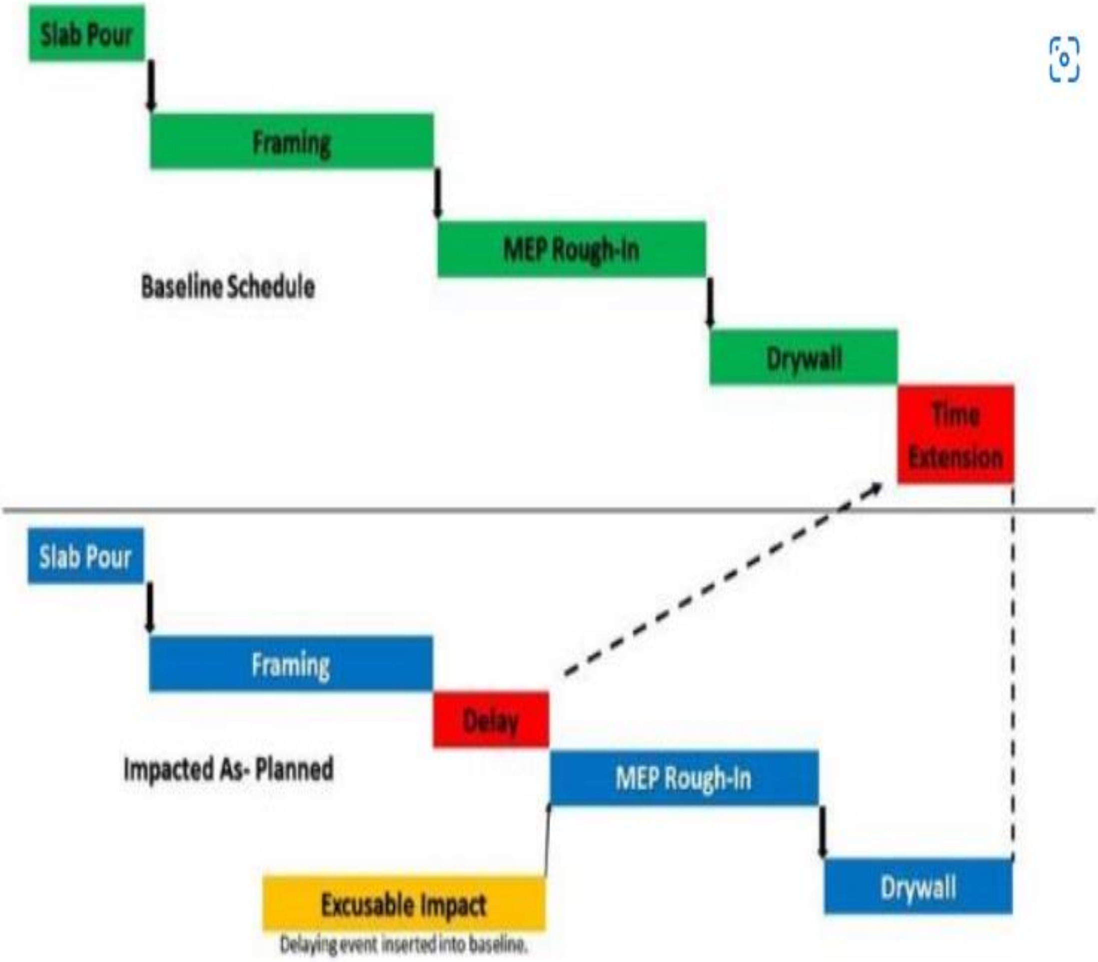


Figure 19 Graphical explanation of a delay As Impacted As-planned method

(ANDREW SARGENT, 2020)

The following are the impacted as-planned integration phases as mentioned in (AACE, 2011) (Hegazy, 2012):

- As the baseline schedule, the CPM programme must be authorized.
- The critical and non-critical routes must be specified.
- Agreed-upon EOTs must be identified, together with the appropriate documentation; delays must also be measured.
- Insert and reschedule activities to see what happens.
- The contractor's EOT is what separates the as-planned from the impacted.
- Check to see if the CPM has a continuous route with no delays.

Table 2 The IAP Technique’s Strengths and Weaknesses (Caletka & Keane, 2015).

Strengths	Weaknesses
• Easy to understand • Least amount of variables in 'cause–effect' equation • Does not require as-built programme • Can be carried out contemporaneously • Does not require progressed programmes	• Does not account for changes to logic or durations of planned activities • Produces theoretical results based on a hypothetical question • Cannot identify true concurrent delay

2.3.4.3 Collapsed as-built method

Using the collapsed as-built schedule analysis approach, a project's completion may be shown even if a third party delays it. If the other party's delays had not happened, the work would have been finished sooner. A time extension is thus required for the claimant since the anticipated and final completion deadlines vary (SARGENT, 2021). There are a number of variables that influence which schedule analysis approaches are used:

- Time constraints
- Project type
- Project complexity
- Project records are available

The author also added that the collapsed as-built technique is suitable for determining delay allocation. However, delay analysis gives a straightforward and easy-to-understand method for measuring project consequences. This research is usually done – and works best – on projects that have good as-built schedule information but no current important dates, such as monthly reports, or there is no reliable foundation timetable accessible. On the other hand, the claimant's as-built schedule is vulnerable to attack due to a lack of historical evidence. As a result, it is critical to follow tight rules and review all accessible project documents adequately.

As Trauner (2009) points out, this technique has a number of major faults, among them:

1. A CPM network diagram must be drawn up by the analyst using as-built data.
2. It's quite subjective and may be easily changed.
3. It is possible for the analyst to swiftly establish an as-built timeline that supports a chosen outcome.

Most people can easily grasp and apply the idea of the collapsed as-built schedule analysis (SARGENT 2021), which states that the effect of one party on the results may be evaluated by removing that influence and comparing the results. Due of its familiarity, the strategy promotes a wide range of users.

It is thus easy to understand and communicate the findings from a compressed as-built delay analysis; the following are some benefits of the model:

- Concurrent delays may be easily measured
- less resources are required to conduct the study.

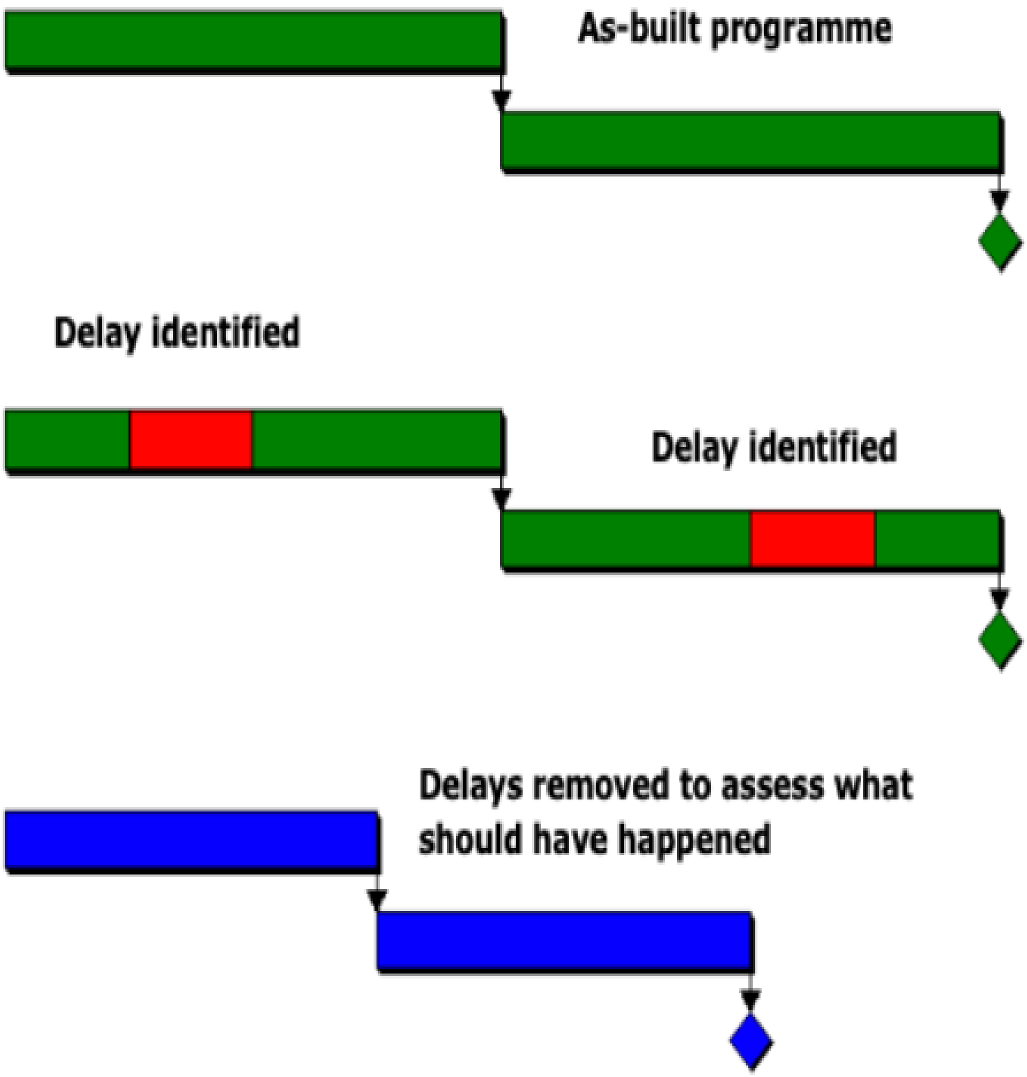


Figure 20 Diagram demonstrate the Collapsed as-built method (Martin, n.d.)

2.3.4.4 Window analysis method

Window analysis, a temporal impact analysis, performs the study using weekly or monthly updates. Every time the schedule is updated, delayed events are put into it, and delays are accrued (Wickwire, Driscoll and Hurlbut, 1991).

The window analysis approach divides the construction process into discrete time increments known as "windows" and evaluates the consequences of delays due to each project participant as they occur. It makes use of the timeline as it was designed to serve as its foundation, but it is routinely revised soon after each time that it is planned to occur. Because it takes into account the delays experienced by both parties, the windows analysis method stands apart from both the Effect as intended and the collapsed as-built evaluations. In addition to this advantage, window analysis offers contractual parties a disciplined foundation on which to keep a project schedule accurate and up to date while also making the necessary modifications. (Mohammed, 2001).

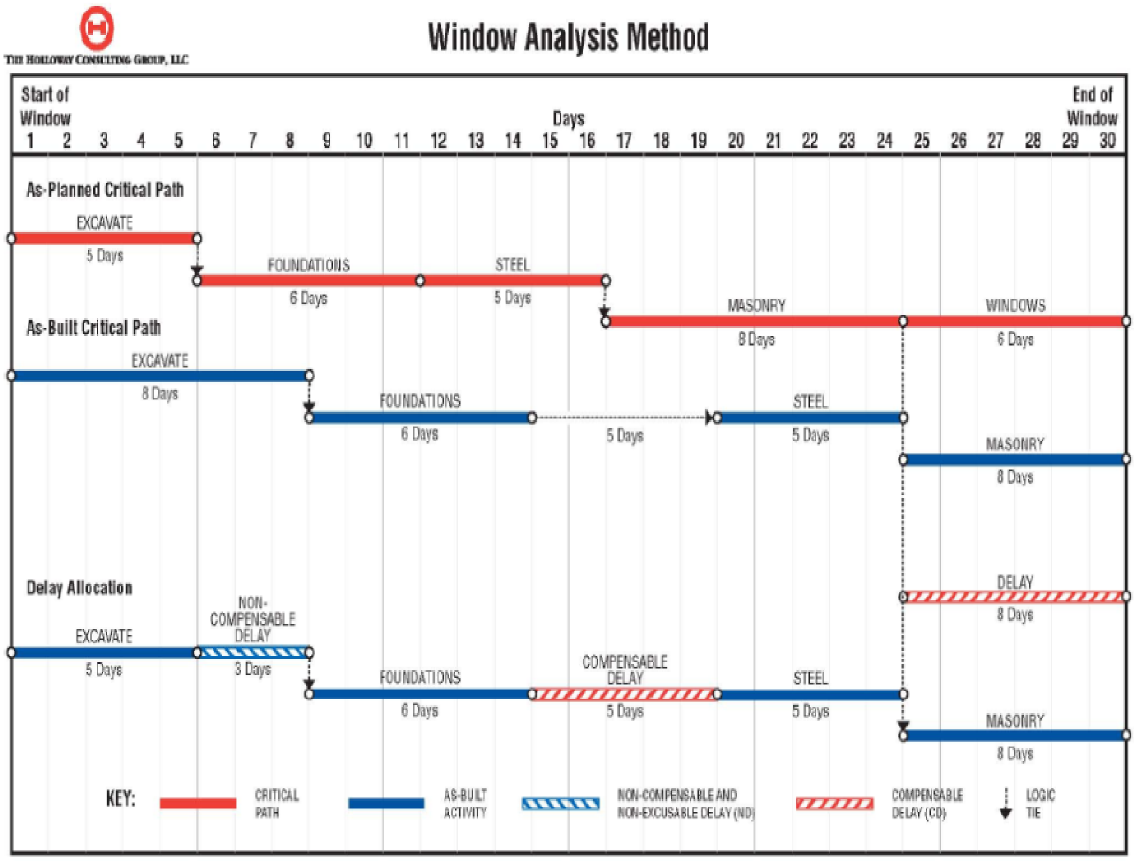


Figure 21 Windows Analysis (Hegazy,2012)

2.3.4.5 Time impact analysis method

The time impact technique is predicated on the notion that delays in a project may be quantified by a number of different evaluations on alterations to the schedule. Concepts from CPM are used in the methodology known as time impact analysis. It does this by doing frequent, often daily, analyses of the project schedule in order to determine how the delays will affect it.(Wickwire, Driscoll and Hurlbut, 1991).

First, delays are analyzed sequentially, and each one is incorporated into an updated CPM schedule (typically through fragmentation or subnetworkThe analyst calculates the amount of delay that will be experienced by the project by analyzing the difference between the original project completion date on the schedule and the new date that has been updated to include a delay for each activity that will cause a delay.(Ndekugri, Braimah, and Gameson, 2008). Implementation is time- and cost-consuming and difficult for this strategy due to the presence of many delaying activities, according to the authors. This technique is endorsed by the Society of Construction Law in spite of its shortcomings. When an excusable risk arose, the best technique to establishing the right length of time extension was to use Time Impact Analysis.

The construction delays in the case study's work plan were evaluated with the use of a technique called Time Impact Analysis. The Society of Construction Law Delay and Disruption Protocol suggests doing a Time Impact Analysis.Figure 22 depicts the TIA in dynamic and prospective (seeing forward) modes. Describe the steps in the flow chart that describe this method (TAHER, 2013).

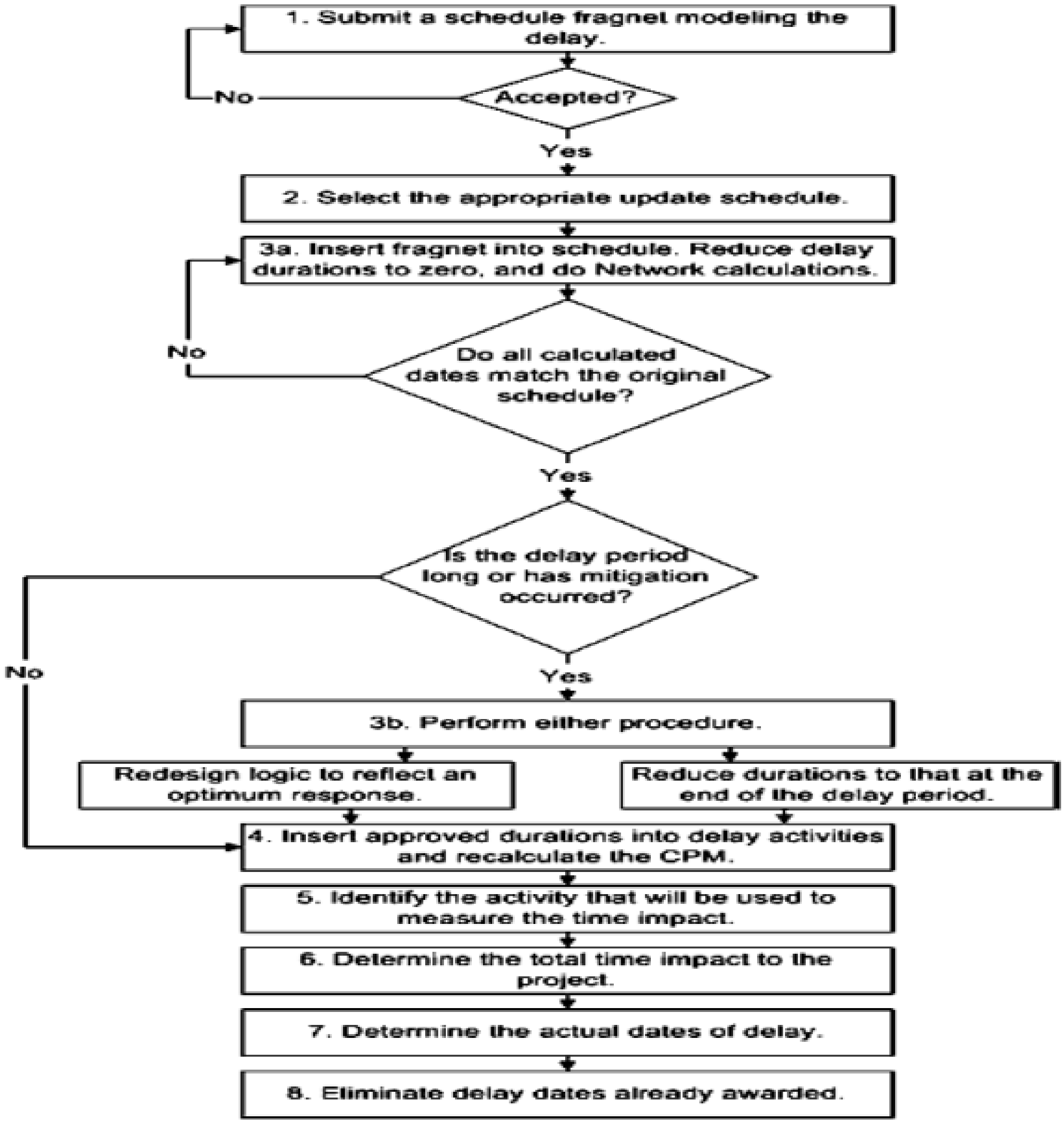


Figure 22 Time Impact Analysis Flow Chart (Arditi and Pattanakitchamroon, 2008)

3. Methodology

3.1 Overview

This chapter aims to describe the research methodology. The study will be carried out utilizing quantitative and qualitative approaches. It is critical to get a thorough comprehension of these parts of techniques to comprehend the genuine issues at hand and the required enhancements. This study seeks to expand this knowledge by describing the primary causes of construction delays, examining the fundamental variations between delay techniques, and investigating the impact of project delays on all stakeholders in terms of time and money. Data on project delays were collected and analyzed based on prior research, and the most popular DATs were evaluated based on a case study. A number of factors impact the results of delay assessments, including the software used to do them, the amount of resources loaded, the level of elevation required, and the amount of time required to resolve any concurrent delays. There is an urgent need to improve the report's integration of these issues and future research that address them.

3.2 Methodology

Elaborating the main causes of delay based on two case studies and discuss the strategies already established in Previous studies and observations data related to project delays based on previous studies. Examination of a Variety of Delays Various methods were used to calculate the length of the construction delays, as well as who was responsible for them. Construction delays were identified, their influence on the project completion date was quantified, and all stakeholders were held accountable. In order to avoid accusations of delay among project participants, accurate allocation of blame is critical in timetable delay studies.They were finally, elaborating on the impact of the project delays on all the parties in terms of time and cost. The selection of the case studies was based on both the availability of the data and the reliability of these data. The limitation of the selection that faced the author were that there is lack of data regarding this topic because it might affect the construction companies’ business.

The following sections cover the three phases of this investigation. The first phase is answering the study first question is there delay in construction or not ? The analysis for this part is based on experts working on the construction field and previous studies.The next phase is a case study elaborating the delay Consequences in construction and how to minimize them. This part of the study is answering the second and the third questions. Finally, another case study was conducted to calculate the project delay and to identify how much each party (Contractor, owner, or neither) is responsible for this delay. Moreover, a List of the limitations of each method is elaborated from the analysis of this case study.

3.2.1 Collection of Data

Several building sites and associated businesses were observed. Next, previous research and observations were used to obtain data on the particular issues and delayed occurrences in the case studies.The required data on conducting the different delay analysis techniques were discussed with a project control engineer and based on the ASCE database.

Figure 23 Data source ASCE

The BER case study is based on audit office reports, FBB press releases, interviews with key communicators, This architect even wrote a book on the project. All of the above, including personal declarations, media reporting (both print and broadcast), statements made in public forums, and non-scholarly writings.

Figure 24 Data source FBB

3.2.2 Identification of Delay Causes

Identifying delays was the first step in putting the chosen strategy into action. The precision with which the schedule delay analysis can detect and pinpoint project delays and their underlying causes is critical. It was discovered by analyzing the contractor's time extension requests, payment invoices issued by owner, and project change instructions issued by consultant throughout the construction phase. To find out who was to responsible for these incidences, investigators looked at the following possibilities.

3.2.2.1 Delays By Consultant

The reasons for delays that are related to the consultant are explained in detail by the (Commercial General Contractor, 2019):

- Delay in completing the sites furnishing and delivery

When the construction site isn't equipped or prepared for excavation on time, this causes a delay. Also, the site is not ready to begin building work. Thus it is not provided to the contractor on time. This causes the consultants site mapping and other key site analysis work to be delayed. As a result, the projects start date has been pushed back.

- Design Documents Revision and Approval Delays

A building projects blueprints and floor plans go through many alterations and revisions to preserve architectural correctness. However, if the project owner does not approve drawings on time, the procedure will be delayed. If the architect and civil engineer are allowed too many revisions, they will waste time rewriting floor designs. Receiving late approvals on blueprints might cause further delays in project deadlines.

- Communication and coordination between parties are lacking.

For the project to function effectively, the owner, architect, and consultant must have open lines of communication. A lack of communication can cause delays in the acceptance of materials, design concepts, and licenses. The projects specified deadlines may be tampered with due to this delay.

- The projects documentation is incomplete.

If the site registration paperwork is incomplete or specific permissions and legal papers are still pending, the building process may halt until additional approvals are obtained.

- Financial Issues

Payment delays to contractors, labourers, and the architect might all delay the projects completion. If the firm is experiencing financial difficulties, the project will be delayed, with payments taking longer than intended.

- Consultants with insufficient experience

The consultant and his team must be on-site to deliver the appropriate instructions and deal with any emergencies that may develop. If the consultant lacks expertise, he may not be able to handle on-site crises or manage the project effectively. This might cause significant delays on the job site.

- Planning and Scheduling are insufficient.

Architects and civil engineers require these fundamental project management abilities. On the ground, several tasks and planning must be completed. These project management choices must be made swiftly and accurately.

- Errors in construction necessitate redoing the project.

Some precasting or slab installations may have structural flaws that may only be fixed by reworking or repeating the procedure. The project will undoubtedly be delayed as a result of this rework procedure.

- Work Productivity is undervalued

Although some contractors and their technical employees may be busy at first, they tend to work slower than planned as the project progresses. To avoid this, employ contractors that have worked on large-scale construction projects before.

3.2.2.2 Delays caused by the third party

The causes for delays that a third party causes are detailed by the (Commercial General Contractor, 2019):

- Natural disasters create delays.

These are delays resulting from ‘acts of God.’ Natural disasters such as fires, floods, snowfall, severe rainfall, hailstorms, and wind damage can stymie building operations. These delay-causing variables are not compensable, yet they result in a significant delay in project completion and a significant financial loss to the owner.

- Suspensions

The government may suspend permissions for some building projects on legal grounds. For example, a certain piece of land may only be used for commercial purposes. So, if another type of project runs, it will be halted immediately.

- Delays in Transportation

It takes time for some modular building pieces to be delivered to their final destination.

- Contract Amendments

If the owner makes specific changes to the construction project’s contract, obtaining additional approvals for each change causes a delay in fulfilling the deadlines.

- Strikes and Labor Disputations

Unsatisfied workers may have problems with contractors about late payments throughout a project. These disagreements can snowball into strikes, with workers refusing to work on building sites. This can create significant delays in the completion of work.

Figure 25 Workers strike in Germany (Deutsche Welle (www.dw.com, 2017)

3.2.2.3 Delays caused by contractors

The causes for delays that a third party causes are detailed by the (Upadhyay, Himanshu Agrawal and Jain, 2016):

- Ineffective planning and organizing a project's schedule

Project planning and Scheduling that are not capable of executing efficiently or as intended are included in this delay cause. The most important reason for project delays may be inaccurate time and expense estimates. Estimating mistakes in construction may be both costly and humiliating. Normally, the contractor does not provide time for some common problems that often occur throughout the building period, such as missed supply deliveries, equipment breakdowns, accidents, crises, etc. As a result of this issue, real-time will exceed the anticipated time. As a result, the entire project may be delayed.

Similarly, errors in cost estimation can be due to various factors, such as the use of incorrect units or mathematical errors. Contractors may measure for a second time for a given job if a cost estimate is incorrect. Finally, certain building work will be delayed owing to re-measurement time. As a result, the contractor should account for any potential planning and scheduling issues that may arise throughout the project and extra time to avoid delays.

- Contractor’s lack of experience

Lack of expertise of the contractor is one of the primary causes of delays, In the opinion of Abd Majid and McCaffer (1998). An experienced contractor's lack of expertise was noted as an important contributor to delays in Battaineh's (2002) study Long et al. (2004) found that a lack of contractor expertise was one of the most common causes of construction delays.Several projects are experiencing delays throughout the building phase. However, due to a lack of experience, the contractor could not remedy the situation immediately. Because of the difficulty, certain works were completely halted. It took the contractor to figure out how to repair them for a long time. The contractor must have sufficient resources. The contractor should have adequate operating capital and more efficient work equipment and the ability to solve difficulties on the job site. The contractor's history should be reviewed before engaging him for the job.

- Subcontractors are changed regularly

When a construction company is involved in a large construction project, a contractor is usually hired to complete the task. On the other hand, the contractor seldom completes all of the jobs. The work that is left over is carried out by subcontractors who are employed by the contractor, who is usually the prime contractor. Subcontractors may designate their subcontractors to do a portion of the task they have been hired. Subcontractors often sign agreements with the contractor, including the contractor's and the owner's contracts. Suppose the project is delayed as a result of these factors. In that case, a subcontractor who fails to complete work on schedule or whose work falls short of the contract's requirements may be required to pay compensation if the contractors or the subcontractor themselves make alterations in the course of the job these issues. Therefore, the project is delayed since the new subcontractor has no or very little understanding of the project and must begin from the beginning to comprehend it, which takes time and increases the risk of errors. As a result, changing subcontractors between project tasks should be avoided. If it is essential, the contractor should schedule regular meetings with the new subcontractor to ensure that they have a complete and accurate understanding of the project.

- Technology that is no longer used

Constructions have been built for a long time, but the difference is technology since early structures were rudimentary and only served as housing. Innovative building changes have appeared over time, all because of technology, which may be described as the effective application of knowledge. Houses were once made of stones and mud, but nowadays, we utilize various materials such as stone, glass, concrete, wood, metals, and so on to construct structures.

The building industry offers a wide range of structures suitable for individuals of various socioeconomic strata. Domestic construction, heavy or civil construction, industrial construction, and commercial building are only a few examples of construction methods that demonstrate mastery. Different technical procedures are required for each of these. Simple technological methods are typically utilized for household building, and easily available materials are typically employed. These are often low-cost and short-term initiatives. The most important consideration in a commercial building is infrastructure, which is responsible for the project's strength, use, and longevity. Government agencies are frequently the ones to initiate them. The latest construction technology, techniques, and materials are required for these projects. More recent construction procedures are more effective than those that are older. As a result, using old-fashioned techniques will slow down the pace of construction projects. To avoid such delays, work should be done with the most up-to-date technological equipment and supplies.

- Construction methods that are inappropriate

The process of constructing a structure for real estate is known as construction. In a single building project, many different activities are carried out. Every activity has a variety of ways or approaches for carrying out the task. As a result of implementing efficiency rules in recent years, new building methods and technologies have emerged. Construction management sectors are at the forefront of current construction practices to increase performance and efficiency and reduce waste. Sometimes a contractor will pick an ineffective strategy for completing a building assignment that is not appropriate or appropriate for the job. This is usually due to a contractor's lack of expertise or misconceptions. This aspect contributes to the cause of the delay and the loss of money in this case. To reduce these delays, the contractor should thoroughly analyse the project before deciding on a method and compare it to previous projects to see if it is appropriate for the job.

- Errors require to rework

Work measures that must be completed more than once are known as rework. According to one researcher, Rework is the "unnecessary practice of redoing a work task that was carried out incorrectly the first time." "Effort made to obey the original requirements by rectification at least one more time owing to nonconformance with wishes," according to another definition that captures the core of rework. Rework isn't commonly defined to include the potential of missing work revisions and change orders carried by end owners, which aren't regarded as nonconformance in the first place. Rather, these changes are motivated by a desire to change due to financial constraints or other unrelated circumstances. In a hugely complex environment with numerous phases of tasks, dealers, and installers, and when many operations occur simultaneously, omissions, blunders, and bad management practices commonly result in neglect, which may lead to quality failures that must be redone. If rework is done frequently, it can lead to time and cost overruns. As a result, it should be avoided during the construction process. For this reason, an inspection engineer should inspect each phase of the job.

3.2.3 Case Study

3.2.3.1 Case Study Description

In recent years, the Berlin-Brandenburg International Airport (Berlin Airport) is one of Europe's most significant and difficult transportation infrastructure developments. The project encompasses over 1000 hectares and employs 3,000 people. Once completed, the terminal should handle between 25 and 27 million passengers per year.

The work was divided into five sections: planning, terminal and service building construction, civil engineering, technological infrastructure, and rail. For procurement reasons, each component was subdivided into smaller contracts, resulting in 45 service packages granted through independent bidding procedures.

By November 2011, the project had included 567 separate bidding processes, and 900 signed contracts for more than €2.1 billion (including design, construction, and supply). The project's entire cost was once anticipated to be €2.4 billion. The ultimate cost will be much higher due to several project design modifications during implementation and additional delays caused by technical issues. Furthermore, no evidence exists that any of the present cost overruns or delays result from or link to corruption. The exact date of the opening is currently unknown. However, it is believed to be in late 2014 or early 2015 (Macola, 2021).

The Berlin Brandenburg International Airport officially launched on October 31, 2020, nine years later than expected, with the arrival of airplanes operated by EasyJet and Lufthansa. Berlin Chancellor Michael Müller and German Transport Minister Andreas Scheuer were in attendance for a ceremony marking the inauguration. For the airport's namesake and former Chancellor of West German Germany (the Federal Republic of), Willy Brandt, there was an honor wall.

Government authorities proposed the construction of an airport for Berlin after the country's reunification in 1990. It was previously suggested for the new airport to be constructed at Jüterbog, Schönefeld, and Sperenberg, all of which are located in Brandenburg's north-eastern area and existing airfields. It was six years later that the project's stakeholders—the city-state of Berlin, Brandenburg, and the German Federal Government—rejected the original idea to build a new regional hub in favor of expanding Schönefeld Airport and renaming it Berlin Brandenburg International Airport (Macola, 2021). Because of its closeness to the city, Schönefeld benefits both Berlin and Brandenburg. The airport was enlarged by 9.7 kilometers to a total size of 14.7 kilometers as part of the renovation project.

Planning clearances and preliminary work began between 2000 and 2004, along with public hearings and talks with people opposed to the proposal. The Brandenburg Aviation Authority granted Brandenburg airport planning authority in 2004, Approval and award of the first contracts for planning based on financial principles. The ground has been prepared for construction. During the Cold War, Berlin-Tegel Airport was the only exit for West Berliners, and In 2005, the Berlin-Brandenburg Higher Administrative Court dismissed allegations that were brought up by five different airlines in opposition to the closing of the airport.The new airport's license was supposed to expire, according to the court, after Berlin-operating Tegel's was put into operation (Macola, 2021). The idea to turn Tegel into Berlin-Brandenburg International Airport was accepted by the Federal Administrative Court – one of Germany's federal top courts – in 2006, allowing for the initial ground-breaking activities and site preparation. When construction started, the airport was scheduled to open in October 2011.

Construction on the railway tunnel and underground train station and the north taxiway, south runwayA year after the Federal Administrative Court authorized the proposal, construction started on the road infrastructure. When the airport terminal finally got under way in 2008, the outer structure was completed a year after that. As of 2010, FBB had said that the opening date for the new terminal will be moved back from October 30 to June 3, 2012, even though work had been completed. The business blamed delays in airport technical construction systems and the need of adding security screening lines in the north and south pavilions for the situation (Macola, 2021). On the other hand, experts feel that the postponement of the inauguration date was due to the bankruptcy filing of the building planning business, Planungsgemeinschaft Berlin-Brandenburg International, in February 2010.

Between 2011 and 2014, the Berlin Brandenburg project faced some of its most difficult years. It was only until the German Federal Administrative Court announced that the airport may open on June 3rd, 2012, that the project received a major boost. FBB CEO Rainer Schwarz praised the court's decision, saying, "The Federal Administrative Court's judgement now offers the airport operating business, the airlines, and local inhabitants a strong foundation for planning for the future." This judgment ensures that Berlin Brandenburg Airport remains competitive while also safeguarding the interests of individuals living in the local area.. " Due to a lack of time to finish the airport's construction and structural handover, FBB canceled its planned opening on May 8, 2012, less than a month before it was supposed to begin.Fire safety regulations were cited as the cause for the postponement. Officials noticed that fire detectors and protective flaps were not working, according to various sites, including the BBC. The project's supervisory board declared the revised opening date on March 17 2013, eventually pushed again to October 27 2013. Due to ongoing issues with fire prevention systems, As of early January 2013, all opening data for October 2013 have been canceled (Macola, 2021). In addition to the departure of former Berlin Mayor Klaus Wowereit as chairman of the project's supervisory board and the dismissal of Berlin Brandenburg CEO Rainer Schwarz, this year witnessed a number of leadership changes at the airport. Jochen Grossman, the airport's former technical director, was also accused with bribery.

After Hartmuth Mehdorn, the new CEO who took over after Schwarz stepped down, was fired In 2015, less than a year after the previous CEO's departure, a new one was appointed, and additional charges of malfeasance surfaced. Further charges of corruption, including the payment of airport officials, surfaced after Mehdorn was removed from his position as mayor of Berlin and Michael Müller, Berlin's newly elected mayor, was selected as chairman of the supervisory board. One of the officials was found to be guilty of accepting bribes from Imtech Deutschland, the business that was responsible for the construction of fire and smoke vents but which is now bankrupt. On January 21, 2017, the opening of the airport was pushed back to an indefinite date. Eleven months later, on January 21, 2018, the management board of the airport stated that the opening would take place in October 2020.(Macola, 2021).

Terminal 2's topping-out ceremony was conducted on July 30, 2019, while the interim terminal was finished in 2018. After executing principle and compound tests, FBB was able to set an opening date of October 31, 2020, due to the robust construction progress.Despite the Covid-19 epidemic, the project was completed, and the airport obtained its operational authorization from the Berlin Brandenburg Joint Aviation. On October 1, 2020, the authority will be granted. FBB was ecstatic to hear the news. Englebert Lütke Daldrup, who replaced Mühlenfeld as CEO in 2017, says that after gaining building authority clearance to use Terminal 1 in late April, he has now received the final notifications that we have an airport that is ready for operation in line with all rules and regulations. There seems to be no obstacle to the BER opening on October 31, 2020, as far as we can tell.The airport ultimately opened its doors on October 31, as planned. However, due to a decrease in travellers due to the Covid-19 epidemic, Berlin Brandenburg’s Terminals 5 and 2 will be temporarily closed beginning February 23, 2021(Macola, 2021).

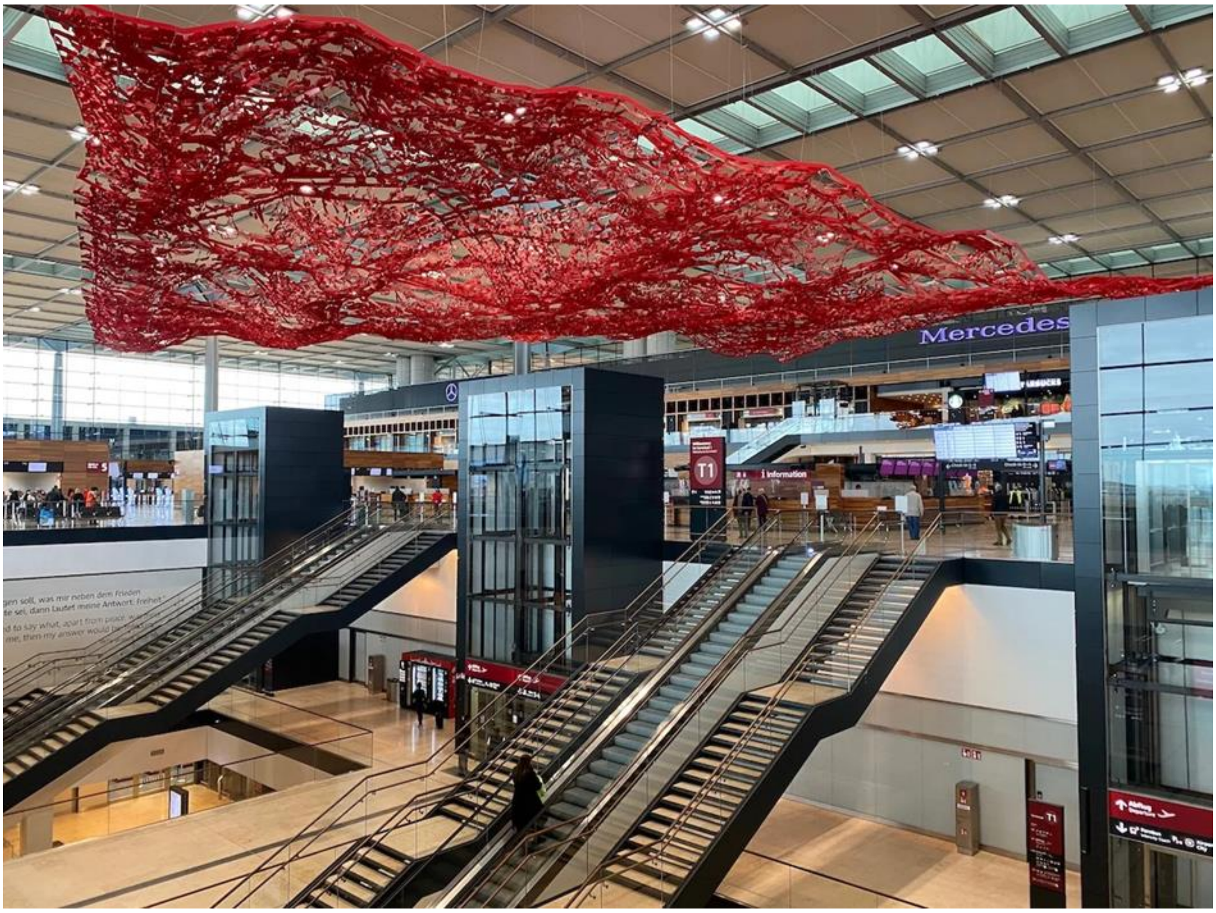


Figure 26 *Brandenburg Airport terminal* (Schlappig et al., 2021)

3.2.3.2 Case Study Question

What were the key delays in the Airport Project's governance that caused severe time delays and cost rises, and how can the BER experience be used to improve how to deal with delays in the future?

3.2.3.3 Case Limitations

Some limits, both in terms of time and topic matter, were chosen to keep the scope of this investigation within reasonable bounds: Study spans 2003-2013, beginning with decision to provide Airport Initiative as public project and ending with cancellation of a start date. Passenger terminal building completion is the main emphasis here. The runway system and auxiliary buildings were left out since they only had a few cost and budgetary difficulties.

3.2.3.4 Case Study Hypothesis

A literature review can be used to create a set of appropriate success criteria that will help you navigate the large amount of case-specific information. The literature on megaprojects contains a number of potentially useful ideas and concepts that have direct relevance to BER. Using a literature review, you may come up with a set of success criteria that will guide you through the minefield of case-specific information. Errors were made in the design and implementation of the governance structure and the implementation of important operations within that framework at BER. To begin, it is important to note that the megaproject was inserted into an existing corporate governance system that was built to support an ongoing business. As a second point, it's difficult to see how the rising costs can be justified given the constant changes in size and layout (as argued by Hartmut Mehdorn). When it comes to cost increases, size and layout changes are not a viable answer, but rather the root cause of the numerous issues that have arisen (Kostka, Jobst Fiedler and Springer International Publishing Ag, 2018).

3.2.3.5 Reasons for project failures

The reasons for the project's failure are explained in detail by (Organisation For Economic Co-Operation And Development, 2015):

Management and supervision by inexperienced, non-specialists

In 2003, the project's political leadership chose to dismiss the private-sector consortium formed to fund, build, and run the airport and instead make it a public enterprise, stating that the private sector should not profit at the expense of the public sector. This was done to save money, promote local construction, and keep the project on track. None of the political leaders had any real-world experience with large-scale construction projects. Politicians, public officers, and union officials were virtually solely in charge of supervision. The supervisory board's lack of skill and technical understanding hampered adequate and thorough control of the project supervisory board's lack of skill, and technical understanding impeded effective and thorough control of the planning and development, resulting in delays, confusion, and significant cost overruns.

Budget estimation inaccuracy

According to some experts, the airport's early cost projections were considerably underestimated, producing management issues through implementation. To maintain political support, it was critical for the political leadership to keep the predicted costs of the new airport development low. Experts noted this as a typical trait in significant infrastructure projects by experts. According to the research, a similar trend exists in democratic countries, where politicians tend to mislead the public about the true costs of initiatives. As a result, cost overruns are rarely unexpected. Politicians frequently attempt to calculate the price as low as feasible to gain support for initiatives, obfuscating the potential hazards. Those in positions of power frequently take a calculated risk by figuring they will not be held personally liable if expenditures begin to spiral out of control. Bent Flyvbjerg of Oxford University, a Danish researcher, argues that the projects that "are designed to seem best on paper (and that also) are the initiatives that accrue the largest cost overruns and benefit deficits in reality" are typically finished. The term "survival of the most unfit" describes this phenomenon.

Poor planning and procurement

The preparatory team lost a lot of time due to an adjustment being made in the organizational structure of the governance at the outset of the project. In 2007, it was necessary to create brand new blueprints and send out invitations to bid. Despite the fact that the principal building contracts were awarded at the beginning of 2009, the opening of the airport was not expected to take place until October 2011.The European Court of Auditors found flaws in the airport infrastructure project's project preparation: planning papers were unavailable when the tendering process began, forcing large cost overruns. Because of the weak planning procedure, the operating agency could award numerous more contracts without going through a bidding process. This meant that the airport corporation was breaking E.U. public procurement regulations regularly. According to the auditors, the additional work covered by those contracts was foreseeable by management and should have been allocated through a bidding procedure. The European Court of Auditors' comptrollers discovered numerous things that raised eyebrows, including a plan to build elevated parking places for Berlin Mayor and his VIP visitors at EUR 567,000 to have quicker access to gates.

Variations and changes

Several major (and reportedly needless) alterations were included in the project, raising expenditures and time resources. For example, the board debated The board had to decide whether or not to construct a two-story jetway for the Airbus A380, and soon before the project was to begin, the board decided to move the expensive jetway from the main terminal, where all airlines are permitted to dock, to the Air Berlin departure area.Variations or modification orders contributed to the project's execution becoming muddled, allowing for abuse and raising total expenses.

Figure 27 *A* jetway for the Airbus A380 Flying on an Emirates A380 from New York to Dubai. (Pallini, n.d.)

Internal communication is lacking.

The channels of communication and information between the governance and management groups were reportedly skewed, particularly regarding the probable launch date. This is due to a lack of technical experience, resulting in inadequate project oversight. The various entities' knowledge imbalance resulted in both management and public communication concerns.

3.2.4 Conducting the various methods of delay analysis

To critically evaluate current approaches, a simple case study was created and simulated utilizing different delay scenarios. The case study project focuses on the creation of a restaurant storage facility. The project started on schedule, however progress was delayed by three significant delays. (1) occurrences whereby the contractor carries the time and cost impacts (commonly referred to as "Nonexcusable–Noncompensable" delays (NN)); (2) occurrences whereby the contractor is responsible both to time extensions and reimbursement of increased fees caused as a result of the delay (typically called as the "Excusable Compensable" delays (EC)); and (3) occurrences where no participant seems to have power above or carries the threats (e.g., actions of God

Figure 20 depicts the project's as-planned schedule (in bar chart format for clarity), which indicates a total project duration of 54 days. The red bars represent the crucial route as designed. The delay situations experienced in the example project are depicted in Figure 20. The as-built timetable had a total project length of 60 days, which included any delays that occurred during construction.

Table 3 Events that caused delays in the sample project (Own work).

Activity	As planned duration	Chronology of delay	Description	Type	Delay Duration
Concrete works	6	1	Due to a labor shortage, the contractor had to extend the activity by two days.	NN	2
Doors Fixing	2	2	The owner changed his mind about the storage door and instructed the contractor to make the necessary alterations. This resulted in four more days of labor.	EC	4

3.2.4.1 As-Planned vs. As-Built

A comparison of the construction delays in the case study construction project's work schedule using the As-Planned vs. As-Built method was used to identify the causes of these delays and to assign blame to all stakeholders.. Delays in construction had to be pinpointed in order to determine how much time they would add up and assign responsibility to everyone concerned. In order to avoid delay claims among project participants, accurate culpability allocation is critical in timetable delay studies.

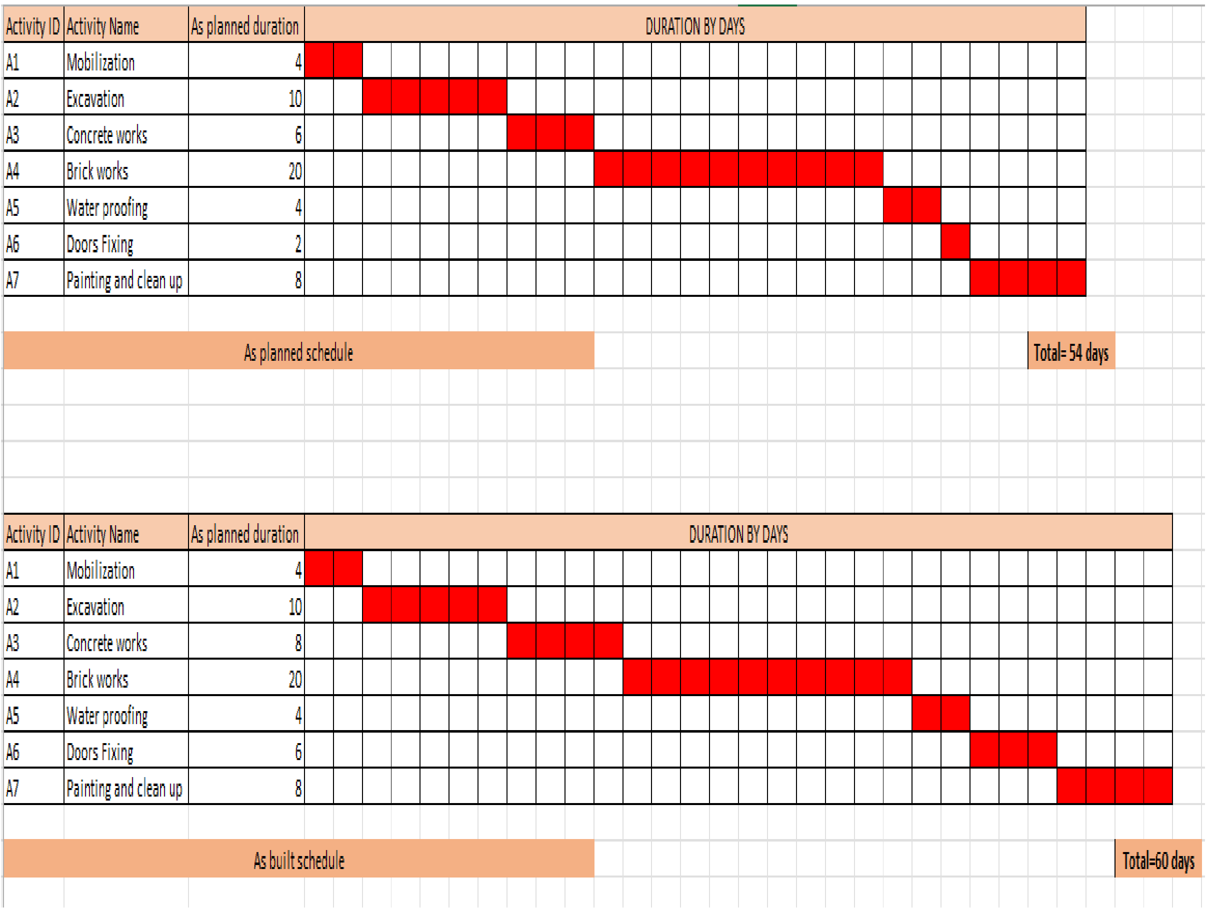


Figure 28 The as-built and as-planned schedules (Own work)

On the project's as-built schedule, this approach is used to illustrate all delayed events (EC, EN, and NN delays). The period in which the claimant will seek compensation is the difference between the as-planned and as-built project schedules.In both the as-built and as-planned timetables, the key route is determined twice. The net impact bar chart approach and this method are similar in that they both show the cumulative impact of all reported delays. The following figure represents the distribution of delay responsibility between the contractor and the owner for the example project. Total contractor-induced delays (NN) = NNi = 2 days ECi = 4 days (sum of owner-caused delays). The contemporaneous delay due to both parties is expected to be 0 days based on the aforesaid ("i.e., the lesser of the two types of delays"). As a consequence, the net project delays for which the owner is responsible = 4 - 0 = 4 days; Figure 27 demonstrate that the net total project delay is 60 - 54 = 6 days, with the contractor responsible for the remaining 6 - 4 = 2 days.

3.2.4.2 Impacted As-Planned

CPM timetable delays are calculated using this approach. One by one, these delays have been incorporated to the intended network as activities and shown in the order in which they occurred.The amount of delay is equivalent to the change in project schedule between both the timetables prior to the actual impacts.The method may be used to analyze delays before, during, and after a project's completion. The example project's delay analysis was carried out using this approach by sequentially adding the delays to the as-planned timetable.

The first and second delays (NN = 2 & EC= 4) occurred in the crucial path, resulting in a six-day delay in the original schedule. Because the delays occurred on non-critical lines, no slippage occurred; nevertheless, in our case study, there were no delays of this kind.

Table 4 Impacted as-planned Outcomes (Own work).

Chronology of delay	Activity Id	Type	Delay Duration	Impacted delays
1	A3	NN	2	2
2	A6	EC	4	4

From Table 4, The owner is accountable for four days of project delays, while the contractor is liable for two.

3.2.4.3 Window Analysis

At particular points during the project, this approach entails assessing delays on new timetables. This may be compared to the "snapshot approach." A variety of time periods (windows or snapshots) are used to break up the total project duration based on significant planning changes or critical project milestones. Within each window, the schedule is adjusted to reflect the real durations and orders at the time of the delay, but the remainder of the schedule is left unchanged once the window period has passed.. Analyses are used to pinpoint the most crucial path and reassess the original completion date.This updated completion date is compared to the previously intended finish date to determine the amount of time lost during the window period. The overall contract length was initially divided into discrete time periods at days 22 and 60, resulting in two "window" periods using this approach on the sample project. Figures 28 illustrate the results of the analysis for each "window" at the various updates.

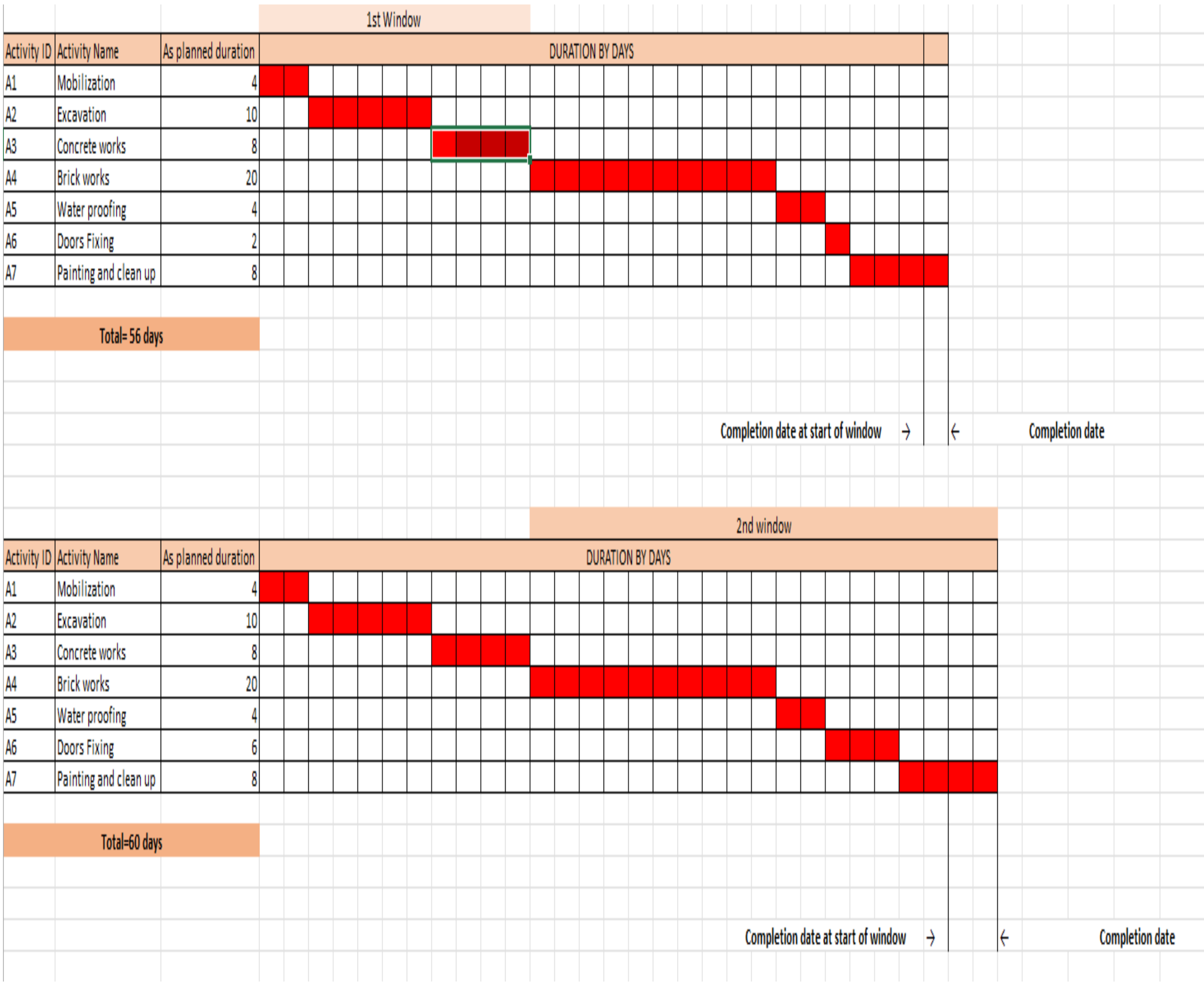


Figure 29 Updated schedule on days 22 & 60. (Own work)

It took two days longer to finish the first window because the contractor was two days behind schedule on the critical route.The amended schedule at the conclusion of the second window revealed a four-day slippage due to the owner's critical route delay of four days. The findings of this investigation are summarized in Table 8. As a result, the contractor is accountable for two project delays, while the owner is responsible for four.

Table 5 Window analysis Outcomes. (Own work).

Number of the window.	Updated schedule (day No.)	Date of completion (day No.)	NN Delays	EC Delays
0	0	52	0	0
1	22	54	2	0
2	60	60	0	4
Total			2	4

3.2.2.4 Time Impact Analysis

However, unlike the window strategy, this approach concentrates on only one delay or delaying event, rather than a series of delays or postponing events over an extended period of time. A stop-action picture of the building is done each time a significant delay is encountered. A finalising date is set after a revision of the schedule and an assessment of the consequences of the delay.

The additional time incurred as a result of this effect is determined by subtracting the new project completion from the old date. A "fragnet" or subnetwork is widely used to depict the impact of a delay event, such as a change order, on the timetable. Using real-time CPM to assess delays is an effective method. It may be utilized while and after the project is finished. The sample project did not employ the time effect analysis since it is so similar to the window analysis.

4. Results & Analysis

4.1 Is there delay in Construction? How to prove it?

The resulting list of delay causes was subjected to three different dimensions:

- Important Delay Causes by Project Sector (Appendix A)
- Most Important Causes by Project Size (Appendix A)
- Important Causes by Project Party

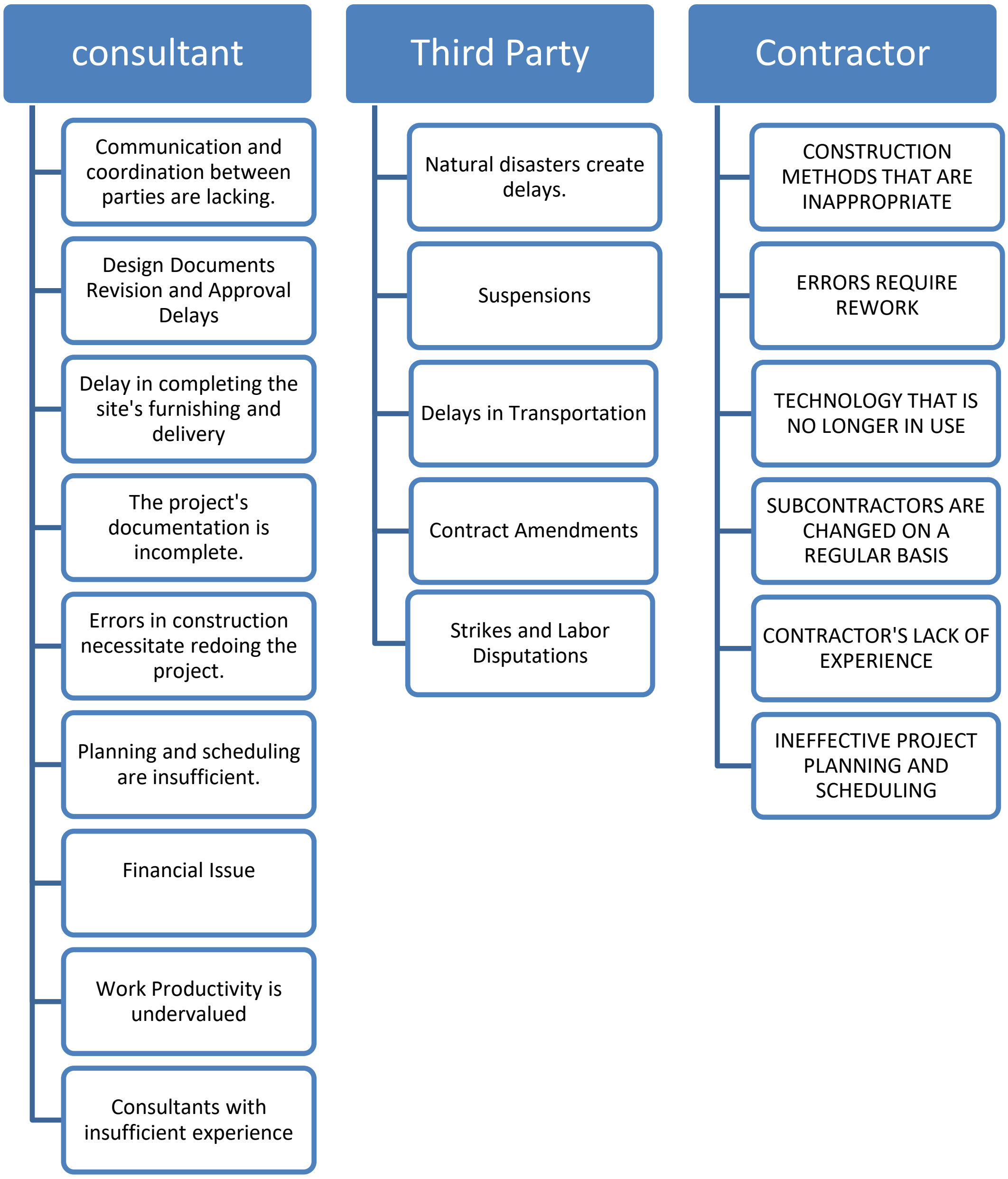


Figure 30 Types of construction delays Caused by Project Party (Own work)

4.2 Explain the delay consequences in construction ?

4.2.1 Case study main findings (Time overrun)

"Infrastructure" refers to physical assets that "enable, sustain, or improve social living circumstances." Infrastructure is an instance of statehood co-production that depends on collaboration and effective governance, with legislative control, technical abilities, a wide range of state and non-state organisations with varying levels of financial and service capabilities. Big projects like megaprojects, which are both complicated and costly, draw attention from both the public and the political establishment.This is accentuated in infrastructure projects or megaprojects. Program failure may have serious implications for governments in control, corporate sector service providers, investors from both the public and the private sector, as well as end users. Brandenburg Airport ("BER" or "Airport Project"), now under completion in Schoenefeld (Brandenburg), has been such a high-profile catastrophe, having been finished over four years late and at about 70 percent over budget. Based on the Organisation For Economic Co-Operation And Development report in 2015. There have been four delays in BER's official opening date since it was originally scheduled for October 2011. Rescheduled opening dates for the Airport Project have been announced by Flughafen Berlin Brandenburg GmbH, the project's developer, since January 2013.

4.2.2 Case study main findings (Cost overrun)

The cost issue at BER has been opaque throughout the project. Only high-level statistics concerning additional equity infusions, one in 2012 and the other in 2014, have been made public since the delays began. Minister of Finance and supervisory board member for the State of Brandenburg claims that since Mehdorn took office, neither the supervisory board nor parliaments have received a one-year financial plan from the three shareholder governments.

However, it has become evident that FBB management has adopted a policy of ‘discussing away’ that future cost rises are unavoidable due to planning mistakes and construction flaws. For the time being, FBB CEO Hartmut Mehdorn is hiding behind a media release that quotes him as making three significant public declarations, criticizing the board of directors, and apologizing to shareholders. Construction has increased the estimated passenger capacity from 17 million to 27 million, which means that "more airport costs more money." Second, the cost of noise insulation for resident dwellings has grown due to the new noise abatement rule. Finally, a total cost of “just over 5” billion euros would still be “excellent value.” (Organisation For Economic Co-Operation And Development, 2015).FBB requested an extra Euro 1.2 billion in the capital in 2012. Because the building shell was completed after that, large-scale capacity additions were not conceivable.

The Organization for Economic Co-Operation and Development (OECD) identifies the following as initial sources of funding:

To make Schoenefeld a "single" airport for Berlin, the Federal Republic of Germany and the cities of Berlin and Brandenburg agreed in 1996 to lend Euro 224.5 million to the airport company.Shareholders chose to convert their debt into equity and inject an extra Euro 430 million in 2005. shareholders' decision. In 2007, the state of Brandenburg decided to contribute Euro 74 million to the airport's access road.The European Investment Bank granted a loan of Euro 1.0 billion in 2007 and made it available to the country by the end of 2008.

A further 1.2 billion euros were invested by shareholders after the third delay in 2012, increasing the overall funding sources to 3.1 billion euros, compared to the initially expected construction costs of 2.4 billion euros. To compensate for increased noise prevention costs incurred after a June 2012 court judgement, Euro 305 million has been allocated. 180 Euro 4.3 billion is currently the sum amount of all sources.

If the Euro 1.049 billion had been included, the total amount supplied by the owners and lenders would have risen to Euro 5.4 billion. To put that in perspective, the additional noise abatement demands translate into increases of 125% and 74% above the initial construction estimate and financing sources of Euro 2.4 billion.

4.3 How to minimize construction delay consequences?

Lessons learned and recommendations

The lessons aim to distil the unique case study findings and new developments into four concise conclusions that may be used by decision-makers working on large-scale infrastructure projects for the public good based on the Organisation For Economic Co-Operation And Development recommendations are:

1st lesson In order to be successful, governance mechanisms must be staffed with experts at all levels; personnel with extensive project management experience and skill must be given the support they need to succeed. Detailed governance structures and procedures are necessary to aid in the management and execution of the project and all of its components by skilled and knowledgeable persons. There are several high-profile projects by Gerkan, Marg and Partners architects all throughout the globe. There was no effective change request system, no educated customer, and no complete control and steering framework to help them succeed in this setting. A statutory supervisory board, for example, is useless if it does not seek or does not have the knowledge and skills required to properly appreciate problems and make well-informed decisions. Because of the complexity of large-scale processes, they are also inadequate if they fail to understand that the level of monitoring and counsel, they can provide is not sufficient, and that a project-specific governing system is needed.

2nd lesson Ordinarily, appointing a general contractor is a smart option, but it necessitates that the public side be well-prepared in advance of the project. If the governance system is poor, as it is in the BER example, carrying out the project without the need of a general contractor who could really carry on the operational and economical liabilities of the implementation stage and appropriately oversee the subcontractors is exceedingly risky and nearly lethal. FBB and its stakeholders, i.e., taxpayers' money, bore the full brunt of the BER risk. As a result of FBB management's incapacity to oversee and coordinate 50 subcontractors, the completion of the airport terminal and its complicated fire-prevention system failed. The insolvency or firing of the contractors hired to undertake this task exacerbated the problems. The BER case is a sad illustration of the severe implications of the ensuing rush to completion in terms of time and money required to rectify the damage. The public sponsor is nevertheless put under a lot of pressure when choosing a general contractor. Floods of costly modification requests can only be prevented if meticulous pre-planning and contract quality are high. The instance of the Elbphilharmonie is a wonderful illustration of this.

3rd lesson Allow enough time for detailed preparation before and throughout contract implementation. In the case of BER, it became fatal because adequate time was not provided when it was decided to go through 50 procurement procedures and award contracts. This should have been followed by a postponement of the airport's construction and opening dates. Concurrent planning and execution create a slew of coordination challenges when not enough time is allowed, whether by thorough pre-planning or by pushing back the target completion date. Assurance, Assurance First, FBB's management was unable to keep track of what was happening on the ground. Through its supervisory board members, FBB management likely vetted and/or distorted information for the benefit of the sponsoring countries. Parliaments could only perform ex-post examinations since they lacked access to reliable and up-to-date information as the problems developed.

4th lesson to be a “smart client,” the customer must be offered all internal and external resources. Project managers must be able to locate, negotiate, and supervise the private sector firms that will eventually carry out the design and construction work. out of the agreement. It's easy to underestimate the amount of time and effort that this requires.

4.4 Comparison between different delay analysis techniques limitations

Delay claims have become a major cause of contention in the construction business, as well as one of the most hardest to settle. As a result of this, academic scholars and practitioners alike have attempted to build DATs and good practice guides to guide practitioners through effective claim analysis and resolution. Understanding the limitations and capabilities of these strategies in practice, as well as opportunities for development, requires a thorough understanding of their implementation. This paper, as part of a larger research project, aims to create such knowledge and understanding through a case study review of the most prevalent DATs, a discussion of the major important concerns commonly overlooked by the approaches, and their improvement needs.

Delay claim analysis software now on the market has a wide range of features and capabilities. Some crucial scheduling processes, such as projects calender, rescheduling activities with delays, and status updates, all of which have an impact on the delay analysis process, are not transparent and are handled in various ways. These factors make it more likely that claimants and defendants may arrive to diverging delay claim conclusions, making a peaceful settlement of delay claim conflicts more difficult to achieve. [*] Attempting to come to an agreement on a single software application for the analysis and how it should be executed amongst opposing parties is justified by this.

Resource-loaded and leveled baseline programs are essential for more reliable delay analysis findings because they allow for reliable task time, network logic and realistic float values in noncritical processes. A lack of consideration for these limits might lead to erroneous and untrustworthy findings if the baseline program was not considered into account in this study, resulting in incorrect and unreliable results.Although considering resource loading provides credible analyses and outcomes, which contributes to effective claims settlement, little study has been done on how to appropriately include this factor in DATs. As a result of this constraint, further research investigations in this field are required

A major challenge in solving concurrent delays is that existing DATs fail to take into account for them in overall evaluations. Analysts should employ variable multiple time intervals or windows to keep track of changes in the key route. On the other hand, different time periods would provide different results since the amount and type of concurrent are guaranteed to produce distinct conditions and outcomes. Due to this, it is vital that opposing parties agree on the most suitable time period for assessment, which might be dependent on status of the project dates or the incidence of essential project milestones.

Table 6 Comparison between different delay analysis techniques limitations (Own work).

Delay Analysis technique	Limitations
As-Planned vs. As-Built	- Ignores the critical path's flexibility and any changes to the timetable logic. - In order to evaluate the effect of each delay on project completion, no effort is made to do so. For every delay, including those on the non-critical route, their cumulative impact was computed.
Impacted As-Planned	- Out of context and temporal delays are analyzed using a set as-planned timetable. - A realistic model for the whole study may not be the initial baseline program.
Window Analysis	- If you're looking for an efficient way of keeping track of your projects, you'll have to spend a lot of time and money. - Different outcomes may be obtained if the time periods (or "windows") are varied.
Time Impact Analysis	- The analysis takes a lot of time and work. - If there are a large number of events that cause delays, it may not be practicable or reasonable to employ.

5. Conclusion

Delays in the construction timeline of a project may create substantial difficulties for both the contractors and the owners of the project, which can lead to expensive conflicts, contentious issues, and strained relationships between all of the participants in the project.

Claims of delays are currently one of the most common causes of disagreements in the construction business, and they are also one of the most challenging to settle. As a result of this, both academic researchers and practitioners have engaged in a great deal of activity in the form of the development of DATs and good practice guidelines with the intention of directing practitioners toward the appropriate analyses and resolutions of the claims. It is of the utmost significance to have knowledge of the use of these approaches in order to comprehend their limits and capabilities in practice, in addition to the areas in which there is a need for development. This paper goal is to develop such knowledge and understanding through the following means: an evaluation of the most common DATs based on two case studies; a discussion of the key relevant issues that are often not addressed by the techniques; and their improvement requirements.

Answering the study's first question, "Is construction being delayed or not?" Construction industry professionals and past research were consulted for this section's study. Delay Consequences in construction will be examined in a case study in the next phase of the project. The second and third questions are being addressed in this section of the research. It was then determined how much each party (Contractor, Owner, or none) was liable for the project delay. Furthermore, a list of each method's limitations was compiled from this case study's examination.

The resulting for the first question Is there delay in Construction? was subjected to three different dimensions:

- Important Delay Causes by Project Sector (Appendix A)
- Most Important Causes by Project Size (Appendix A)
- Important Causes by Project Party

The following questions What is the current compensation of the project delays on all the parties in terms of time and/or cost? How to minimize it?

The study of the approaches demonstrated that the various DATs offer varying allocates of delay liabilities when applied to the same collection of delay data available, validating the general assumption that the best methodology for each claims scenario relies on the claims circumstances and the project. There are a variety of outcomes since each methodology has its own set of needs and methods for implementing those objectives.

Concurrent delays are still one of the most challenging challenges to solve since present DATs do not take them into account in the assessments. As a solution, the analyst should use a dynamic windowing strategy that allows him/her to track changes in the critical path. Although various time periods would generate different outcomes, the level and kind of concurrency would yield distinct circumstances and effects. Hence, it is critical that the parties in dispute agree on the most relevant time period to be utilized for the analysis, based either on status dates or the occurrence of key/milestone project events.

These findings have substantial implications for the settlement of construction delay claims as well as the necessity for further enhancement of the current DATs. As a first step, the parties engaged in such claims should be aware of the methodologies' limits and capabilities, as well as the aforementioned difficulties, in order to include them as fully as possible in their analysis. Because of this, claims settlement disagreements may be reduced by increasing openness and rigor in the claims analysis. As indicated by delay analysis literature, the highlighted difficulties have gotten relatively little attention and study focus so far.

Delays in projects may be attributed to many factors, but this thesis focuses on analyzing two case studies and discussing the techniques that have been used in the past. An investigation on a wide range of delays. Different approaches were explored to figure out how long the construction delays had lasted and who was to blame. Finally the paper resluts is including a table contains a comparison beteew delay analysis techniques limitaitions which is showing the differnet techniques have different limitations which might force the Projetc party to use a specific delay techniques based on this study findings.

A case study was explained to answer these questions Explain the delay Consequences in construction? How to minimize construction delay consequences?

The analysis for this case study showed that delay in construction might lead to two main consequences in the project:

- Time overruns
- Cost overrun

Now at Schoenefeld (Brandenburg), Brandenburg Airport ("BER" or "Airport Project") has been finished about four years late and nearly 70 per cent over budget. As of now, BER's official opening date has been postponed four times since it was set for October 2011.. Owners and lenders would have contributed a total of Euro 5.4 billion. The extra noise abatement requirements lead into increases of 125% and 74% above the original construction estimate and funding sources of Euro 2.4 billion, respectively.

Because of this, project management must be an integral element of not just identifying delays but also understanding what caused them, so that the length of the delay can be calculated. To help decision-makers working on large-scale infrastructure projects, the lessons strive to distil unique case study results and new innovations into simple conclusions that may be utilised. It is essential to have detailed governance structures and processes in place so that the project can be managed and executed by informed and qualified individuals. In addition, hiring a general contractor makes sense, but the public must be well-prepared for the project before hiring a general contractor. Further-more, give yourself enough of time to prepare thoroughly before and throughout the execution of the contract. It's also important that Project Managers know where and how to find and interact with private sector businesses that will ultimately carry out their task.

5.1 Recommendations

Here are some broad suggestions based on the findings of this research that may have helped to reduce or eliminate the negative effects of the construction delays in the project under consideration in the first place. Owners should not be able to demand changes to a project's design after it has been awarded the contract. The project's owner should allot enough time and resources to the design phase. A pre-qualification process should be used to pick a contractor. A contract shouldn't be signed until the owners have gathered all of their resources and obtained all essential approvals. Early completion incentives should be included in the contract. Contractors and consulting firms should work together to create a detailed timetable for the project. In order to increase management and technical abilities, the contractor should hire competent teams and train employees in-house. A project manager should also be part of the contractor's team to monitor the progress of the project and guarantee that supplies are delivered on schedule. Finally, and perhaps most importantly, good communication must be established amongst all parties involved if issues are to be resolved quickly.

5.2 Future Research

Future study should thus concentrate more on these Buildings ignored concerns, in order to expand the minimal information and understanding that exists about them, such as how best they may be handled in delay analysis. Despite the fact that the case study was based on a hypothetical project, the suggested claims scenarios substantially resemble those of a normal construction delay claims setting, both in applicability and context. As a result of this study, it is advised that researchers do a comparable study using real-world project data in the future in order to verify the results.

Declaration of Authorship

I declare that all information in this paper is accurate and provided ethically. I additionally certify that I've credited and referenced any non-original material and findings as necessary.

Berlin, 05/07/2022

Location, Date

Signature of the student

Appendix

Appendix A

- Important Delay Causes by Project Sector

Table 7 Ten most Important Delay Causes by Project Sector (Abd El-Razek, Bassioni and Mobarak, 2008).

Rank	Housing	Tourism	Industrial	Commercial	Educational/Research
1	Financing by contractor during construction	Financing by contractor during construction	Slowness of the owner decision making process	Design errors made by designers	Financing by contractor during construction
2	Design changes by owner or his agent during construction	Design changes by owner or his agent during construction	Financing by contractor during construction	Design changes by owner or his agent during construction	Delays in contractor's payment by owner
3	Delays in contractor's payment by owner	Partial payments during construction	Nonutilization of professional construction/ contractual management	Slow delivery of materials	Partial payments during construction
4	Partial payments during construction	Slow delivery of materials	Lack of database in estimating activity duration and resources	Changes in materials types and specifications during construction	Slow delivery of materials
5	Obtaining permits from municipality	Delays in contractor's payment by owner	Difficulty of coordination between various parties working on the project	Lack of database in estimating activity duration and resources	Controlling subcontractors by main contractor in the execution of work
6	Changes in materials types and specifications during construction	Slowness of the owner decision making process	The relationship between different subcontractors' schedules	Obtaining permits from municipality	Slowness of the owner decision making process
7	The relationship between different subcontractors' schedules	Nonutilization of professional construction/ contractual management	Preparation of shop drawings and material samples	Difficulty of coordination between various parties working on the project	Shortage in construction materials
8	Unexpected foundation conditions encountered in the field	Difficulty of coordination between various parties working on the project	Poor organization of the contractor or consultant	Shortage in construction materials	Poor organization of the contractor or consultant
9	Nonutilization of professional construction/ contractual management	Lack of database in estimating activity duration and resources	Delays in contractor's payment by owner	Excessive bureaucracy in project owner operation	Poor labor productivity
10	Slow delivery of materials	Design errors made by designers	Poor labor productivity	Nonutilization of professional construction/ contractual management	Nonutilization of professional construction/ contractual management

- Most Important Causes by Project Size

Table 8 Ten most Important Delay Causes by Project size (Abd El-Razek, Bassioni and Mobarak, 2008).

Rank	A <5,000,000 EGP	B 5,000,000–24,000,000 EGP	C >24,000,000 EGP
1	Design changes by owner or his agent during construction	Financing by contractor during construction	Partial payments during construction
2	Financing by contractor during construction	Slowness of the owner decision making process	Design changes by owner or his agent during construction
3	Unexpected foundation conditions encountered in the field	Difficulty of coordination between various parties (contractor, subcontractor, owner, consultant) working on the project	Delays in contractor's payment by owner
4	Obtaining permits from municipality	Controlling subcontractors by main contractor in the execution of work	Slow delivery of materials
5	Delays in contractor's payment by owner	Delays in contractor's payment by owner	Financing by contractor during construction
6	Inspection and testing procedures used in the project	Partial payments during construction	Lack of database in estimating activity duration and resources
7	Slowness of the owner decision making process	Nonutilization of professional construction/ contractual management	Nonutilization of professional construction/ contractual management
8	Excessive bureaucracy in project owner operation	Slow delivery of materials	Slowness of the owner decision making process
9	Nonutilization of professional construction/ contractual management	Shortage in construction materials	Changes in materials types and specifications during construction
10	Errors committed due to lack of experience	Design changes by owner or his agent during construction	Poor organization of the contractor or consultant

Appendix B

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