



Quantitative Analysis of Project Delays and Mitigation Strategies at an Engineering Organisation in the UAE

**التحليل الكمي لتأخيرات المشاريع واستراتيجيات الحد منها في مؤسسة هندسية
في دولة الإمارات العربية المتحدة**

by

SUHAIB ALI MOHAMMED (SUHAIB AL AZZAWI)

**Dissertation submitted in partial fulfilment
of the requirements for the degree of
MSc ENGINEERING MANAGEMENT
at
The British University in Dubai**

October 2025

Declaration

I warrant that the content of this research is the direct result of my own work and that any use made in it of published or unpublished copyright material falls within the limits permitted by international copyright conventions.

I understand that a copy of my research will be deposited in the University Library for permanent retention.

I hereby agree that the contents of this dissertation for which I am author and copyright holder may be copied and distributed by The British University in Dubai for the purposes of research, private study or education and that The British University in Dubai may recover from purchasers the costs incurred in such copying and distribution, where appropriate.

I understand that The British University in Dubai may make a digital copy available in the institutional repository.

I understand that I may apply to the University to retain the right to withhold or to restrict access to my thesis for a period which shall not normally exceed four calendar years from the congregation at which the degree is conferred, the length of the period to be specified in the application, together with the precise reasons for making that application.



Signature of the student

Copyright and Information to Users

The author whose copyright is declared on the title page of the work has granted to The British University in Dubai the right to lend his/her research work to users of its library and as an open source, and to make partial or single copies for educational and research use.

The author has also granted permission to the University to keep or make a digital copy for similar use and for the purpose of the preservation of the work digitally.

Multiple copying of this work for scholarly purposes may be granted by either the author, the Registrar or the Dean only.

Copying for financial gain shall only be allowed with the author's express permission.

Any use of this work in whole or in part shall respect the moral rights of the author to be acknowledged and to reflect in good faith and without detriment the meaning of the content, and the original authorship.

Abstract

Complex operational environments, tight deadlines, fast-tracked projects and high demands from multiple stakeholders (both internal and external) present significant challenges in the engineering sector, particularly Mechanical, Electrical and Plumbing (MEP) and energy retrofit fields in the UAE. These changes often lead to project delays, which result in increased budgets and stakeholder or customer dissatisfaction. Energy efficiency and sustainability are two of the primary motivators for the UAE construction and engineering industry, yet both are negatively affected by project delays. This research provides a quantitative analysis of project delays based on three comprehensive real-world case studies of MEP and energy retrofit projects executed by an engineering organisation in the UAE. A retrospective delay analysis of As-Built vs As-Planned schedules was applied to quantify delays, identify and categorise primary and secondary causes, and measure their time impact and critical contributions. Supporting tools such as Root Cause Analysis, Gantt Charts, Risk Assessment and Mitigation Strategies were employed. The findings highlight client-related delays as the major contributors, followed by insufficiencies in internal processes, procurement and supply chain management. This dissertation offers valuable insights into proactive delay management and proposes actionable strategies tailored to the unique characteristics of MEP and energy projects executed within an operational shopping mall facility in Sharjah, where numerous external and internal factors critically influence project performance. The study also outlines future recommendations and research limitations to enhance adaptability to evolving project and market requirements in the UAE.

Keywords: project management, engineering project delay, delay analysis, mitigation strategies, root cause analysis, risk management, MEP projects, energy projects, energy retrofit projects, UAE

الخلاصة

تُشكل البيئات التشغيلية المعقدة، وضيق الجداول الزمنية، وتسريع وتيرة انجاز المشاريع، وارتفاع متطلبات أصحاب المصلحة المتعددين (سواء داخل المؤسسة أو خارجها) تحديات كبيرة في قطاع الهندسة، لا سيما في مجالات الميكانيكا والكهرباء والسباكة (MEP) ومشاريع إعادة تأهيل الطاقة في دولة الإمارات العربية المتحدة. وغالباً ما تؤدي هذه التحديات الى تأخيرات في تنفيذ المشاريع، مما ينتج عنه زيادة في ميزانيات المشاريع واستياء أصحاب المصلحة أو العملاء. تُعد كفاءة الطاقة والاستدامة من أبرز المحفزات الأساسية في قطاعي الإنشاءات والهندسة في دولة الإمارات، إلا أن كليهما يتأثر سلباً بسبب تأخيرات المشاريع. يقدم هذا البحث تحليلاً كمياً لتأخيرات المشاريع استناداً الى ثلاث دراسات شاملة لمشاريع واقعية نفذت من قبل إحدى المؤسسات الهندسية في دولة الإمارات. وقد تم استخدام تحليل التأخير الاسترجاعي للمقارنة بين الجداول الزمنية "كما بنيت" و "كما خطط لها" (مقارنة بين المخطط والمنفذ) من أجل قياس التأخيرات، وتحديد وتصنيف الأسباب الأولية والثانوية لها، وقياس أثرها الزمني ومساهمتها في المسار الحرج. كما تم استخدام أدوات داعمة مثل تحليل الاسباب الجذرية، ومخططات غانت، وتقييم المخاطر، ووضع إستراتيجيات التخفيف. وقد أبرزت النتائج أن التأخيرات المرتبطة بالعمل كانت المساهم الرئيسي في التأخيرات، تليها أوجه القصور في العمليات الداخلية والنقص في كفاءة المشتريات وسلسلة التوريد. وتأخيرات تمثل الأسباب الكبرى للتأخيرات. تقدم هذه الرسالة رؤى قيمة لإدارة التأخيرات بشكل استباقي، وتقتراح استراتيجيات عملية قابلة للتطبيق ومصممة خصيصاً لتناسب الخصائص الفريدة لطبيعة مشاريع (MEP) ومشاريع الطاقة التي نفذت في مركز تجاري وتشغيلي في اماره الشارقة، حيث تؤثر العديد من العوامل الداخلية والخارجية بشكل حاسم علأ أداء المشروع. كما تسلط الدراسة الضوء على التوصيات المستقبلية وتحديد حدود الدراسة بهدف تعزيز القدرة على التكيف مع متطلبات المشاريع واحتياجات السوق في دولة الإمارات العربية المتحدة.

الكلمات المفتاحية: إدارة المشاريع، تأخير المشاريع الهندسية، تحليل التأخيرات، استراتيجيات لتخفيف وإدارة المخاطر، تحليل الأسباب الجذرية، إدارة المخاطر، مشاريع الميكانيكا والكهرباء والسباكة، مشاريع الطاقة، مشاريع إعادة تأهيل الطاقة، الإمارات العربية المتحدة.

Acknowledgements

بسم الله الرحمن الرحيم

In the name of Allah, the Most Gracious, the Most Merciful, all praise and gratitude belong to Allah Almighty, for granting me strength, clarity and resilience needed to overcome every challenge of life's journey, academic and career journey. Without his mercy and guidance, none of this would have been possible.

I am eternally indebted to my beloved mother Mrs Zahra Mohammed (My One & Only), whose unconditional love, unwavering support and endless prayers are the foundations of every success I have achieved. Your sacrifices, love and guidance shaped me into the person I am today.

My heartfelt gratitude extends to my brothers: Eng. Abdulrahman Al Azzawi, Eng. Abdulaziz Al Azzawi, Dr Mustafa Al Azzawi and the Only World Champion Mr Salim Al Azzawi. Your constant encouragement, support and prayers have been my source of strength. Thank you for believing in me, lifting me up in moments of doubt, and for sharing your love and joy. To my beloved and cherished sister Dr Huda Al Azzawi, your kindness, affection and radiant smile have been a true blessing to me.

To Professor Alaa A-Ameer, your mentorship, insightful feedback and encouragement have been instrumental in shaping this research and my academic development. Thank You from the bottom of my heart. My sincere gratitude and appreciation to my academic mentors: Professor Alaa A-Ameer and Dr Sa'Ed M. Salhie, for their invaluable guidance, mentorship, constant support and profound knowledge greatly enriched my academic experience.

To my wonderful friends who have been the pillars of support throughout life: Eng. Abdulrahman, Lawyer Mr Yasser Haidary, Mr Marwan Al Hashimi, Mr Soud Al Mahiri, Mrs

Aalya Lala. Thank you for your friendship, and the countless memorable moments we have shared.

Finally, to my future wife Inshallah. Your understanding and support have made life's journey meaningful. I am looking forward to sharing with you the joy of our life's accomplishment, and building a future filled with love, faith and purpose. Alhamdulillah For Everything.

Table of Contents

Chapter 1: Introduction.....	1
1.1 Research Overview	1
1.2 Problem Statement of the Research.....	3
1.3 Aim of the Research	3
1.4 Research Objectives	3
1.5 Research Questions	4
1.6 Dissertation Structure	4
Chapter 2: Literature Review	6
2.1 Project Definition	6
2.1.1 Project Characteristics	7
2.1.2 Project Life Cycle and Phases	7
2.1.3 Project Phases Characteristics	10
2.1.4 Project Life Cycle Characteristics	10
2.2 The Triple Constraints Theory of Project.....	11
2.3 Project Management.....	13
2.3.1 The Twelve Project Management Principles	14
2.4 Understanding Project Delay	17
2.5 Methodologies and Techniques of Project Delay Analysis.....	17
2.5.1 Retrospective Delay Analysis Techniques	18
2.5.2 Prospective Delay Analysis Techniques.....	21
2.5.3 Considerations and Limitations of Delay Methodologies	23
2.6 Project Delay Barriers	23

2.6.1 Sociotechnical Barriers	24
2.6.2 Managerial and Organisational Barriers	24
2.6.3 Economical and Financial Barriers	25
2.6.4 Policy and Regulatory Barriers	26
Chapter 3: Research Methodology	27
3.1 Introduction to Research Methodology	27
3.1.1 Qualitative Method	28
3.1.2 Quantitative Method	28
3.1.3 Mixed Method	28
3.2 The Importance of Collected Data	29
3.2.1 Research Analysing Steps	31
3.2.2 Summary of Delay Analysis Process.....	33
Chapter 4: Research Analysis: Results & Discussion	37
4.1 Project No. 1 Discription	37
4.1.1 Project No. 1 Scope of Work.....	37
4.1.2 The Importance of Project No. 1	38
4.2 Project No. 1 Analysis.....	39
4.2.1 Work Breakdown Structure Summary.....	39
4.2.2 Gantt Chart Analysis	41
4.2.3 Critical Path Analysis	43
4.2.4 Critical Task Delay Contribution.....	45
4.2.5 Analysis of Delay Contribution to the Initial Planned Duration	47
4.2.6 Comparison of Phase Delays in Project No. 1	52

4.2.7 Analysis of Root Causes of Delays	53
4.2.8 Risk Assessment and Mitigation Strategies.....	55
4.3 Project No. 2 Discription	56
4.3.1 Project No. 2 Scope of Work.....	56
4.4 Analysis of Project No. 2.....	57
4.4.1 Work Breakdown Structure Summary of Project No. 2	58
4.4.2 Gantt Chart Analysis	59
4.4.3 Critical Path Analysis of Project No. 2.....	61
63	
4.4.4 Critical Task Delay Contribution of Project No. 2	64
4.4.5 Analysis of Delay Contribution to the Initial Planned Duration of Project No.2	
66	
4.4.6 Comparison of Phase Delays in Project No. 2.....	71
4.4.7 Analysis of Root Causes of Delays	72
4.4.8 Risk Assessment and Mitigation Strategies of Project No. 2	74
4.5 Project No. 3 Discription	75
4.5.1 Project No. 3 Scope of Work.....	75
4.6 Project No. 3 Analysis.....	76
4.6.1 Work Breakdown Structure Summary of Project No. 3:.....	77
4.6.2 Gantt Chart Analysis	78
4.6.3 Critical Path Analysis of Project No. 3.....	80
4.6.4 Critical Task Delay Contribution of Project No. 3	83

4.6.5 Analysis of Delay Contribution to the Initial Planned Duration of Project No. 3

85

4.6.6 Comparison of Phase Delays of Project No. 3: 89

4.6.7 Analysis of Root Causes of Delays 90

4.6.8 Risk Assessment and Mitigation Strategies of Project No. 3 92

Chapter 5: Research Conclusion, Recommendations and Limitations..... 93

5.1 Research Conclusion 93

5.1.1 Task Delays in MEP/Energy Projects..... 93

5.1.2 Delay Categories of MEP/Energy Projects..... 98

5.1.3 Summary of Research Conclusion..... 100

5.2 Research Limitation..... 103

5.3 Research Recommendation 105

References 107

Appendices 114

List of Tables

Table 1 The 12 Principles of Project Management	15
Table 2. Review on Selected Projects	31
Table 3. MEP Project Phases and Tasks	32
Table 4. TAPD vs TABD of Project No. 1	42
Table 5. TAPD vs TABD of Project No. 1	43
Table 6. Critical Path of Project No. 1 – BTU Metres Fifth Loop Rectification.	43
Table 7. Project No. 1 Delay Reasons and Delay Contribution to Initial Planned Duration ...	49
Table 8. Delays by Category – Project No. 1	50
Table 9 Risk Assessment and Mitigation Strategies of Project No. 1.....	55
Table 10. Unofficially Requested Pauses of Project No. 2	61
Table 11. Critical Path of Project No. 2 – BTU Metres Sixth Loop Rectification	62
Table 12. Project No. 2 Delay Reasons and Delay Contribution to Initial Planned Duration ..	67
Table 13. Delays by Category – Project No. 2.....	68
Table 14. Risk Assessment and Mitigation Strategies of Project No. 2.....	74
Table 15. Unofficially Requested Pauses of Project No. 3	80
Table 16. Critical Path of Project No. 3 – BTU Metres Seventh Loop Rectification	81
Table 17. Project No. 3 – Reasons for Delay and Delay Contribution to the Initial Planned Duration.....	86
Table 18. Delays by Category – Project No. 3.....	87
Table 19. Project No. 3 Risk Assessment and Mitigation Strategies.....	92
Table 20. Analysis of Project No. 1 or Case Study No. 1	114

Table 21. Category Task Contribution Delay % of Project No. 1	116
Table 22. Critical Task Delay Contribution of Project No. 1	117
Table 23. Analysis of Project No. 2 or Case Study No. 2	118
Table 24. Pauses or Holds Discription of Project No. 2	120
Table 25. Critical Task Delay Contribution of Project No. 2	121
Table 26. Category Task Contribution Delay % of Project No. 2	121
Table 27. Analysis of Project No. 3 or Case Study No. 3	123
Table 28. Pauses or Holds Discription of Project No. 3	125
Table 29. Category Task Contribution Delay % of Project No. 3	126
Table 30. Critical Task Delay Contribution of Project No. 3	127
Table 31. Overall Delay of Energy/MEP Projects	128
Table 32. Compiled 3 Project Cases Delay Analysis	129
Table 33 Level of Risks and Likelihood of Occurrence as Per Existing QHSE Department of an Engineering Organisation	131

List of Figures

Figure 1. Forecast of Construction and Infrastructure Industry Data (United Arab Emirates 2023–2033).....	2
Figure 2. Sample Predictive Life Cycle	9
Figure 3 Sample Life Cycle with an Incremental Development Approach	9
Figure 4 Triple Constraints of Project Management	11
Figure 5 The Relationship between Project Management Principles and Project Performance Domains	14
Figure 6 Delay Analysis Technique	18
Figure 7 Analysis of As-Planned vs As-Built	20
Figure 8 Gantt Chart of ‘As-Built’ of Project No. 1	41
Figure 9 Critical Path of Project No. 1	44
Figure 10 Critical Task Delay Contribution of Project No. 1	45
Figure 11 Task Delay Comparison to TAPD of Project No.1	48
Figure 12 Project No. 1 Phase Delay Comparison to TAPD	52
Figure 13 Ishikawa Diagram of Project No. 1	54
Figure 14 Gantt Chart of Project No. 2	59
Figure 15. Critical Path of Project No. 2.....	63
Figure 16 Critical Task Delay Contribution of Project No. 2	64
Figure 17 Task Delay Comparison to TAPD of Project No. 2	66
Figure 18 Phase Delay Comparison to Task As-Planned Duration of Project No. 2.....	71
Figure 19 Ishikawa Diagram of Project No. 2	73

Figure 20 Gantt Chart of Project No. 3	78
Figure 21 Critical Path of Project No. 3	83
Figure 22 Critical Task Delay Contribution of Project No. 3	83
Figure 23 Project No. 3 Task Delay Comparison to Task As-Planned Duration.....	85
Figure 24 Project No. 3 Phase Delay Comparison to TAPD	89
Figure 25 Ishikawa Diagram of Project No. 3	91
Figure 26 Task Delay Comparison to Task As-Planned Duration for Three MEP/Energy Projects	94
Figure 27 Pareto Chart: Task Delays in MEP/Energy Projects	97
Figure 28 Delay Categories of Energy/MEP Projects.....	98
Figure 29 Overall Delay Percentage of Energy/MEP Projects	102

List of Abbreviations

BACnet MS/TP: (Master-Slave/Token-Passing) it is an advanced communication protocol.

BMS: Building Management System

BTU: British Thermal Unit

CAPEX: Capital Expenditure

CPM: Critical Path Method

DLP: Defect and Liability Period

DODI: Department of Defence Instruction

EVM: Earned Value Management

GDP: Gross Domestic Product

HVAC: Heating, Ventilation and Air Conditioning

ID: Identification

IDF: Intermediate Distribution Frame

IP: Internet Protocol

IT: Information Technology

LEED: Leadership in Energy and Environmental Design

LOI: Letter of Intent

MEP: Mechanical, Electrical, Plumbing

MS: Microsoft

NZE: Net Zero Energy Buildings

PABD: Project As-Built Duration

PAPD: Project As-Planned Duration

PMBOK®: The Standard for Project Management and A Guide to The Project Management

Body of Knowledge

PMI: Project Management Institute

PO: Purchase Order

PV: Photovoltaic

QHSE: Quality, Health, Safety and Environment

RCA: Root Cause Analysis

SOW: Scope of Work

TABD: Task As-Built Duration

TAPD: Task As-Blanned Duration

TOD: Task Overall Delay

TWADC: Task Weighted Average Delay Contribution

UAE: United Arab Emirates

US: United States

VLAN: Virtual Local Area Network

WBS: Work Breakdown Structure

Chapter 1: Introduction

1.1 Research Overview

Engineering projects, particularly projects involving mechanical, electrical and plumbing systems and energy-related retrofit works, often face complex implementation environments (e.g. shopping and retail malls, and operational facilities and buildings), tight project delivery deadlines and high demands from multiple stakeholders (the direct client or customer, and the tenant as the indirect client). These factors frequently lead to project delays. Globally, buildings contribute significantly to greenhouse gas emissions and global warming. They are responsible for one-third (1/3) of total global energy consumption (Cabeza, 2022).

Optimisation of energy performance and the reduction of energy consumption in existing buildings and facilities has become a critical goal, with global strategies gaining considerable attention as Net Zero Energy Buildings (NZEBs), and locally in line with the energy, infrastructure and construction forecasted growth in the UAE (BMI, 2024; Altalaa, 2017).

Based on the forecast from 2023 to 2033 by the UAE Federal Competitive & Statistic Authority (BMI) (see Figure 1), the construction industry is expected to expand from 140.2AED billion to 165.2AED billion, that is about 17.83% growth over a 10-year period (BMI, 2024).

This rise is expected even though growth rates have gradually slowed down, averaging 1.8% annually. In July 2023, the UAE released a revised Energy Strategy, announcing plans to increase investment in the energy sector by 150AED billion to 200AED billion by 2030, some of which will be directed towards increasing renewables production to 14 GW by 2030.

Low-carbon infrastructure and construction sectors, such as renewable energy, green steel and hydrogen, are likely to be bright areas for investment in the upcoming decades given the UAE government's decarbonisation agenda and the rising importance of environmental, social and corporate governance globally (BMI, 2024).

Figure 1

Forecast of Construction and Infrastructure Industry Data (United Arab Emirates 2023–2033)

Construction And Infrastructure Industry Data (United Arab Emirates 2023-2033)

Indicator	2023e	2024f	2025f	2026f	2027f	2028f	2029f	2030f	2031f	2032f	2033f
Construction industry value, AEDbn	140.2	143.3	144.7	149.5	151.8	154.2	156.5	158.8	161.3	163.3	165.2
Construction industry value, real growth, % y-o-y	2.6	2.4	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2
Construction industry value, % of GDP	8.2	8.0	7.7	7.6	7.4	7.2	7.0	6.8	6.6	6.4	6.2

e/f = BMI estimate/forecast. Source: UAE Federal Competitiveness And Statistics Authority, BMI

Note. (BMI, 2024).

Such growth in the construction industry will result in more opportunities and risks in current, and future construction projects. Project delivery delays continue to remain a critical challenge globally, as infrastructure and building performance keep on developing and improving globally. Delays in project delivery affect project costs (cost overruns), stakeholder satisfaction (stakeholders within the same organisation, and clients or customers to whom the project is being delivered) and the overall project outcomes (Osei-Asibey, 2025; Durdyev, 2020).

1.2 Problem Statement of the Research

While previous research has explored delays mostly in the construction sector in general and in PV Solar construction, there is insufficient analysis of delays and mitigation strategies tailored specifically for MEP, and energy retrofit projects in retail malls in the UAE. These projects are unique due to their need for integrating advanced technology into existing old systems, increased reliance on HVAC systems and the push for energy optimisation through monitoring and control systems.

1.3 Aim of the Research

The aim of this research is to conduct a quantitative analysis of retrospective delay analysis and propose mitigation strategies to reduce the impact of delays on engineering projects, with a focus on MEP and energy retrofit projects in shopping malls in the UAE.

1.4 Research Objectives

The main objectives of this research paper are:

1. Identify and analyse the main causes and factors contributing to delays, using retrospective delay analysis methodologies, specifically in MEP and energy retrofit projects (operational retail mall).
2. Quantify the impacts of identified delays on project overall timeline performance.
3. Propose comprehensive and tailored delay mitigation strategies for engineering projects in general, and specifically for energy and MEP projects.

4. Identify the limitations of this research and analysis, then propose recommendations for future studies and the enhancement of project management practices in similar engineering organisations.

1.5 Research Questions

This research paper answers the following main questions in order to achieve the research objectives:

1. What are the main factors contributing to delays, particularly in MEP and energy retrofit projects?
2. What is the impact of identified delays on overall project timeline performance?
3. What mitigation strategies are effective for these project types?
4. What lessons can be learned from real-life cases to prevent future recurrence?

1.6 Dissertation Structure

This research paper has five chapters:

1. **Chapter One:** introduces the research, including the objectives, research questions and research problem statement.
2. **Chapter Two:** reviews and represents the available literature on project definition and project characteristics, the triple constraints of project, project delay and delay barriers.
3. **Chapter Three:** explains the research methodologies and analysis steps used in this research. Also provides an overview of the data collected and their importance.

4. **Chapter Four:** presents a detailed research analysis and discussion on each of three real-life projects, including Work Breakdown Structure (WBS), Gantt Chart Analysis, Critical Path Analysis, Root Cause Analysis of Delays, Risk Assessment and Mitigation Strategies of each delay.
5. **Chapter Five:** concludes the research, highlighting how delays impact MEP and energy projects. Also outlines the limitations of this study, and provides recommendations for future research and improvements in project management practices in similar project types and in engineering organisations.

Chapter 2: Literature Review

2.1 Project Definition

The concept of a 'project' has been extensively debated and defined by scholars and professional organisations (e.g., Project Management Institute). Although the term might seem a simple and straightforward definition, it comprises a complex set of characteristics that differentiate it from other organisational activities such as operations. Organisations generally carry out work; this work consists of either projects or operations. Even though operations and projects may overlap, they share certain characteristics:

1. Projects and operations are planned, controlled and executed.
2. Projects and operations are executed by people.
3. Projects and operations are constrained by resources.

However, operations differ by continuity and repetitive characteristics, while projects differ by being unique and temporary. The Project Management Institute (PMI) has provided one of the most widely accepted definitions of a project: 'A temporary endeavour undertaken to create a unique product, service, or result. The temporary nature of projects indicates a beginning and an end to the project work or a phase of the project work. Projects can stand alone or be part of a program or portfolio' (Project Management Institute, 2021). Every project (even megaprojects) is unique and has uncertainty that results usually in risks and challenges. Examples of projects that involve different activities, produce value and are undertaken by different organisations include (Project Management Institute, 2021):

1. Creating brand-new services or products.

2. Launching a political campaign.
3. Creating or acquiring a modified information system.
4. Putting a new business process or method into place.

Projects originate from requirements and demands across governmental sectors, public sectors and private sectors. For example, a new medicine or drug to be launched, or deployment of high-efficiency solar PV for a sustainable community (e.g., Sharjah Sustainable City, Masdar City in Abu Dhabi) are real-life projects.

2.1.1 Project Characteristics

Projects are unique because they entail accomplishing something that has never been done before, and they have some degree of uncertainty, thus necessitating tailored approaches for each project. Below are several project classifications (Blak Bernat, 2023):

1. Maintenance projects: ongoing projects that provide routine maintenance services.
2. Enhancement/Growth projects: projects necessary for a business to maintain its competitive edge, promote strategic initiative, with expectation of value growth.
3. Transformation projects: projects that provide a unique opportunity to take a business to the next level or dominate the market.

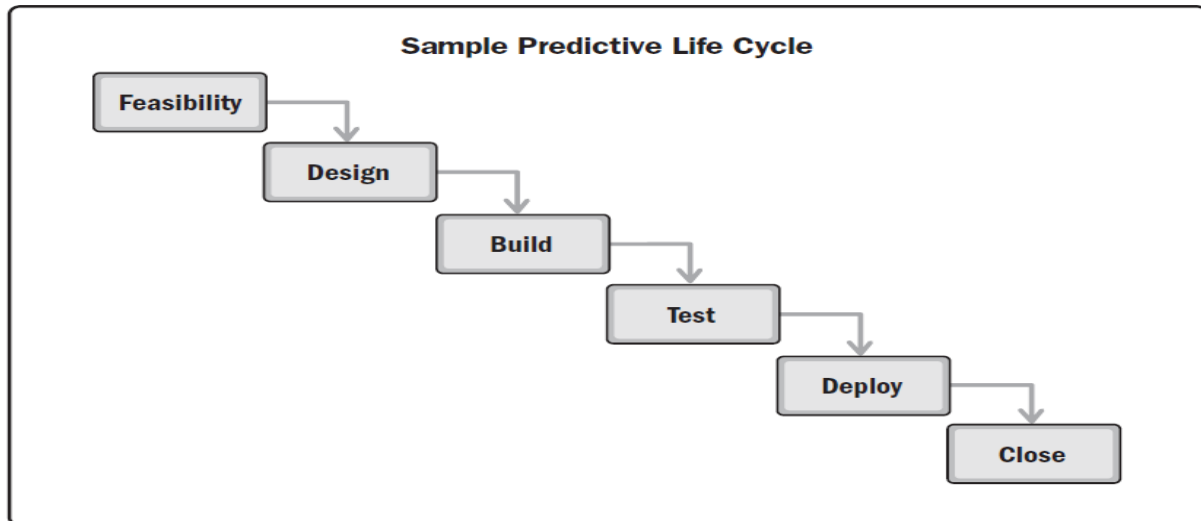
2.1.2 Project Life Cycle and Phases

Projects are unique and involve uncertainty. Typically, organisations divide each project into several phases to achieve better managerial control and to establish a connection between the project and the organisation's current operations. The project life cycle is the collective

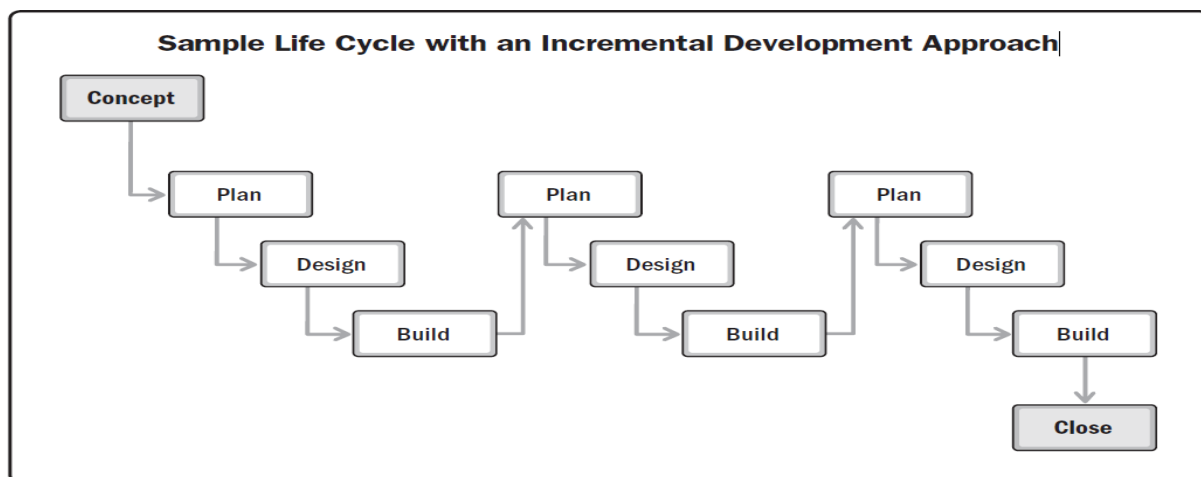
term for a project's phases. Phases of the project may overlap; this is often called fast-tracking or concurrent engineering.

Before moving on to the next phase of a project, there is usually a phase-gate review (also known as a stage gate) to ensure that the targeted results or exit criteria for the phase have been met. Exit criteria may relate to acceptance requirements for deliverables, contractual responsibilities, the fulfilment of particular performance objectives or other tangible metrics. Project Management Institute (PMI) provides two examples with different project life cycles depending on the project's requirements and deliverables (Project Management Institute, 2021).

2.1.2.2 First Example of Sample Predictive Life Cycle. Figure 2 represents a life cycle in which one phase doesn't start until the previous phase has ended. This type of life cycle is ideal for predictive development, as each phase focuses on a certain scope of work and is performed only once. Nevertheless, some scenarios might force phases to be repeated, such as an extended scope, a change in requirements or a change in the market, as stated in Figure 2.

Figure 2*Sample Predictive Life Cycle**Note.* (Project Management Institute, 2021)**2.1.2.2 Second Example of Sample Life Cycle with an Incremental**

Development Approach. The Project Management Institute also provides an example of a life cycle with an incremental development approach, as shown in Figure 3.

Figure 3*Sample Life Cycle with an Incremental Development Approach**Note.* (Project Management Institute, 2021)

2.1.3 Project Phases Characteristics

At the end of each project phase, one or more tangible and verifiable deliverables, along with up-to-date project performance, are typically reviewed. This review or evaluation (called phase gates or kill points) allows the organisation to:

1. Decide whether the project should move on to the next phase.
2. Identify problems and resolve them with cost-effective solutions.

2.1.4 Project Life Cycle Characteristics

The PMBOK® Guide, Seventh Edition, discusses the concept of project life cycles as follows: ‘The series of phases that a project passes through from its start to its completion’ (Project Management Institute, 2021).

Project phases can be sequential (one after another), iterative (repeated) or overlapping. The project life cycle provides a basic framework for managing the project from beginning to end.

For example, an organisation sees an opportunity and wishes to respond. It will start by assessing this opportunity via a feasibility study to determine and decide whether the organisation should pursue the project or not. The unique life cycle of this project (turned from an opportunity) will define whether the feasibility study should be considered as the initial project phase, meaning that this solely depends on the project’s characteristics and the organisation’s structure.

Each phase in the project life cycle involves specific deliverables, technical work and resource requirements. At the end of each phase, a formal review (phase gates, stage gates, decision points, milestone reviews) takes place to evaluate:

1. The deliverables completed during the phase.
2. The Project's performance against its objectives (scope, schedule, cost, quality, etc.).
3. Whether the project should change direction, be terminated or continue.

In general, the project life cycle defines:

1. The technical work required in each phase.
2. The resources required in each phase.

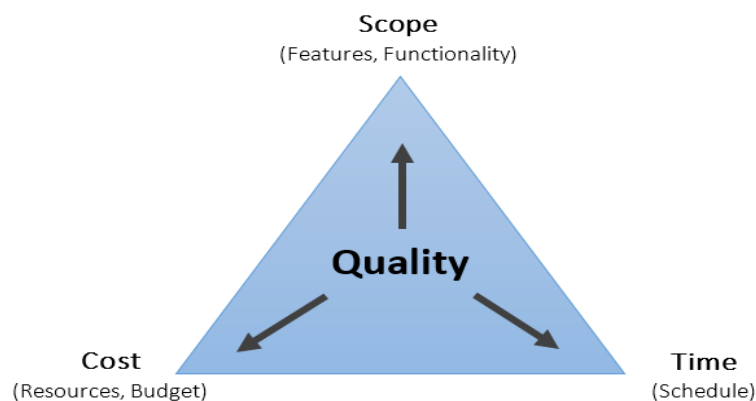
2.2 The Triple Constraints Theory of Project

Chaowarat Watanabe (2024) explains the Triple Constraint Theory (project cost, project time, project quality) as a function and the interrelation between these variables and their influence on a project's outcome; if one variable changes, the others are affected.

Organisational support is acknowledged to positively impact the project triple constraints (cost, time, quality) and the project success. The classical Triple Constraint Theory is shown in Figure 4 below.

Figure 4

Triple Constraints of Project Management



Note. (Harpreet Dhillon, 2018)

Understanding and managing the triple constraints (time, scope, cost) is critical to project success, since each variable has a significant impact on achieving overall project performance (PMI Phoenix Chapter, 2025).

A project's financial basis is built on cost, which includes labour, materials, equipment and contingency planning. Thus, effective cost management maintains commitment to a project's budget and avoids cost overruns, which can compromise project objectives and stakeholders' trust (PMI Phoenix Chapter, 2025).

The scope of a project establishes its deliverables, objectives and boundaries, and guides the project team while aligning with stakeholder expectations. Given scope's dynamic nature, comprehensive change management processes are necessary to analyse and assess potential impacts on both cost and time (PMI Phoenix Chapter, 2025).

Time determines the project deadline and specifies the deadlines for tasks, milestones and deliverables. To achieve project deadlines, effective time management involves prioritising, scheduling and planning tasks (PMI Phoenix Chapter, 2025).

The Triple Constraints Theory (cost, time, scope) highlights that if one element changes, it will impact the others. Scope creep can lead to increased costs and an extended timeline, whereas reducing the project's budget may reduce scope or extend deadlines. Effectively managing this equilibrium demands clear objectives, continuous communication and informed decision-making to ensure the project's compliance with its goals and stakeholder expectations (PMI Phoenix Chapter, 2025). The next chapter will explain project management and project delays.

2.3 Project Management

The Project Management Institute defines project management as the practice of applying knowledge, skills, tools and techniques to project activities in order to achieve project requirements (Project Management Institute, 2021). Many project-management processes (many of these processes are iterative in nature) for projects that use a process-based approach may employ the following five process categories as an organisational structure:

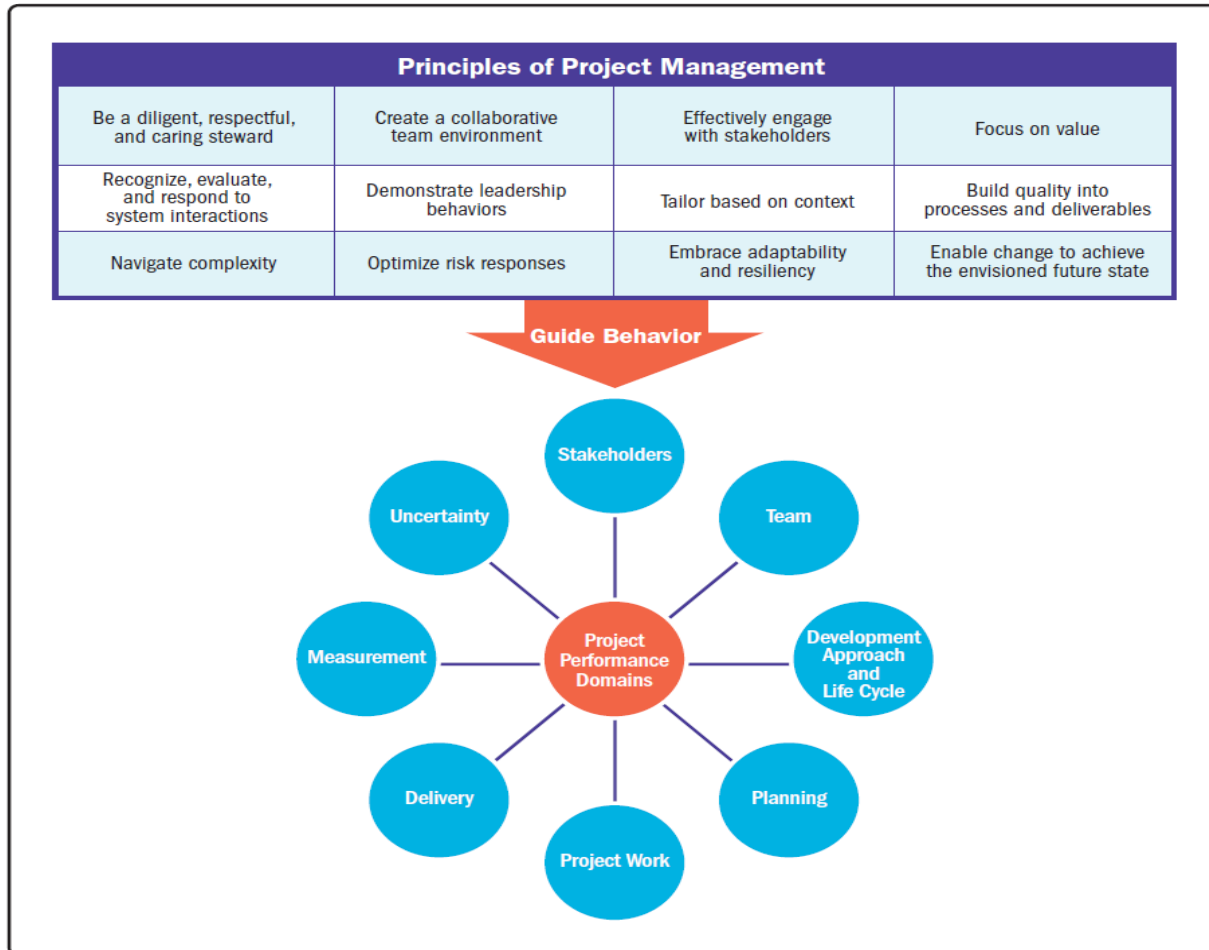
1. Initiation process: defining a new project or phase and receiving authority to begin.
2. Planning process: defining the project scope, objectives and the course of action to achieve its goals.
3. Executing process: completing the tasks described in the project management plan to meet the project requirements.
4. Controlling process: tracking, reviewing and regulating project progress, identifying areas for change and initiating the necessary changes.
5. Closing process: the formal completion of a project, phase or contract.

The standard for project management serves as a foundation for understanding project management and how it achieves desired results. This standard is applicable regardless of industry, location, size or delivery approach (predictive, hybrid or adaptive). It explains the system or framework within which the project operates, including project environment, regulations or governance, potential activities and the link between project management and product management (Project Management Institute, 2021).

Figure 5 explains the relationship between project management principles and project performance domains (Project Management Institute, 2021).

Figure 5

The Relationship between Project Management Principles and Project Performance Domains



Note. (Project Management Institute, 2021)

2.3.1 The Twelve Project Management Principles

The PMBOK® Guide Seventh Edition, published by PMI, represents a significant evolution in project management standards by focusing on outcomes and value rather than perspective processes. It acknowledges the dynamic nature of modern projects and the necessity of flexible approaches including hybrid approach, predictive approach and adaptive approach. It introduces twelve (12) project-management principles, shown in Table 1, that serve as a foundational guideline for effective decision-making and behaviour.

Complementing these twelve principles are eight critical aspects of project performance domains (Stakeholders, Team, Life Cycle, Planning, Project Work, Delivery, Performance Measurement and Uncertainty) (Project Management Institute, 2021).

Table 1

The 12 Principles of Project Management

No.	Principle Name	Description	Purpose or Focus Area	Application Example
1	Stewardship	Be a diligent, respectful and caring steward.	Ethical leadership and responsibility	Acting transparently and considering sustainability.
2	Team	Create a collaborative project team environment.	Empowering and supporting collaborative teams	Encourage open communication within project teams.
3	Stakeholders	Engage stakeholders to understand their interests and needs.	Stakeholder engagement and alignment	Regular feedback sessions with users and clients.
4	Value	Focus on value creation throughout the project.	Delivering outcomes that provide business value	Measure success through customer satisfaction.
5	Systems Thinking	Recognise, evaluate and respond to system interactions.	Understanding the broader organisational context	Aligning project goals with enterprise strategy.

6	Leadership	Demonstrate leadership behaviours to achieve project objectives.	Influencing and guiding teams effectively	Adapting leadership style to team maturity level.
7	Tailoring	Tailor project approach and methods to context.	Adaptive planning and execution	Choosing hybrid methodologies for complex projects.
8	Quality	Build quality into processes and deliverables.	Ensuring fitness for purpose	Include QA checkpoints in every project phase.
9	Complexity	Address complexity using knowledge, experience and learning.	Complexity assessment and mitigation	Breaking down a large project into manageable parts.
10	Risk	Optimise responses to project risks.	Proactive risk management	Maintaining a risk register and response plan.
11	Adaptability and Resilience	Adapt to change and recover from setbacks.	Change management and resilience	Quickly adjusting plans during a market shift.
12	Change	Enable change to achieve the envisioned future state.	Leading organisational and team-level change	Supporting teams through process or scope changes.

Note. (The PMBOK guide® – Seventh Edition Summary, 2021; Project Management Institute, 2021)

2.4 Understanding Project Delay

The cost of delay is what an organisation loses in terms of money, opportunity, risk, customers' respect and satisfaction. Reinertsen (2009) stated: 'If you only quantify one thing, quantify the cost of delay.'

Project completion on time is a sign of efficiency and a good performance (although this depends on deliverables and context). In the construction industry, Amoah (2024) defines delay as exceeding the contractually agreed project completion or delivery timeline. Delay means the project is running behind the planned schedule and is most commonly observed in construction projects. For owners, delay means loss of revenue. For contractors, delay results in overhead (indirect) costs, higher labour and staff expenses and increased material (direct) cost. Moreover, Anil Cherian (2020) notes that: 'Construction delays have an adverse impact on project success in terms of time, cost, quality, and safety. The effects of construction delays, however, are not confined to construction companies but can influence the overall economy of a country like the United Arab Emirates, where construction plays a major role in its development and contributes a major share to the GDP. So, it is crucial to identify the main causes and effects of delay of construction projects in the UAE to control economic stability.'

2.5 Methodologies and Techniques of Project Delay Analysis

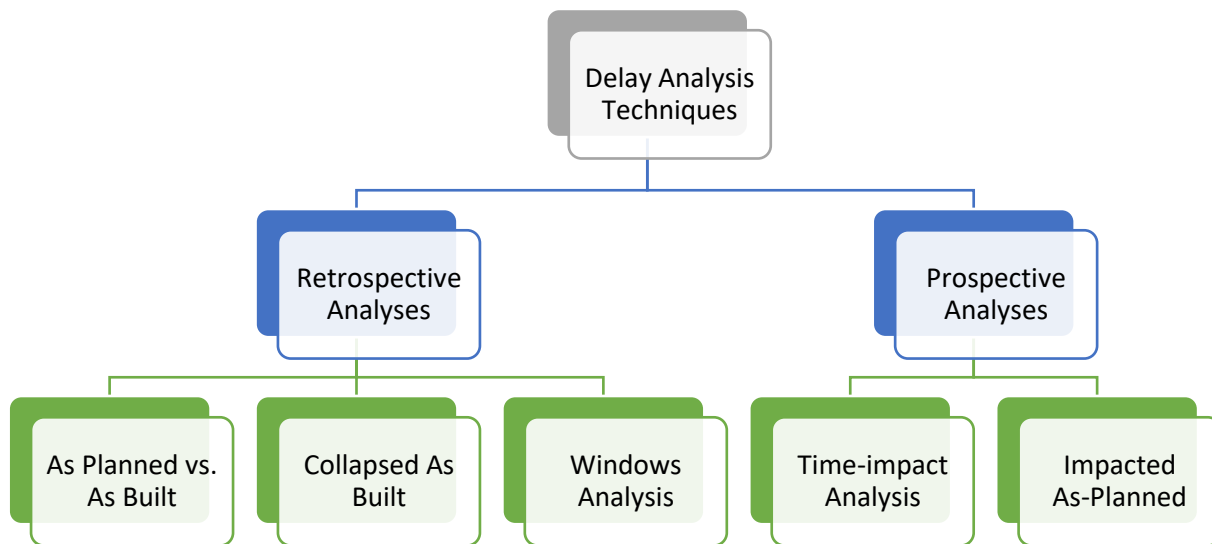
Delays in engineering projects, particularly in construction, MEP and energy sectors, significantly impact project feasibility, stakeholder satisfaction and cost reduction. Assessment and analysis of delays are critical to maintain performance against timeline or schedule, avoid contractual disputes and satisfy customers.

Construction project delay is defined as exceeding the contractually agreed project completion timeline. It can refer to failure to hand over a specific task meant to be completed within a certain timeframe due to unforeseen circumstances or events (Al-Khalidi, 2022; Durdyev, 2020).

Many delay-analysis methodologies have been developed over the years. Their aim is to estimate the impact of any delay occurring during the project timeline. The most common methodologies are divided into prospective and retrospective methods as shown in Figure 6.

Figure 6

Delay Analysis Technique



Note. (Al-Khalidi, 2022; International AACE, 2011)

2.5.1 Retrospective Delay Analysis Techniques

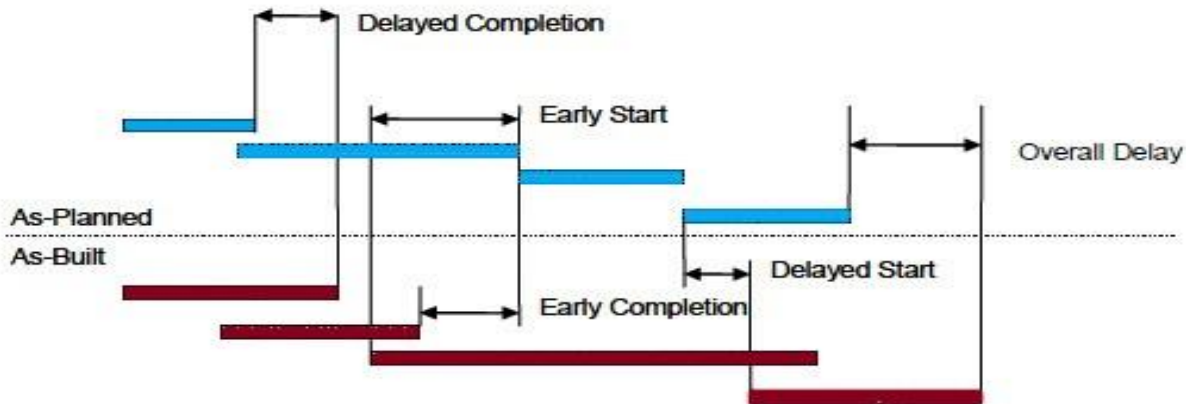
Also called forensic delay analysis, this approach is to assess and evaluate delays once projects are completed and handed over, or once delay events have already occurred. These methods are based on historical data (project data) to determine the following:

1. What caused the delay?
2. When did the delay happen?
3. Who is accountable or responsible for the delay?

The technique typically uses the critical path method (CPM) and requires access to baseline schedules, as-built records, daily reports, scope-change documentation and correspondence. The main objectives are to establish liability, quantify delays and assist in claims or disputes settlements. Key retrospective methods used in project delays are covered in the following sections.

2.5.1.1 As-Planned vs As-Built Analysis. A simple comparison between the first initial phase of what was planned and of what really occurred in the project life cycle. As-planned can be measured using either the initial original plan or the most recent approved plan (revised timeline).

To find delays, this technique compares the activities/tasks of the as-built schedule (or revised schedule) with the baseline or called as-planned schedule (see Figure 7). This approach illustrates numerous delaying events or activities that occur in the project's as-built timeline.

Figure 7*Analysis of As-Planned vs As-Built*

Note. (Al-Khalidi, 2022; Sargent, 2020)

The simplicity of the as-planned vs as-built analysis is complemented by its minimal resource needs. Because the procedure is less demanding than other methods, the time necessary to produce the analysis is usually less than that of other complex analyses.

One weakness of this approach is that it is not ideal for detecting causation (delay cause) when a project is complicated, involves extended durations or is created in a way that considerably deviates from the planned sequence (Sargent, 2020).

Even though this technique is widely adopted due to its simplicity, it lacks the capacity to differentiate between the impact of concurrent delays and non-critical delays, and it doesn't capture dynamic schedule changes (Ghimire, 2019).

2.5.1.2 Collapsed *As-Built Methodology*. The technique also known as 'but-for' analysis, this retrospective tool begins with an as-built timetable, then gradually removes the activities that caused delays or modifies activities that would affect the completion date. It is used to evaluate how particular delays affect the project completion timeline (Al-Khalidi, 2022).

The tool is frequently used when information on the as-built timetable is available. This approach or technique can be used when the baseline schedule is unavailable or unreliable. To show how the project would have developed in the absence of certain delays, this method adjusts the actual as-built schedule by eliminating activities that reflect delays attributed to a single party, then assesses how the project would have completed without these delays (Al-Khalidi, 2022).

2.5.1.3 Window Analysis. This technique is considered part of the forensic delay analysis and divides the project into segments (windows), assessing the schedule impacts within each segment. It also captures changes or updates in project schedules, including critical-path changes, resulting in more dynamic and robust comparisons rather than simple ones. Weaknesses include being time-consuming, and strongly dependent on accurate and regular schedule updates, therefore requiring intensive resources (Al-Khalidi, 2022).

2.5.2 Prospective Delay Analysis Techniques

These techniques evaluate potential future delays and their impact. They are used before or during the execution phase to analyse and identify potential delay impact as a proactive decision-making analytical tool (Wasfy, 2022). They are key and main techniques used in project delays, and are considered prospective.

2.5.2.1 Time Impact Analysis. The main concept of Time Impact Analysis is to insert delay event into the current critical-path method (CPM) schedule to forecast the delay impact. It is recognised by engineering industry standards and legal forums, and is best suited for extensions of time claims during the project timeline. It is frequently used in MEP projects to generate or simulate scenarios where delays in the procurement phase or installation phase of a

subsystem could spread across interconnected systems or the main system. One limitation is the need for accurate data and simulation logic (Kim, 2022).

2.5.2.2 Impacted As-Planned Analysis. Also called ‘what-if’ analysis, this method adds hypothetical delay events to the original baseline as-planned schedule to simulate their impacts. It provides added value, such as flexibility and scenario-based analysis that can be used in risk management and in the early stages of the projects, where the as-planned schedule is available but regular updates are not accessible (Kim, 2022).

2.5.2.3 Schedule-Cost Curve (S-Curve) and Earned Value Management (EVM).

Both of these are graphical tools to support effort tracking and resources utilisation and to monitor project performance based on cost and schedule in engineering and construction projects.

Schedule-Cost curve is a graphical representation of cumulative progress over time; the curve ‘S’ resembles a slow start in the planning phase, rapid growth and a peak at the execution phase, slowing down at the closeout phase of the project. There are three types of S-Curve:

1. Planned S-Curve: to track the baseline planned values.
2. Actual S-Curve: to track the actual cumulative values.
3. Earned Value S-Curve: to track the performance based on earned progress.

The S-Curve is useful for visual tracking of deviation from the baseline plan, helps identify late or early execution phases and can be used with the earned value management (EVM) method for a deeper analysis. These are particularly useful in retrofit and energy

projects, where actual progress is monitored and compared with planned or forecast progress (e.g., HVAC upgrades, lighting retrofits) (PMI, 2021 & Konior, 2020).

2.5.3 Considerations and Limitations of Delay Methodologies

While delay-analysis techniques are essential, their application is context-based. Retrospective methods such as as-planned vs as-built have limitations in projects with overlapping activities or tasks (e.g., fast-track construction, MEP projects). Prospective methods require reliable and accurate baseline schedules with regular periodic updates, which may not be possible in constrained environments (e.g., some energy retrofit projects).

Moreover, both prospective and retrospective analysis methods frequently use Root Cause Analysis (RCA) and Ishikawa (fishbone) diagrams to identify systemic problems that contribute to delays, such as miscommunication between teams or delays in utility approvals.

2.6 Project Delay Barriers

Delays in engineering projects generally, and in MEP and energy retrofit projects specifically, are complex and are caused by one or a combination of technical, managerial, economic and policy challenges. These barriers interfere with project timelines or deadlines and contribute to increased risks of cost overruns, contract conflicts and customer or stakeholder dissatisfaction. Based on an existing study (Bas, 2022), delay barriers are categorised into main four groups: sociotechnical barrier, managerial and organisational barrier, economic and financial barrier and policy and regulatory barrier.

2.6.1 Sociotechnical Barriers

In engineering projects, sociotechnical barriers refer to challenges arising from the interaction between technological advancement and the organisations that utilise these technologies (Hane Hagström, 2023). Common challenges include:

1. Insufficient technical expertise or capabilities among on-site personnel, especially when upgrading advanced systems such as building automation, HVAC control upgrades or low-voltage systems in general. Rework and re-testing may result from improper installation or improper integration due to insufficient trained personnel (Bas, 2022).
2. Work disruption in sensitive project environment, specifically retrofit projects where collaboration with the client (e.g., facility team, facility managers and tenants) is necessary. This can limit working hours, slow access or cause work disruptions (pauses).
3. Misalignment between the new implemented system and existing infrastructure, particularly in MEP and energy retrofit projects in older buildings, which may not have been originally designed to accommodate new loads (e.g., mechanical and electrical loads) or to accommodate new space requirements.
4. Extended overtime with associated fatigue and error risks.

2.6.2 Managerial and Organisational Barriers

In engineering projects, notable managerial barriers represent core challenges where collaborative coordination is necessary:

1. Poor collaborative planning or handover between departments within the same organisation; for example, delays in civil work can delay the next phase of the project (MEP installation) due to inadequate coordination.
2. Weak record-keeping and documentation of projects, particularly as-built records and commissioning protocols, which can extend the planned timeline and result in project delay (Durdyev, 2020).
3. Poor management skills to adapt to scope change (scope creep) or undocumented client requests that interfere with the original planned deadline.

2.6.3 Economical and Financial Barriers

Engineering and MEP projects are frequently delayed by financial constraints and limitations, especially where capital cost is a primary consideration (e.g., energy retrofit projects). Here are a few examples:

1. High initial capital cost of projects (CAPEX), particularly for energy-efficient systems, advanced technological controls or LEED-compliant equipment, which can burden client budgets, resulting in extending the procurement timeline. A study by Goggins (2020) emphasises that initial capital investment significantly impacts the feasibility of green retrofits, and may prevent clients from pursuing such projects in the absence of financial incentives or support.
2. Late payment and cash-flow challenges, especially for subcontractors (service providers), which reduce resources availability, and delay delivery of materials and site mobilisation.

2.6.4 Policy and Regulatory Barriers

In the engineering and MEP sectors, policy restrictions can either accelerate or slow the project delivery. Here are a few important challenges (Enker, 2020):

1. Outdated or inconsistent building codes that result in complications in compliance, especially when integrating the old infrastructure and systems with advanced technological systems.
2. Long approval procedures and unclear roles of authorities among clients, facility teams, engineering consultants, governmental departments and utility providers.

Chapter 3: Research Methodology

3.1 Introduction to Research Methodology

Research methodology is a systematic process that researchers use to collect, analyse, evaluate and interpret data in an effort to understand a phenomenon or provide a response to a particular question. It includes the overall approach of the research, including the theoretical framework, research design, methods of data collection and analytical approaches (Creswell, 2017).

Creswell (2017), in his book, refers to three research methodologies:

1. Qualitative
2. Quantitative
3. Mixed Methods

‘Qualitative and quantitative approaches should not be viewed as rigid, distinct categories, polar opposites, or dichotomies. Instead, they represent different ends on a continuum’ (Creswell, 2017). Studies are typically more qualitative than quantitative, or the other way around. Since mixed-methods research combines both aspects of qualitative and quantitative methodologies, it falls in the centre of this continuum.

The methodology adopted in this research is based on extensive quantitative analysis, utilising real-life engineering projects to evaluate and assess the causes and impacts of project delays. The methodological approach in this research aims to identify the level of criticality of delays and analyse their root causes across multiple projects with several phases and tasks. This is explained further in the next chapter. The following sections detail a few considerable definitions given by Creswell (2017).

3.1.1 Qualitative Method

This is a research method that explores and understands the significance and meaning that individuals or groups assign to social or human problems. The process includes developing questions, gathering data and analysing data to move from specific themes to broader and general themes (Inductive Theory). The structure of the final written report is adaptable (Creswell, 2017).

3.1.2 Quantitative Method

This is a research method that tests objective theories by analysing the relationship between variables. These variables should be measured, usually by tools, in order to apply statistical processes to the collected data. The structured set of the final written report is as follows:

1. Introduction
2. Literature Review & Theory
3. Methodology
4. Results
5. Discussion

Similar to the qualitative method, researchers using the quantitative method have assumptions for testing their theories (Deductive Theory) and the ability to generalise and replicate the findings (Creswell, 2017).

3.1.3 Mixed Method

This is a research method that uses both qualitative and quantitative data, combines both types of data and information, and then applies a unique design that may involve theoretical

frameworks and philosophical assumptions. The fundamental assumption of integrating both qualitative and quantitative data is to produce new information or insight that cannot be obtained by either source alone.

3.2 The Importance of Collected Data

Primarily, the data for this research has been gathered from handed-over and completed engineering projects within a retail landmark located in Sharjah, UAE. The shopping mall is considered one of the most active in the UAE, where foot traffic exceeds 25,000 visitors per day and HVAC Systems run across hundreds of thousands of square feet. Effective and efficient energy monitoring and control is therefore a necessity.

Failures in communication over time were noticed within the BTU Metre system, which resulted in a loss of control over energy consumption. This is where the three projects were implemented and successfully completed. The work included rectification and integration of the existing looped network, which suffered from incomplete data logging, obsolete cabling and trunking, misconfigured communication paths and outdated BTU Metres.

The communication protocol of the outdated metres is pulse-type communication (electrical dry contact pulse), which is susceptible to pulse loss or pulse noise without diagnostic feedback. Changing the existing communication loop and the outdated BTU metres into BACnet MS/TP communication protocol provided the client with effective and efficient energy monitoring and control, including the following advantages:

1. Accurate digital transmission Communication via RS-485 bus ports through single twisted pair (2core) RS-485 cables.

2. Real-time data value (e.g., power, energy, temperature, temperature differences and flow rate) for load profiling and demand management.
3. Early fault detection through status, alert and diagnostic options, which support proactive maintenance.
4. Direct integration with existing BMS using communication protocol converters (BACnet Routers).

This research follows the same methodology used for solar PV construction projects by Al-Khalidi (2022), but places emphasis on high-critical engineering projects in general, and particularly MEP installation and energy retrofit initiatives. These are vital for achieving sustainability, operational efficiency and energy savings, through energy monitoring and control of existing systems and existing infrastructure in major shopping mall in the UAE.

Retrospective delay analysis of As-Planned vs As-Built (APAB) has been applied to:

1. Quantify the delays.
2. Identify and categorise primary and secondary causes of delays.
3. Measure their time impact and critical contributions.

This research focuses on root causes of delays, the impact of delays, the risks associated with them and the mitigation strategies to mitigate these risks in future. The actual real-life collected data includes:

1. Contractual project timeline.
2. Revised project timeline.
3. Minutes of Meetings.
4. Official documents.

5. Any type of official and non-official communication (mails, WhatsApp, verbal communication).

Table 2

Review on Selected Projects

Project Number	Project Location	Project Category	Project Description (General SOW)
Project No.1	UAE, Sharjah	MEP and Energy Retrofit	63 BTU Metres generating approximately 3 million data points per month, enabling precise tracking of energy consumption.
Project No.2	UAE, Sharjah	MEP and Energy Retrofit	37 BTU Metres generating approximately 1.6 million data points per month, enabling precise tracking of energy consumption.
Project No.3	UAE, Sharjah	MEP and Energy Retrofit	31No's of BTU Metres generating approximately 1.4 million data points per month, enabling precise tracking of energy consumption.

Note. MEP = (Mechanical, Electrical & Plumbing), BTU Metre = (British Thermal Unit Metre), UAE = (United Arab Emirates), SOW = (Scope of Work).

3.2.1 Research Analysing Steps

Based on work breakdown structure (WBS), all projects had the same five phases and nine tasks or activities, then each phase was divided into specific technical, administrative and commercial tasks (see Table 3). Moreover, each project in Table 2 was analysed as follows:

1. Starting date and finishing date of as-planned tasks vs as-built tasks.
2. Task as-planned duration (TAPD) vs task as-built duration (TABD).

3. Identification of critical delays and float time calculations.
4. Percentage of phase delay compared to TAPD.
5. Percentage of task delay compared to TAPD.
6. Reasons and causes of each delay event.
7. Identification of paused or hold durations during the project timeline.
8. Risk categorisations and mitigation strategies.

Table 3*MEP Project Phases and Tasks*

MEP Project Phases and Tasks	
1. Site Inspection & Value Engineering	First Phase
1.1 Site Inspection Detail	1 st Task
2. Contract Signature / Purchase Order / LOI	Second Phase
2.1 Purchase Order / LOI	2 nd Task
3. Procurement Phase	Third Phase
3.1 Internal Processes	3 rd Task
3.2 Material Delivery	4 th Task
4. Mechanical, Electrical & Plumbing Installation	Fourth Phase
4.1 Work Permit & Site Access	5 th Task
4.2 In-House installation, assessment and inspection	6 th Task
5. Testing and Commissioning (T&C)	Fifth Phase
5.1 T&C of system	7 th Task

5.2 Project Handover (Signed Work Completion Report)

8th Task

5.3 Project Invoicing

9th Task

This research applies one of the primary retrospective delay quantification techniques: As-Planned vs As-Built (APAB). Task as-planned durations (TAPD) and task as-built durations (TABD) were compared to calculate the task overall delay (TOD%). This method is reliable specially with limited resources availability; actual data and planned baseline durations are available and documented.

Each delayed task was assessed for its impact on the critical path; the following analyses were carried out:

1. Float time calculations.
2. Classifications of delays as critical delays or non-critical delays.

Moreover, an Ishikawa (Fishbone) diagram was used for Root Cause Analysis and delays were categorised as:

1. Client-related delays.
2. Procurement and supply chain delays.
3. Internal process delays.

3.2.2 Summary of Delay Analysis Process

The following structured and summarised steps were used to perform the delay analysis for all the three projects as follows:

- 1) **Data collection:** this is the foundational data required to assess and evaluate the accuracy of the planned timeline and actual timeline. Gathered from contracts or purchase orders, revised project timeline, minutes of meetings, official correspondence

(emails, letters or any official document) and informal communications (WhatsApp, verbal commitments).

2) **Data review:** analysed each project schedule or timeline, then analysed and organised each key task and project phase for all projects using Microsoft Excel.

3) **Quantitative delay analysis:** applied formulas to identify, quantify and assess delays and their criticality:

a) **Project As Planned Duration (PAPD)** = *End Date of Planned – Start Date of Planned.*

b) **Project As Built Duration (PABD)** = *End Date of Built – Start Date of Built.*

c) **Task As Planned Duration (TAPD)** = *End Date of Planned Task – Start Date of Planned Task.*

d) **Task As Built Duration (TABD)** = *End Date of Built Task – Start Date of Built Task.*

e) **Float or Slack** = *(TAPD – TABD) in Days*

f) **Task Overall Delay (%) (TOD%)** = *(Duration of Built Task – Duration of Planned Task) / Duration of Planned Task * 100*

g) **Critical Task:** task was critical if it matched the following conditions using Microsoft Excel:

I. Condition 1 (task took longer than planned): $(TABD) > (TAPD)$.

II. Condition 2 (task caused delay): $(@[Delay Occurrence?]) = 'Yes, delayed phase'$.

III. Condition 3 ($\text{float} \leq 0$, which means any delay directly affects the project): $([TAPD] - [TABD]) \leq 0$.

h) **Contribution of Task Delay (%)** = $(\text{Duration of Built Task} - \text{Duration of Planned Task}) / \text{Total Duration of Delay} * 100$

i) **Project Overall Delay (%)** = $(\text{Actual Duration} - \text{Planned Duration}) / \text{Planned Duration} \times 100$ (it shows by what percentage the project was delayed or ahead of schedule).

j) **Task Weighted Average Delay Contribution (TWADC) (%)** = $(\text{Sum of each Task's Delay \%}) \times 100$ (it measures how much each task contributes to total project delay).

- 4) **Gantt Chart creation:** created from as-built schedule using online tool due to limited resources. The main reason for the as-built schedule only is to understand how the project unfolds, to reflect actual activities and timelines and how different tasks are related to each other.
- 5) **As-Planned critical path identification:** analysed the as-planned duration and critical path using Microsoft Excel.
- 6) **As-Built critical path identification:** analysed the as-built duration and critical path using Microsoft Excel.
- 7) **Delay identification and quantification:** identified delay durations, where they occurred and the significance of each delay.
- 8) **Categorisation of delay causes:** based on previous steps of analytical data, grouped delays into main categories.

- 9) **Root Cause Analysis:** created Ishikawa diagram using online tool for each project to identify recurring delays, to visualiae and track the main and secondary causes of delays.
- 10) **Mitigation strategies:** developed based on critical observed delays and their causes.

Chapter 4: Research Analysis: Results & Discussion

4.1 Project No. 1 Discription

In a retail landmark and one of the most vibrant shopping destinations (a shopping mall) where daily foot traffic exceeds 25,000 visitors per day and HVAC systems cover hundreds of thousands of square feet, efficient and effective energy monitoring and control is not a luxury; it is a necessity.

Over time, communication breakdown within the BTU Metre system led to data blind spots, operational inefficiency and a loss of control over energy analytics and energy consumption.

The existing fifth loop (part of seven loops) network suffered from incomplete data logging, outdated cabling and trunking and misconfigured communication paths.

Therefore, integrating the existing BTU Metres into one central system was essential. This project was initiated in 2023 to rectify and integrate more than 63 BTU Metres in 45 retail shops into the central building management system (Niagara platform BMS).

4.1.1 Project No. 1 Scope of Work

The scope of work of the project consisted of the following:

1. Replacing outdated cables with high-grade communication cables, including trunking or conduits.
2. Installation, testing and commissioning of advanced communication gateways.
3. Integration of BTU Metres into centralised Niagara platform BMS.

4. Configuration of 15-minute interval logging of data points, yielding 1,440 points per day per metre with estimation of 3 million (2,721,600) data points per month for 63 BTU Metre to ensure accurate energy consumption tracking:
 - 1) Supply Temperature (°C).
 - 2) Return Temperature (°C).
 - 3) Temperature Difference between Supply and Return (ΔT) (°C).
 - 4) Flow Rate (L/S)
 - 5) Energy Consumption (kWh)
5. Virtual Local Area Network (VLAN) setup coordination with the mall's IT team to ensure cybersecurity and data flow.
6. On-site training to ensure smooth handover.

4.1.2 The Importance of Project No. 1

Project No. 1 mattered to stakeholders both internally and externally due to:

1. **Energy Cost Recovery and Transparency:** with over AED 4,000,000/Year in estimated HVAC energy expenses across the mall, accurate sub-metering ensures each tenant or retailer is billed fairly. This project improved accurate readings, avoided overbilling disputes and increased tenant or customer satisfaction.
2. **Operational Efficiency and Predictive Maintenance:** centralised data enables the operations team to identify inefficiencies, spot unusual consumption spikes, reduce manual oversight and proactively plan maintenance. 'Incomplete communication in BTU Meters Network leads to 20% to 40% loss in actionable data, resulting in billing and energy monitoring inaccuracy' (ASHRAE., 2023).

3. **Sustainability & Compliance:** The UAE's National Energy Strategy 2050 emphasises energy efficiency and data-driven building management (The Official Portal of the UAE Government, 2024 & UAE Ministry of Energy and Infrastructure). This project directly aligns with those energy strategy 2050 goals.

4.2 Project No. 1 Analysis

This project is comprised of nine tasks and five phases ranging from inspection, contractual approvals, procurement, installation and commissioning.

The quantitative delay analysis was based on a comparison between the As-Planned Schedule (forecasted duration) and the As-Built Schedule (actual duration), including float analysis, delay occurrence and the percentage of delays of critical path tasks (a metric to measure the impact of delays in tasks and phases on project timeline). Further and detailed analysis and calculations of Project No. 1 are provided in Appendix A.

- 1) Task As-Planned Duration (TAPD): 212 days.
- 2) Task As-Built Duration (TABD): 231 days.
- 3) Project Overall Delay: 9%

4.2.1 Work Breakdown Structure Summary

Project No. 1 consisted of five phases; each phase was divided into technical, administrative and commercial tasks:

- 1) Preliminary inspection and estimation phase.
- 2) Contractual documentation phase.
- 3) Procurement and logistics phase.
- 4) Mechanical, electrical and plumbing installation phase.
- 5) Testing and commissioning phase.

The dependencies were finish-to-start basis (waterfall model with sequential dependencies), with limited opportunities of parallel work. However, partial materials delivery, allowed the MEP installation phase to begin earlier.

4.2.2 Gantt Chart Analysis

Figure 8

Gantt Chart of 'As-Built' of Project No. 1

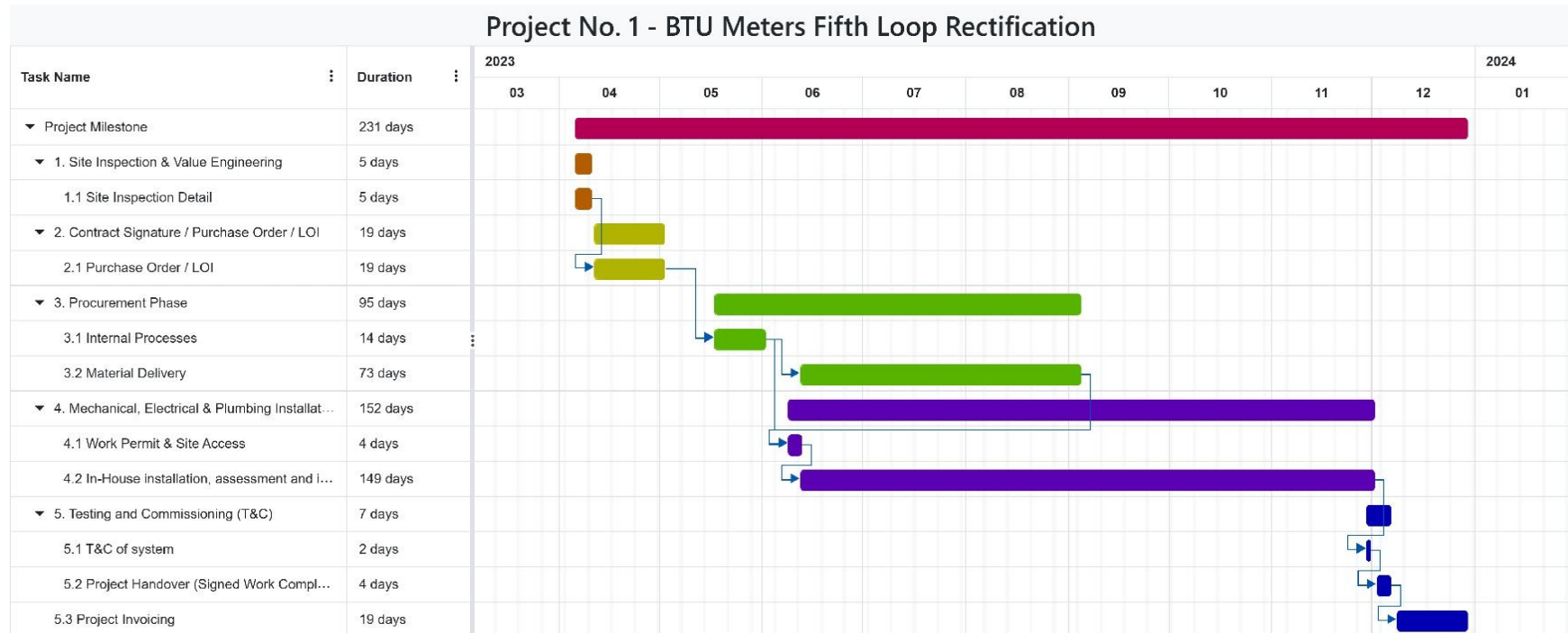


Figure 8 shows the project timeline:

- 1) Start Date: 5 April 2023
- 2) Completion Date: 29 December 2023
- 3) Total Duration: 231 days (excluding Sundays)

The chart demonstrates sequential dependencies with limited concurrency. As per the waterfall model, delays in earlier phases directly impacted downstream phases (e.g. MEP installation and T&C).

Final closing tasks, placed correctly at the end of the chain, were T&C (Phase 5) and Project Invoicing (Task 5.3). Table 4 presents the tasks in this project that were carried out simultaneously:

1. The predecessor task (3.2 Material Delivery) – involving partial delivery of materials – began four days later, on 12 June 2023, than the successor task (4.1 Work Permit & Site Access), which started on 8 June 2023, as shown in Table 4 below.

Table 4

TAPD vs TABD of Project No. 1

MEP Project Tasks	As-planned Schedule – Phase Starting Date	As-planned Schedule – Phase Finishing Date	As-built Schedule – Starting Date	As-built Schedule – Finishing Date
3.2 Material Delivery	24 May 2023	8 August 2023	12 June 2023	4 September 2023
4.1 Work Permit & Site Access	5 June 2023	8 June 2023	8 June 2023	12 June 2023

2. The predecessor task (4.2 In-House Installation, Assessment and Inspection) was completed on 1 December 2023, while the successor task (5.1 T&C of System) had already started simultaneously on Wednesday, 29 November 2023 (2 days earlier), as shown in Table 5.

Table 5*TAPD vs TABD of Project No. 1*

MEP Project Tasks	As-planned Schedule – Phase Starting Date	As-planned Schedule – Phase Finishing Date	As-built Schedule – Starting Date	As-built Schedule – Finishing Date
4.2 In-House installation, assessment and inspection	8 June 2023	28 June 2023	12 June 2023	1 December 2023
5.1 T&C of system	27 November 2023	29 November 2023	29 November 2023	1 December 2023

4.2.3 Critical Path Analysis

The critical path represents the longest sequence of dependent tasks. Any delay in these activities directly extends the overall project timeline. Task criticality calculations and conditions of project No. 1:

- Condition 1: $(TABD) > (TAPD)$.
- Condition 2: $(@[Delay Occurrence?]) = 'Yes, delayed phase'$.
- Condition 3: $([TAPD] - [TABD]) \leq 0$.

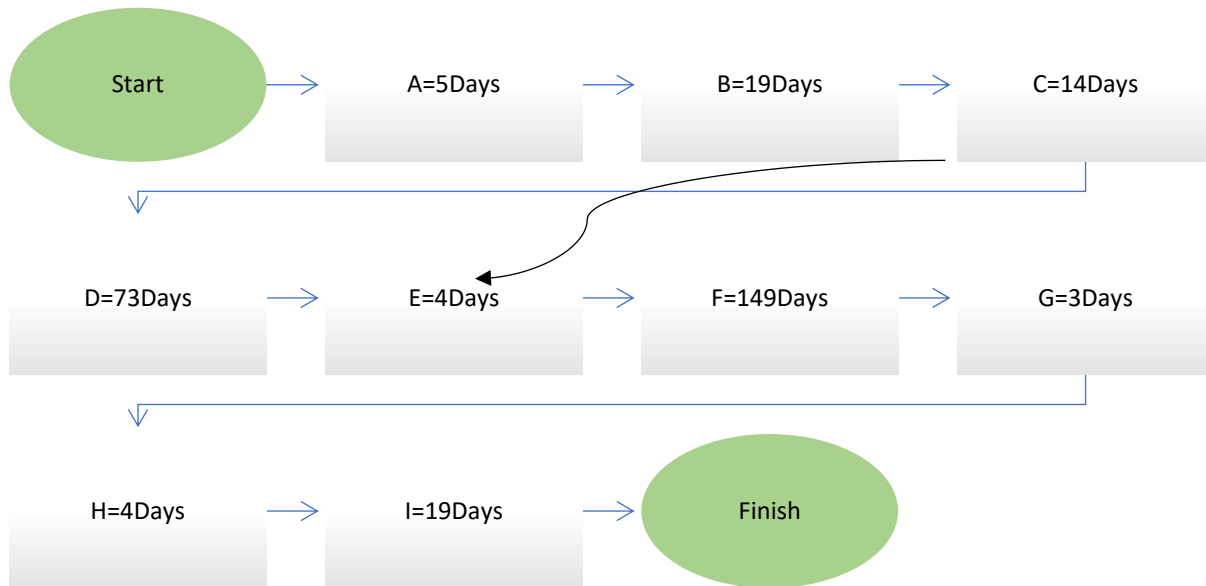
Table 6*Critical Path of Project No. 1 – BTU Metres Fifth Loop Rectification*

ID	Predecessor Activities		Duration in Days	Activity Description
A	-	-	5	1.1 Site Inspection Detail
B	A		19	2.1 Purchase Order / LOI
C	B		14	3.1 Internal Processes

D	C		73	3.2 Material Delivery
E	C	D	4	4.1 Work Permit & Site Access
F	E		149	4.2 In-House installation, assessment and inspection
G	E		3	5.1 T&C of system
H	G		4	5.2 Project Handover (Signed Work Completion Report)
I	H		19	5.3 Project Invoicing

Figure 9

Critical Path of Project No. 1



Note. Blue arrows are to illustrate the critical path, while Black arrows are non-critical paths.

4.2.3.1 Critical Task Control. Figure 9 and Table 6 show that activities

$B \Rightarrow C \Rightarrow D \Rightarrow E \Rightarrow F$ form the backbone of the project. Any deviation in these critical path

activities will significantly impact the handing over of the project. There is also zero slack (float) in any of the critical path activities.

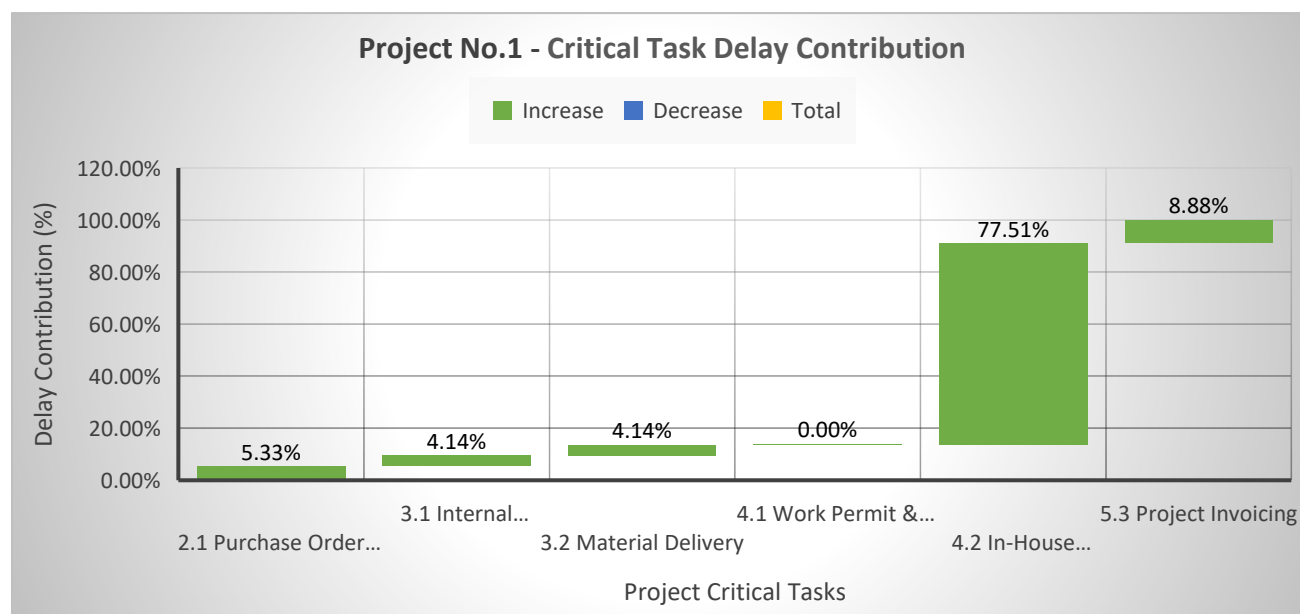
4.2.3.2 Early Stages Vulnerability. Activities Purchase Order (B) and Internal Process (C) are often delayed due to administrative processes and are therefore considered early critical path activities.

4.2.3.3 Parallel Task Risks. The Work Permit (E) activity depends on both the Internal Process (C) and Material Delivery (D) activities. This dependency creates an overlapping point, meaning that a delay in either activity will critically affect the project timeline.

4.2.4 Critical Task Delay Contribution

Figure 10

Critical Task Delay Contribution of Project No. 1



The Bar Chart in Figure 10 presents a systematic approach used to prioritise the impact of delays on the overall timeline, focusing only on critical path tasks. Figure 10 above shows

that Task 4.2 (In-House Installation, Assessment and Inspection) is the major contributor to project delay, accounting for 77.51% of the total project delay.

The secondary delay cause was Task 5.3 (Project Invoicing), which contributed 8.88% to the overall project delay. Task 2.1 (Purchase Order / LOI) delayed the project by 5.3%. In addition, Task 3.1 (Internal Processes) and Task 3.2 (Material Delivery) contributed 4.14% each, representing a combined total of 8.28% of the overall delay.

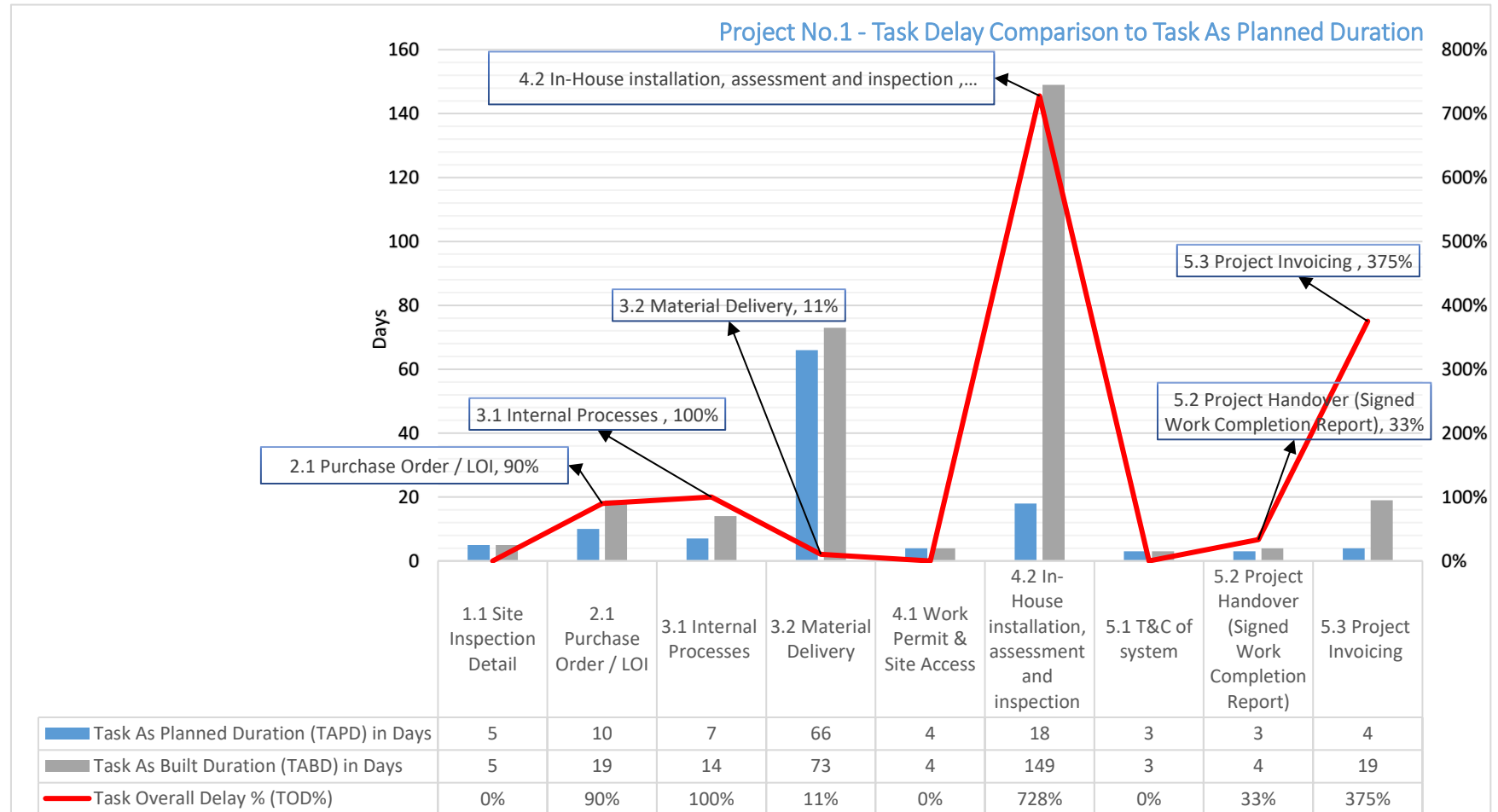
In summary, the critical path clearly illustrates and defines the project's success timeline while emphasising the importance of avoiding delays through proactive management and, where feasible, parallel task planning.

The following sections provide a more detailed analysis of the root causes of delays, their contribution and the mitigation strategies proposed to address such delays in future projects.

4.2.5 Analysis of Delay Contribution to the Initial Planned Duration

Figure 11

Task Delay Comparison to TAPD of Project No. 1



Note. A negative value indicates that task was completed ahead of schedule, whereas a positive value represents a delay.

Table 7

Project No. 1 Delay Reasons and Delay Contribution to Initial Planned Duration

Project Task	Category Task Contribution Delay %	Delay Category	Reason for the Delay
2.1 Purchase Order / LOI	6.9%	Client-Related Delays	Delayed because of client's budgetary approvals.
3.1 Internal Processes	7.7%	Internal Process Delays	Delayed due to the internal approvals of the budget of the project.
3.2 Material Delivery	0.8%	Procurement & Supply Chain Delays	Delay in the process of procurement in the partial delivery due to the lack of availability of some materials.
4.2 In-House Installation, Assessment and Inspection	55.8%	Client-Related Delays	Delayed due to: First) Site Access inside some specific shops was delayed (Client's Process Delay). Second) IP Configuration was delayed for more than 2 months (Client's Process Delay). Third) Work Timings (initial agreement is during 9AM to 6PM) has been changed into night shift (12PM to 6AM), which delayed the project by a total of 25 days, resulting in less manpower, less productivity and less work duration (Client's Process Delay).
5.3 Project Invoicing	28.8%	Client-Related Delays	Delayed because of client processing the invoicing of the project.

Table 8*Delays by Category – Project No. 1*

Project No. 1 – Category Contribution Delay Percentage	
Delays as per Category	Category Contribution Delay %
Client-Related Delays	91.5%
Internal Process Delays	7.7%
Procurement & Supply Chain Delays	0.8%

The analysis findings, as illustrated in Figure 11, Table 7 and Table 8, show that client-related delays had the greatest impact on the project timeline. The main reasons for these delays are as follows:

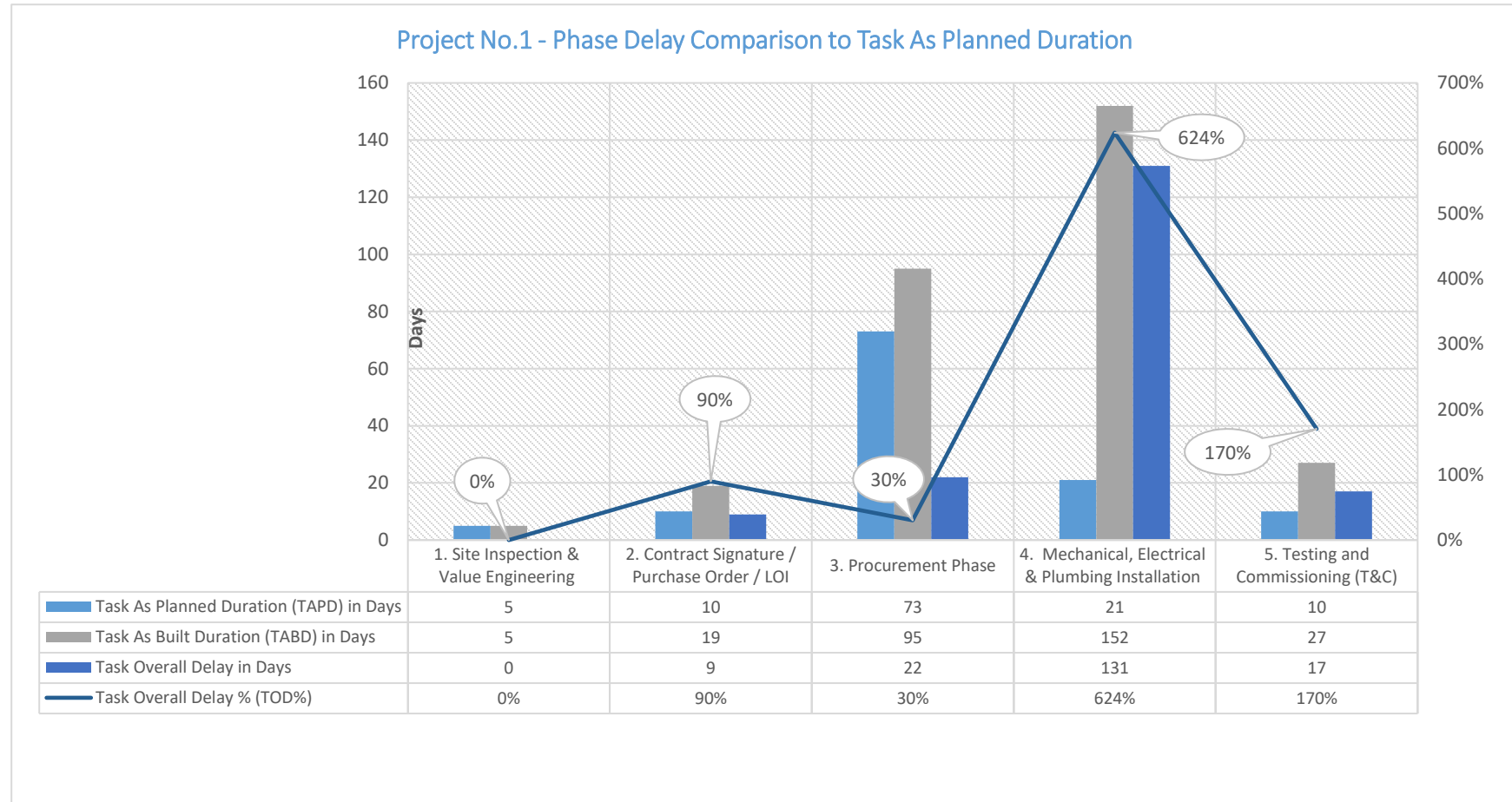
1. Primary delay cause: Task 4.2 (In-House Installation, Assessment and Inspection) impacted primarily the project's planned duration by 728% (131 days) due to:
 - Restricted site access to specific retail shops.
 - Delays in IP configuration, which was completed more than 2 months later than the planned timeline.
 - Shift timing changes, the original verbal agreement (9:00 AM to 6:00 PM) was changed to night shifts (12:00 PM to 6:00 AM), causing a delay of 25 days and reducing manpower efficiency.
2. Secondary delay cause: Task 5.3 (Project Invoicing) impacted the planned project timeline by 375% (15 days) due to client processes. This accounted for 8.88% of the overall delay, as shown in Figure 10 (Bar Chart).

3. Client budgetary approvals: these contributed 5.33% of the total actual project delay, as shown in Figure 10 (Bar Chart).
4. Task 3.1 (Internal Processes) and Task 3.2 (Material Delivery) impacted the planned timeline by 100% and 11% respectively, as shown in Figure 11. These delays were due to client budget approval processes and shortages in partial material delivery.

4.2.6 Comparison of Phase Delays in Project No. 1

Figure 12

Project No. 1 Phase Delay Comparison to TAPD



Note. A negative value indicates that task was completed ahead of schedule, whereas a positive value represents a delay.

The highlighted delay phases compared to TAPD, based on Figure 12, are as follows:

1. Mechanical, electrical and plumbing installation phase: delayed by 131 days (Task Overall Delay Percentage = 624% over the project plan baseline). This formed the most significant contributor to the critical path delay.
2. Testing and Commissioning Phase: delayed by 17 days, resulting in a 170% delay compared to the planned duration.
3. Contract signature/purchase order phase: delayed by 9 days (Task Overall Delay Percentage = 90% over the project plan baseline), primarily due to client budgetary approvals process.
4. Procurement phase: delayed by 22 days (Task Overall Delay Percentage = 30% over the project plan baseline), caused by extended internal approvals processes and partial deliveries due to the unavailability of some materials.

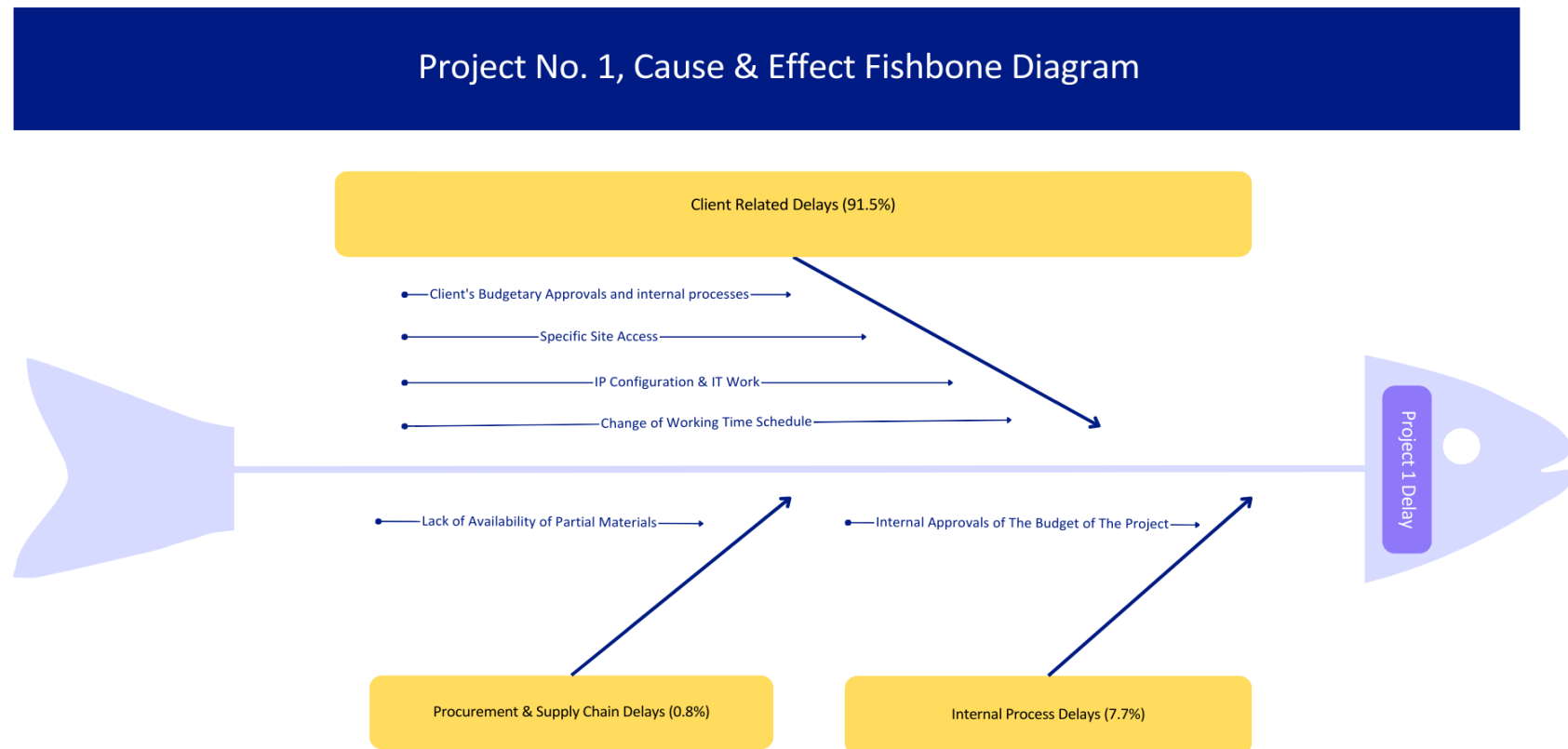
4.2.7 Analysis of Root Causes of Delays

Using an Ishikawa diagram (Fishbone diagram), the root causes of delays are summarised in Figure 13.

The Root Cause Analysis shows that the primary contributor to overall project delay was client-related delays, accounting for 91.5% of the total delay.

Figure 13

Ishikawa Diagram of Project No. 1



4.2.8 Risk Assessment and Mitigation Strategies

Table 9

Risk Assessment and Mitigation Strategies of Project No. 1

Risk Category	Risk Identification	Impact of Risk	Likelihood	Mitigation Strategy
Client-Side Related Delay	Budget approvals, delayed Purchase Order (PO)	High	Medium	Pre-clear budgets; Provisional Letter of Intent (LOI) mechanism
Internal Bureaucracy	Delays in internal approval chains	Medium	High	Streamline approval matrix, delegate authority
Site Access	Delayed access inside operating retail shops	High	High	Pre-schedule access via detailed approved plan of access with Facility Management/Mall's Operations
Material Procurement	Lead time variability from suppliers	Medium	Medium	Advance procurement buffer, diversify suppliers that aligns with project's budget
Inspection/Testing	Rework or inspection timing conflicts	Medium	Medium	Align Quality Assurance or Quality Check checkpoints early in planning phase
Risk Rating Criteria:	Low	Medium	High	

Note. For more information on risk levels and likelihood or impact of risk, see Appendix E.

4.3 Project No. 2 Discription

Within the same retail landmark and among the most active shopping malls in the UAE, where foot traffic exceeds 25,000 visitors per day and HVAC systems cover hundreds of thousands of square feet, effective and efficient energy monitoring is a necessity.

Building on the success of primarily the first project, this initiative continued the rectification and integration of the existing sixth loop network, which suffered from incomplete data logging, obsolete cabling and trunking, misconfigured communication paths and outdated BTU Metres.

Over time, failures in communication within the BTU Metre system were observed, resulting in a loss of control over energy consumption.

Accordingly, this project commenced on 29 April 2023 and was completed on 15 July 2024. The sixth loop project involved integrating and rectifying a communication loop of 37 BTU Metres into the mall's BMS as a centralised system.

4.3.1 Project No. 2 Scope of Work

The scope of work of the project consisted of the following:

1. Replacing outdated cables with high-grade communication cables, including trunking or conduits.
2. Installation, testing and commissioning of advanced communication gateways.
3. Integration of 37 BTU Metres into centralised Niagara platform BMS.
4. Configuration of 15-minute interval logging of data points, yielding 1,440 points per day per metre with an estimated 1.6 million (1,598,400) data points per month for 37 BTU Metre to ensure accurate energy consumption tracking:

- 1) Supply Temperature (°C).

- 2) Return Temperature (°C).
 - 3) Temperature Difference between Supply & Return (ΔT) (°C).
 - 4) Flow Rate (L/S)
 - 5) Energy Consumption (kWh)
5. Virtual Local Area Network (VLAN) setup coordination with the mall's IT team to ensure cybersecurity and data flow.
 6. On-site training to ensure smooth handover.

4.4 Analysis of Project No. 2

Project No. 2 comprised of nine tasks and five phases, ranging from inspection, contractual approvals, procurement, installation and commissioning.

The quantitative delay analysis was based on a comparison between the As-Planned Schedule (forecasted duration) and the As-Built Schedule (actual duration), including float analysis, delay occurrence and the percentage of delays of critical path tasks (a metric showing the impact of delays in tasks and phases on project completion).

The analysis revealed that Project No. 2 experienced an overall delay of approximately 16%, equivalent to nearly two months' delay. This represents an increase of about 77.8% in overall delay compared to Project No. 1 (which experienced approximately 9% delay).

- Task As-Planned Duration (TAPD): 329 days.
- Task As-Built Duration (TABD): 380 days.

All related analysis, quantification and calculations for Project No. 2 can be found in Appendix B.

4.4.1 Work Breakdown Structure Summary of Project No. 2

Similar to Project No. 1, Project No. 2 comprised of five phases, each divided into specific technical, administrative and commercial tasks, as follows:

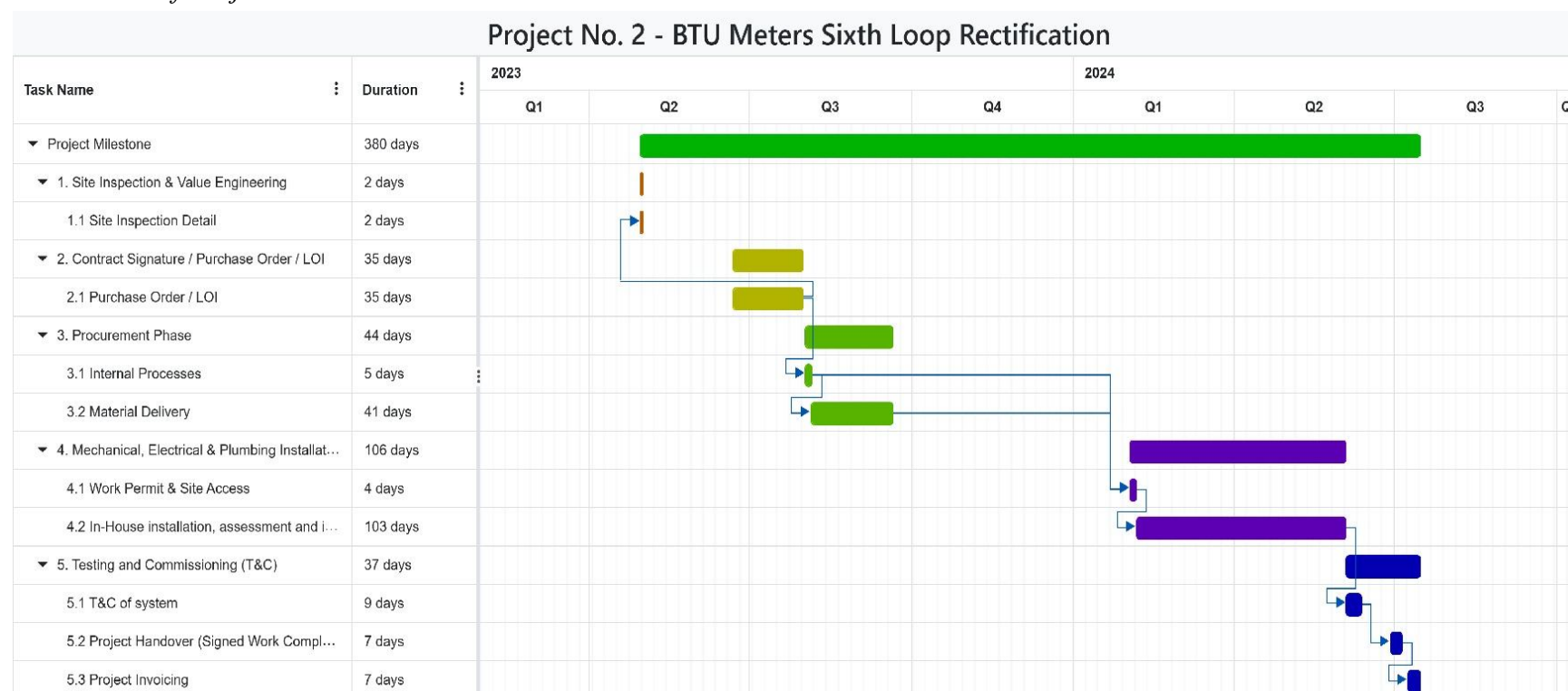
- 1) Preliminary Inspection and Estimation phase.
- 2) Contractual Documentation Phase.
- 3) Procurement and Logistics Phase.
- 4) Mechanical, Electrical and Plumbing Installation Phase.
- 5) Testing and Commissioning Phase.

The project had restrictions on concurrent execution of phases and tasks. As a result, dependencies followed a finish-to-start basis (a waterfall model with sequential dependencies).

4.4.2 Gantt Chart Analysis

Figure 14

Gantt Chart of Project No. 2



The durations shown in Figure 14 (Gantt Chart) represent the As-Built Durations. The project started on 29 April 2023 and was completed on 15 July 2024, with a total project duration of 380 days (excluding Sundays as non-working days, and including 156 days of client-requested pauses).

Each phase or task followed a clear sequential dependency, indicated by the connecting arrows in Figure 14. The project execution model followed a waterfall approach, meaning that any delay in earlier phases had a direct downstream impact on the subsequent phase (e.g. MEP Installation Phase and Testing & Commissioning Phase).

Figure 14 provides a visual timeline of project activities, highlights key milestones and identifies challenges faced during execution, as summarised below:

1. First pause: due to client pre-budget approvals, a delay of approximately 43 days occurred between the completion of Task 1.1 (Site Inspection Detail) and the start of Task 2.1 (Purchase Order / LOI) as shown in Table 10 below.
2. Second pause: a significant delay of approximately 113 days occurred between the completion of Task 3.2 (Material Delivery) and the beginning of Task 4.1 (Work Permit & Site Access) due to:
 - Limited Site Access: difficulty obtaining site access inside the retail shops from client's side, overlapping with Project No. 1.
 - Financial Struggles: delays in client payments affected project progress and manpower deployment.
3. Additional Financial Struggles: continued delays in client payments (previous completed projects) further affected manpower deployment of current projects.
4. Initiation Phase: the project began with a brief site inspection and the submission of a techno-commercial proposal for client approval, followed by the procurement phase.
5. Longest Task: Task 4.2 (In-House Installation, Assessment and Inspection) lasted 103 days, representing the longest single activity in the project timeline.

6. Final Stages: T&C Phase (Phase No. 5) and Task 5.3 (Project Invoicing) were the closing activities of the project.

Table 10

Unofficially Requested Pauses of Project No. 2

Pause or Hold Discription of Project No. 2	Starting Date	Completion Date	Total Days (Excluding Sundays)
First Pause between Task 1.1 (Site Inspection Detail) and Task 2.1 (Purchase Order / LOI)	1 May 2023	21 June 2023	43 days
Second Pause between Task 3.2 (Material Delivery) and Task 4.1 (Work Permit & Site Access)	20 September 2023	1 February 2024	113 days
Total Duration of Project No. 2 in Days			380 days

4.4.3 Critical Path Analysis of Project No. 2

Based on task criticality calculations: Condition 1: $(TABD) > (TAPD)$. Then Condition 2: $(@[Delay Occurrence?]) = 'Yes, delayed phase'$, then Condition 3: $([TAPD] - [TABD]) \leq 0$. Table 11 and Figure 15 clearly distinguish between critical and non-critical tasks. To achieve effective and efficient project management, and to ensure timely project completion, the critical path of this project was identified as follows:

- 1.1 Site Inspection Detail
- 2.1 Purchase Order / LOI
- 3.1 Internal Processes
- 3.2 Material Delivery
- 4.1 Work Permit & Site Access

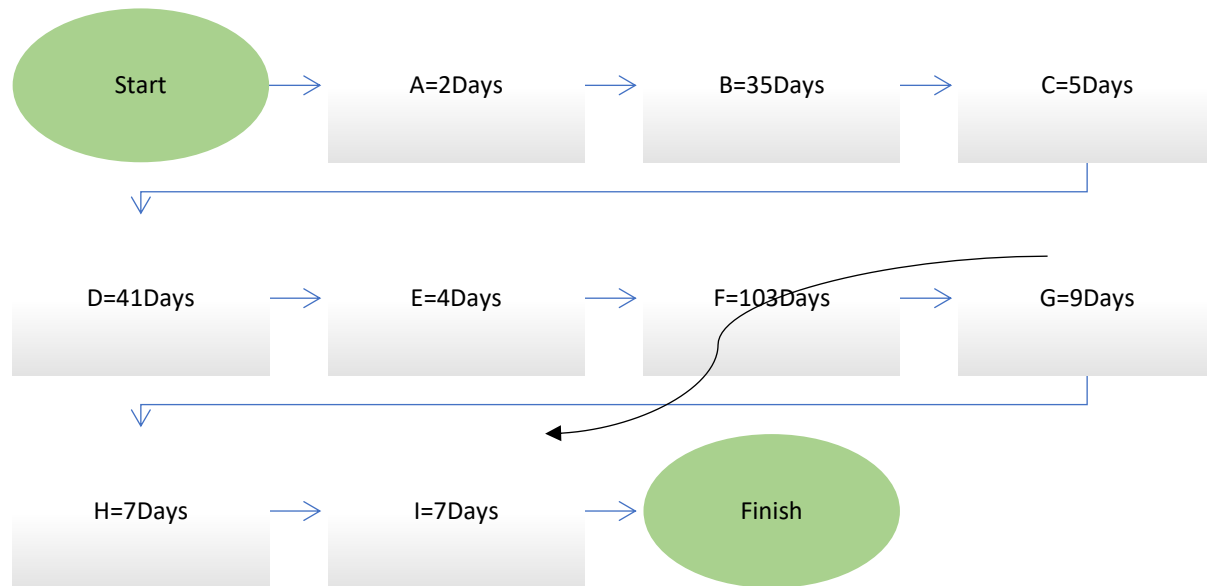
- 4.2 In-House installation, assessment and inspection
- 5.1 T&C of system
- 5.2 Project Handover (Signed Work Completion Report)
- 5.3 Project Invoicing

These activities are extremely crucial to the project timeline, with zero slack (float). Any delay in any of them would directly extend the project's planned duration.

Table 11

Critical Path of Project No. 2 – BTU Metres Sixth Loop Rectification

ID	Predecessor Activities		Duration in Days	Activity Description
A	-	-	2	1.1 Site Inspection Detail
B	A		35	2.1 Purchase Order / LOI
C	B		5	3.1 Internal Processes
D	C		41	3.2 Material Delivery
E	C	D	4	4.1 Work Permit & Site Access
F	E		103	4.2 In-House installation, assessment and inspection
G	E		9	5.1 T&C of system
H	G		7	5.2 Project Handover (Signed Work Completion Report)
I	H		7	5.3 Project Invoicing

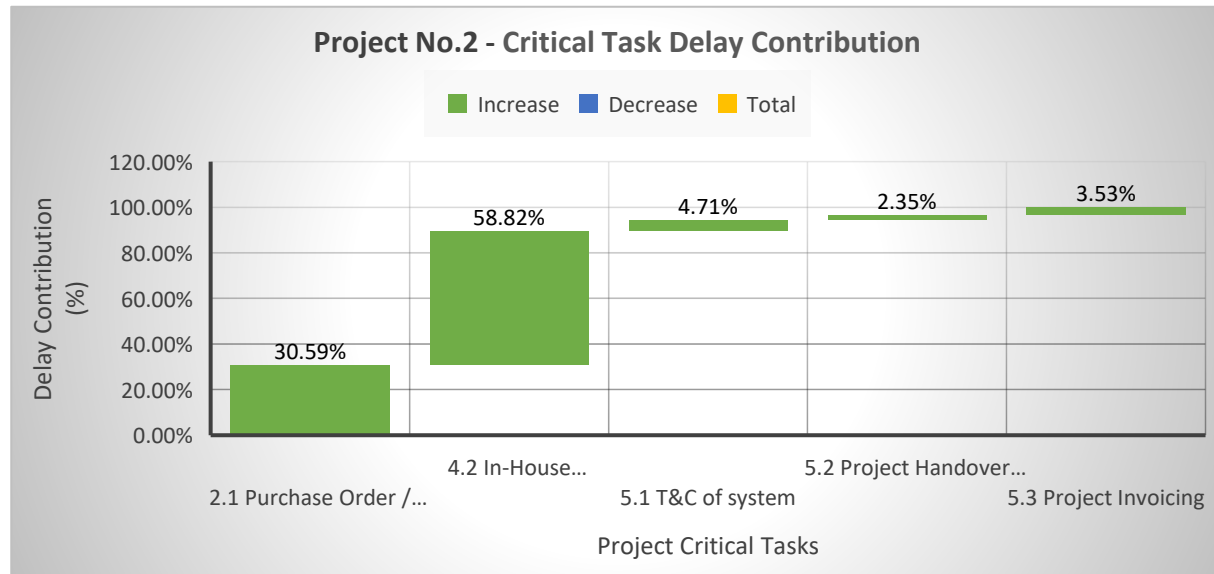
Figure 15*Critical Path of Project No. 2*

Note. Blue arrows are to illustrate the critical path, while Black arrows are non-critical paths.

4.4.4 Critical Task Delay Contribution of Project No. 2

Figure 16

Critical Task Delay Contribution of Project No. 2



Referring to the Bar Chart presented in Figure 16, the effects of delays in critical path activities on the overall project timeline were systematically analysed and prioritised. Figure 16 shows that Task 4.2 (In-House Installation, Assessment and Inspection) was the main cause of the project delay, contributing 58.82% to the total delay. The secondary critical task, Task 2.1 (Purchase Order / LOI), contributed 30.59% to the total actual project delay.

Furthermore, the testing and commissioning phase contributed 10.59% to the overall project delay and comprised the following tasks:

- 1) Task 5.1 (T&C of system)
- 2) Task 5.2 (Project Handover)
- 3) Task 5.3 (Project Invoicing)

It is evident that the overall project delay can be significantly reduced by improving the performance of Task 4.2 (In-House Installation, Assessment and Inspection) and Task 2.1

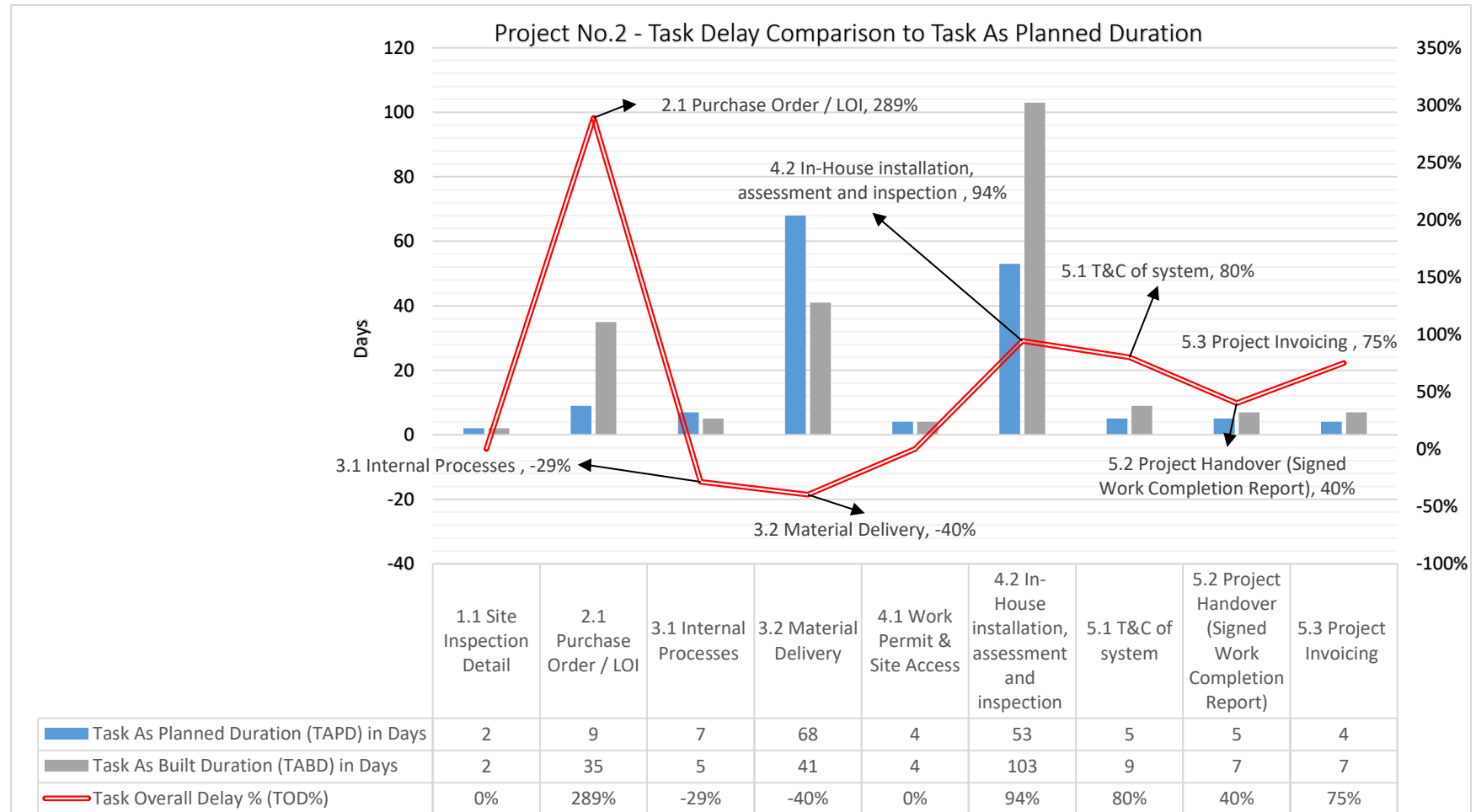
(Purchase Order / LOI). These tasks are further analysed to evaluate their delay contributions, associated risks and impacts on the project.

Proactive project management and parallel task planning, where feasible and in accordance with project requirements, are recommended to minimise delays and ensure smooth and timely project delivery.

4.4.5 Analysis of Delay Contribution to the Initial Planned Duration of Project No.2

Figure 17

Task Delay Comparison to TAPD of Project No. 2



Note. A negative value indicates that task was completed ahead of schedule, whereas a positive value represents a delay.

Table 12

Project No. 2 Delay Reasons and Delay Contribution to Initial Planned Duration

Project Task	Category Task Contribution Delay %	Delay Category	Reason for the Delay
2.1 Purchase Order / LOI	50%	Client-Related Delays	Delayed due to the client's budgetary approval process and internal administrative procedures.
4.2 In-House Installation, Assessment and Inspection	16%	Client-Related Delays	First: Site Access to several specific retail shops was delayed (client's process delay). Second: The field server or communication gateway malfunctioned (client's site mishandling) during the final installation and engineering phase, requiring a replacement order from the manufacturer. The re-supply process took 65 days (Wednesday, 20 March 2024 to Monday, 3 June 2024), and the associated DLP and warranty period affected the next phases. Third: IP configuration was delayed by more than two months (Tuesday, 23 April 2024 to Wednesday, 12 June 2024) due to the client's process delay.
5.1 T&C of System	14%	Client-Related Delays	Delayed due to IT-related work dependencies from the client's process delay.
5.2 Project Handover (Signed Work Completion Report)	7%	Client-Related Delays	Delayed due to the process of signing the completion report and performing final work verification (client's process delay).
5.3 Project Invoicing	13%	Client-Related Delays	Delayed because of extended client processing during project invoicing.

Table 13*Delays by Category – Project No. 2*

Project No. 2 – Category Contribution Delay Percentage	
Delays as per Category	Category Contribution Delay %
Client-Related Delays	100%

Upon reviewing the project data and based on the analytical findings illustrated in Figure 17, Table 12 and Table 13, it was revealed that all project task delays were solely attributed to client-related factors, resulting in 100% contribution to the overall project delay. The findings are summarised as follows:

1. Client-Related Delays – Task 4.2 (In-House Installation, Assessment and Inspection):

This task, considered a critical activity, impacted the project with a delay of 50 days, and contributed 94% to the planned timeline extension. The main causes were:

- a) Client's Internal Process Delay: Restricted access to retail shops postponed the completion of installation work, thereby extending the overall project duration.
- b) Client's Site Mishandling: The communication converter developed a faulty processor due to improper handling at the site by the client. This required a replacement order from the manufacturer, which took 65 days (Wednesday, 20 March 2024 to Monday, 3 June 2024). This defect not only delayed the transition to the next phase, but also impacted the project's DLP (defects and liability period).

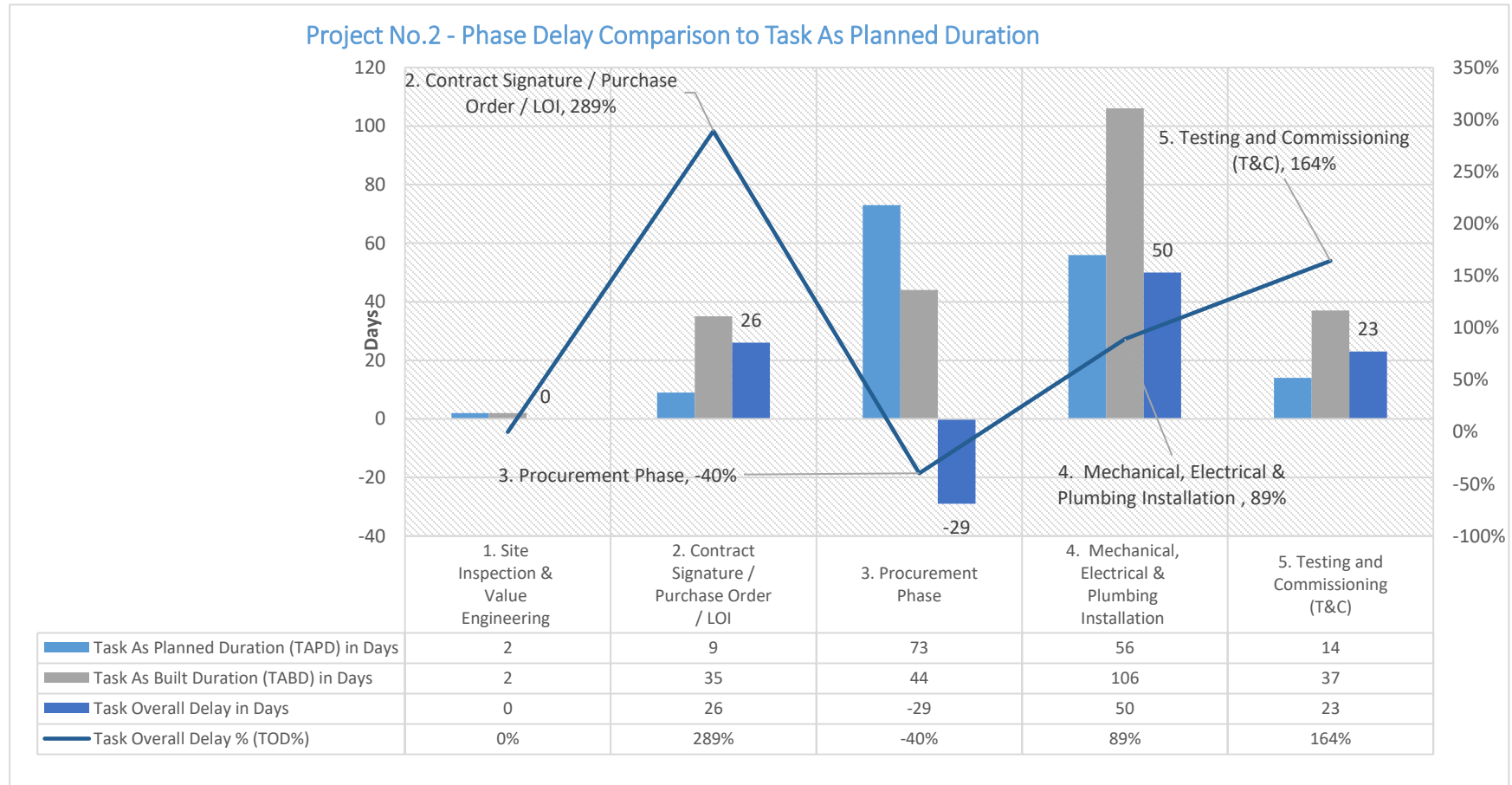
- c) Client's Internal Process Delay: Part of the IT work for this phase was delayed; this scope included supply, pulling and termination of the CAT6 cable between the nearest IDF room and the installed gateway. The delay took 44 days to be completed (Tuesday, 23 April 2024 to Wednesday, 12 June 2024).
2. Client's Internal Process Delay – Task 2.1 (Purchase Order / LOI): This critical task caused a delay of 26 days, representing 289% deviation from the planned duration. The delay was due to the client's pre-budget approval process and the client's internal administrative procedures.
 3. Client's Internal Process – Task 5.1 (T&C of system): This task was delayed by 4 days (80%) compared to the planned duration. The delay resulted from the included client's IT team taking additional time to finalise the IP Configuration, contributing 4.71% to the total project delay, as shown in Figure 17.
 4. Client's Internal Process Delay – Task 5.2 (Project Handover): This task experienced 2 days (40%) compared to the planned duration, and contributed 2.35% to the total project, as shown in Figure 17. The delay was caused by the prolonged process of performing the final work verification and signing the completion report.
 5. Client's Internal Process Delay – Task 5.3 (Project Invoicing): This task was delayed by 3 days (75%) above the baseline planned duration, with 3.53% impact on the actual total project delay, as shown in Figure 17. The delay was caused by extended client-side processing of the project invoicing.
 6. Task 3.1 (Internal Processes): This task was completed 2 days ahead of schedule, representing a 29% improvement compared with the project planned duration.

7. Task 3.2 (Material Delivery): This task was completed 27 days ahead of schedule, achieving a 40% improvement over the planned timeline.

4.4.6 Comparison of Phase Delays in Project No. 2

Figure 18

Phase Delay Comparison to Task As-Planned Duration of Project No. 2



Note. A negative value indicates that task was completed ahead of schedule, whereas a positive value represents a delay.

The highlighted delay phases of Project No. 2, compared to TAPD and as illustrated in Figure 18, are as follows:

- 1) Contract Signature/Purchase Order Phase: Delayed by 26 days (Task Overall Delay Percentage = 289% over the planned baseline). This delay was entirely attributed to the client's internal administrative procedures and pre-budget approvals process.
- 2) Testing and Commissioning (T&C) Phase: Delayed by 23 days (Task Overall Delay Percentage = 164% over the planned baseline). This phase represented the final contributor to the project delay on the critical path, accounting for 10.59% of the total project delay.
- 3) Procurement Phase: The planned duration of this phase was similar to that of the previous project. However, it was completed 29 days ahead of the planned schedule (Task Overall Delay Percentage = 40% below the planned baseline), positively impacting the overall project performance.
- 4) Mechanical, Electrical & Plumbing (MEP) Installation Phase: Delayed by 50 days (Task Overall Delay Percentage = 89% over the planned baseline). This phase represented the most significant critical path contributor, accounting for 58.82% of the total project delay.

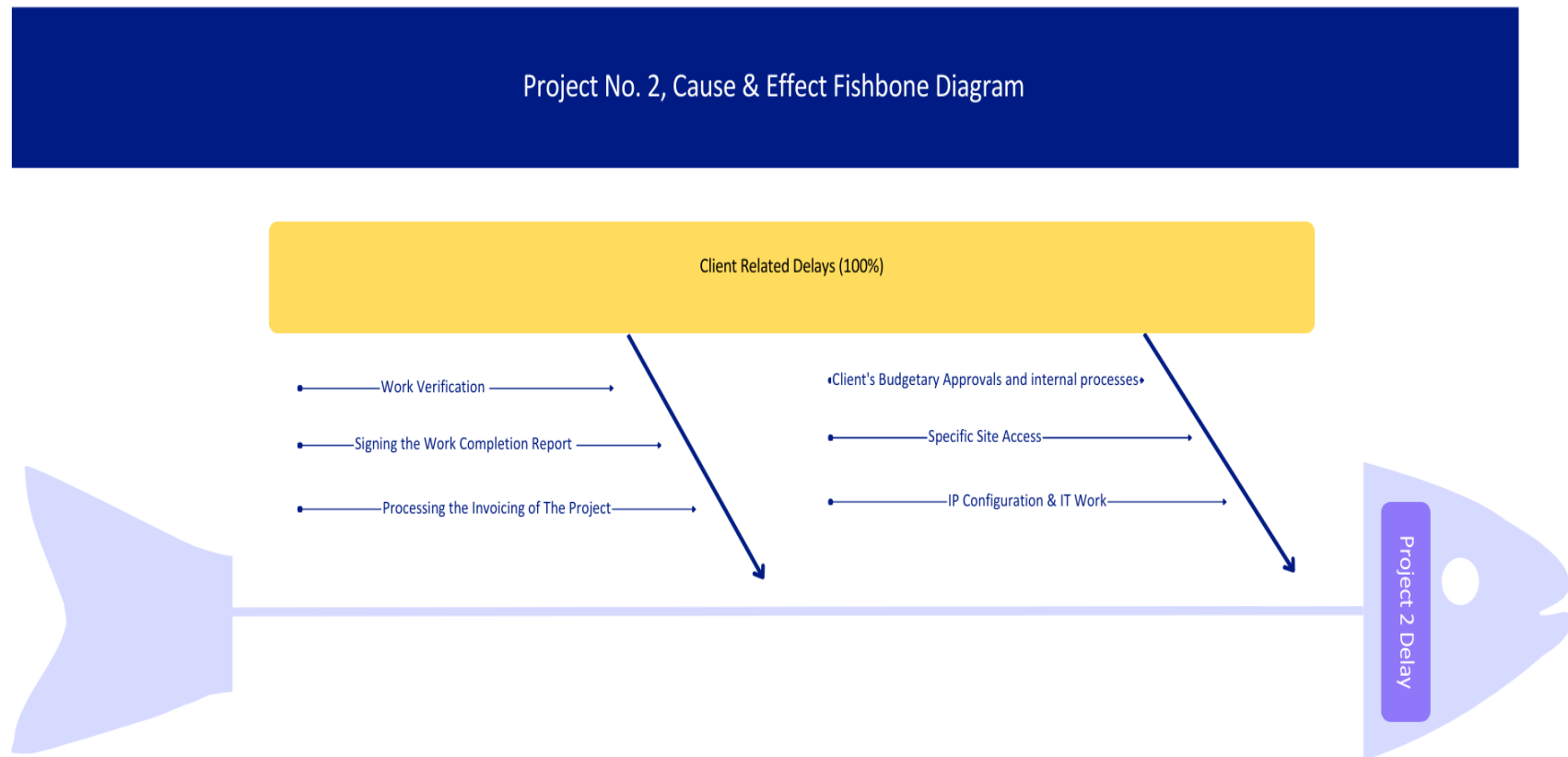
4.4.7 Analysis of Root Causes of Delays

Using an Ishikawa Diagram (Fishbone Diagram), the root causes of delays were summarised in Figure 19.

The root cause analysis shows that the primary overall project delay was entirely attributed to client-related factors, accounting for 100% of the total delay. This excludes two pauses during the project timeline, which were externally imposed on the client.

Figure 19

Ishikawa Diagram of Project No. 2



4.4.8 Risk Assessment and Mitigation Strategies of Project No. 2

Table 14

Risk Assessment and Mitigation Strategies of Project No. 2

Risk Category	Risk Identification	Impact of Risk	Likelihood	Mitigation Strategy
Site Access – Client-Related	Budget approvals, delayed PO	High	Medium	Pre-clear budgets; Provisional LOI mechanism.
Budgeted Project – Client-Related	Financial constraints impacting client's budget approvals (Task 2.1)	High	High	To reduce financial risk, clearly specify payment terms and milestones up front, for example financial verification or guarantees.
Site Access – Client-Related	Restricted site access delaying installation (Task 4.2)	High	Medium	Pre-schedule access via detailed approved plan of access with Facility Management/Mall's Operations with regular coordination meetings to avoid delays.
Site Mishandling by Client	Mishandling causing faulty equipment & reordering (Task 4.2)	High	Medium	Before beginning installation, assess the client site's safety; keep backup supplies on hand or have quick replacement agreements with suppliers.
IT Infrastructure – Client-Related	IT infrastructure delay (CAT6 cable installation scope) (Task 4.2)	High	Medium	Early coordination with the client's IT Team to include extensive infrastructure planned preparation in the project timetable.
IP Configuration – Client-Related	IT team of the mall's operation delayed the IP Configuration scope (Task 5.1)	Medium	Medium	Early coordination with the client's IT Team to include clear planned preparation in the project timetable, also define clear responsibility with deadlines for client teams.
Project Handover – Client-Related	Delayed project handover documentation (Task 5.2)	Medium	Low	Proactively manage client relationships to expedite work verification and sign-offs of handing over documents.
Project Invoicing – Client-Related	Delayed invoicing processing by client (Task 5.3)	Medium	Low	Proactively manage client relationships to expedite the signatures of handing over documents.
Risk Rating Criteria:	Low	Medium	High	

Note. For more information on risk levels and likelihood or impact of risk, see Appendix E.

4.5 Project No. 3 Discription

Project No. 2 and Project No. 3 both commenced simultaneously on 29 April 2023 and were completed on 15 July 2024. The main scope of work involved the integration and rectification of the communication loop for 31 existing BTU Metres into the mall's Building Management System (BMS) as a centralised system.

Effective and efficient energy monitoring was essential within the same retail landmark where the previous projects had been successfully completed. The shopping mall receives over 25,000 visitors per day, and its HVAC Systems cover hundreds of thousands of square feet.

Building upon the success of earlier projects, this phase continued the rectification and integration of the existing seventh loop network, which had become completely faulty. The network suffered from misconfigured communication paths, obsolete BTU Metres, outdated cabling, broken trunking and failures in data logging, all of which resulted in a loss of control over energy consumption.

4.5.1 Project No. 3 Scope of Work

The scope of work of the project is comprised of:

1. Replacing outdated cables with high-grade communication cables, including trunking or conduits.
2. Installation, testing and commissioning of advanced communication gateways.
3. Integration of 31 BTU Metres into centralised Niagara platform BMS.
4. Configuration of 15-minute interval logging of data points, yielding 1,440 points per day per metre with an estimated 1.4 million (1,339,200) data points per month for 31 BTU Metre to ensure accurate energy consumption tracking:

- 1) Supply Temperature (°C).

- 2) Return Temperature (°C).
 - 3) Temperature Difference between Supply & Return (ΔT) (°C).
 - 4) Flow Rate (L/S)
 - 5) Energy Consumption (kWh).
5. Virtual Local Area Network (VLAN) setup coordination with the mall's IT team to ensure cybersecurity and data flow.
 6. On-site training to ensure smooth handover.

4.6 Project No. 3 Analysis

This project (Project No. 3), similar to previous projects, consisted of nine tasks and five phases, ranging from inspection, contractual approvals, procurement, installation and commissioning.

A quantitative project management method was used to conduct the delay analysis, comparing the As-Built durations with the As-Planned duration. The analysis also included calculations of float (slack), delay occurrences and a parentage-based metric formula indicating the impact of task and phase delays on overall project completion.

The overall project delay for Project No. 3 was approximately 4%. Although this percentage appears minor, it still had a measurable impact due to the cascading effects on operations, costs and interdependencies between the client and the contractor (service provider). The actual project duration was 380 days. All related analysis, quantification and calculations of Project No. 3 can be found in Appendix C.

4.6.1 Work Breakdown Structure Summary of Project No. 3:

Similarly to Project No. 1 and Project No. 2, Project No. 3 comprised of five phases, as follows:

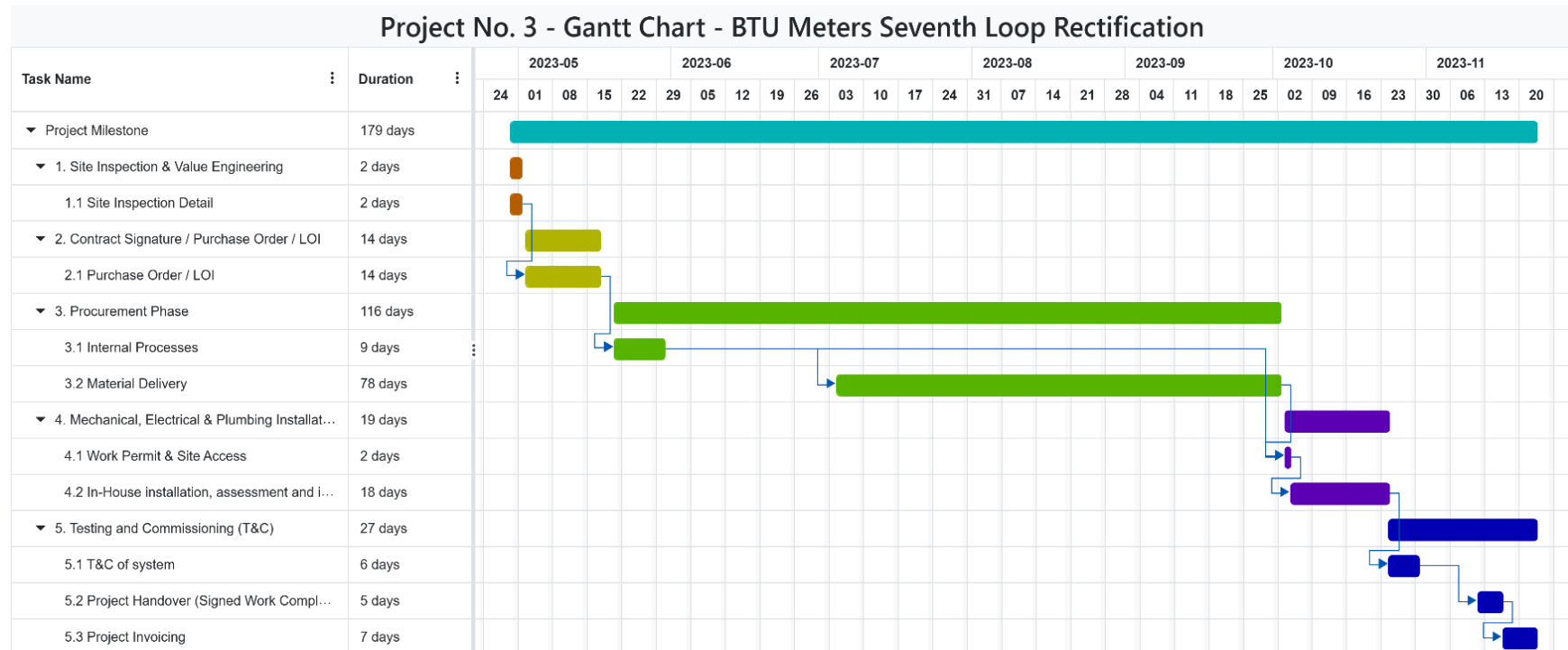
- 1) Preliminary Inspection and Estimation phase.
- 2) Contractual Documentation Phase.
- 3) Procurement and Logistics Phase.
- 4) Mechanical, Electrical and Plumbing Installation Phase.
- 5) Testing and Commissioning Phase.

Each phase was divided into specific technical, administrative and commercial tasks, totalling nine tasks. The project allowed limited concurrency among phases and tasks, resulting in a waterfall model with sequential dependencies based on a finish-to-start relationship, as illustrated in Figure 20.

4.6.2 Gantt Chart Analysis

Figure 20

Gantt Chart of Project No. 3



The As-Built Durations formed the basis of the Gantt Chart in Figure 20. The project commenced on Saturday, 29 April 2023 and was completed on Monday, 15 July 2024, with a total duration of 380 days. This excludes Sundays as non-working days and 253 days of client-requested holds and pauses.

Figure 20 presents a visual timeline of the project activities, highlighting the key milestones, major phases and challenges encountered throughout the execution. The main observations are summarised below:

- 1) First Hold / Pause: The first major hold occurred between two critical tasks. The client requested this pause due to financial constraints, including the need to allocate a budget for this project. This resulted in a gap of 177 days between Task 1.1 (Site Inspection Detail), which ended on Monday, 1 May 2023, and Task 2.1 (Purchase Order / LOI), which started on Thursday, 23 November 2023, as shown in Table 15. Since this hold was initiated by the client and it was outside the contractor's control, it was excluded from the delay analysis as a contributing factor.
- 2) Second Hold / Pause: A second hold resulted in a gap of 25 days between Task 3.2 (Material Delivery), which ended on Wednesday, 24 April 2024, and Task 4.1 (Work Permit & Site Access), which started on Friday, 24 May 2024, as shown in Table 15. This hold was requested by the mall's operations due to the following reasons:
 - a. Limited Site Access: Difficulty in obtaining access inside to several retail shops from the client's side, overlapping with activities from Project No. 2.
 - b. Financial Struggles: Delays in client payments affected project progress and manpower deployment.
- 3) Initiation Phase: The project began with a site inspection and subsequent value engineering and estimation, followed by the submission of a techno-commercial proposal to the client for approval. Upon receiving the purchase order (PO) or letter of intent (LOI), the procurement phase commenced.

- 4) Longest Task: Task 3.2 (Material Delivery) had the longest duration in the project timeline, lasting 78 days.
- 5) Final Phase: The Testing & Commissioning Phase (Phase 5) represented the final phase of the project.

Table 15*Unofficially Requested Pauses of Project No. 3*

Pause or Hold Discription of Project No. 3	Starting Date	Completion Date	Total Days (Excluding Sundays)
First Pause between Task 1.1 (Site Inspection Detail) and Task 2.1 (Purchase Order / LOI)	Monday, 1 May 2023	Thursday, 23 November 2023	177 days
Second Pause between Task 3.2 (Material Delivery) and Task 4.1 (Work Permit & Site Access)	Wednesday, 24 April 2024	Friday, 24 May 2024	25 days
Total Duration of Project No. 3 in Days			380 days

4.6.3 Critical Path Analysis of Project No. 3

Based on task criticality calculations: Condition 1: $(TABD) > (TAPD)$. Then Condition 2: $(@[Delay Occurrence?]) = 'Yes, delayed phase'$. Then Condition 3: $([TAPD] - [TABD]) \leq 0$. Figure 21 and Table 16 distinguish between critical tasks

(shown using blue arrows) and non-critical tasks (shown using black arrows) of the project, as visualised below:

- 1.1 Site Inspection Detail
- 2.1 Purchase Order / LOI
- 3.1 Internal Processes
- 3.2 Material Delivery
- 4.1 Work Permit & Site Access
- 4.2 In-House Installation, Assessment and Inspection
- 5.1 T&C of system
- 5.2 Project Handover (Signed Work Completion Report)
- 5.3 Project Invoicing

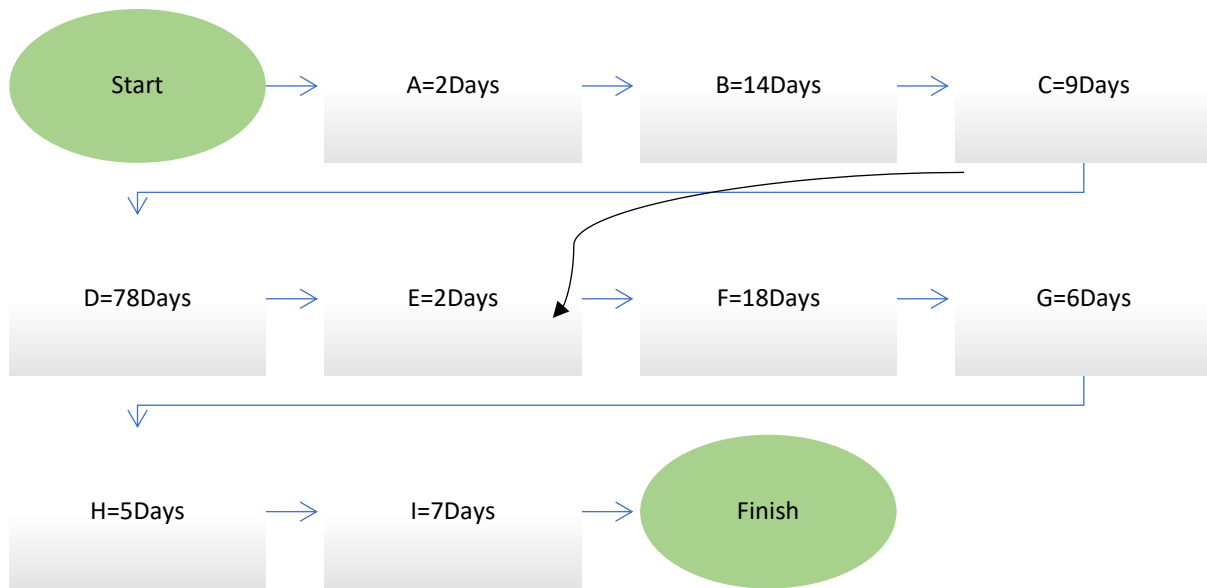
These activities are crucial to the project timeline, with zero slack (float). Each of the above tasks is vital to maintaining the planned schedule, and any delay in one will directly impact the overall project duration, resulting in a potential extension of the completion date.

Table 16

Critical Path of Project No. 3 – BTU Metres Seventh Loop Rectification

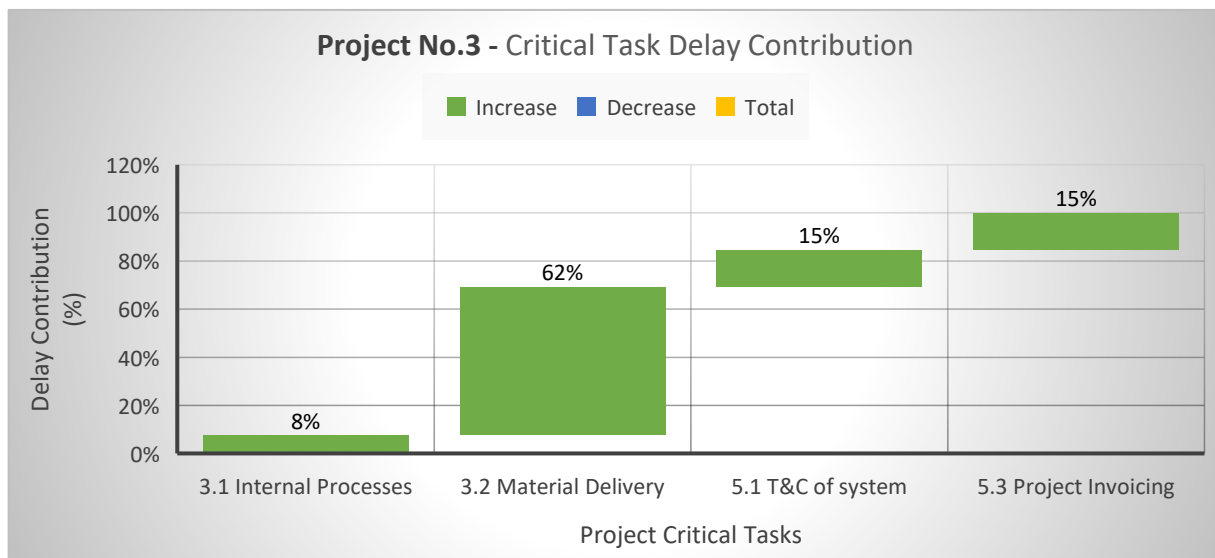
ID	Predecessor Activities		Duration in Days	Activity Description
A	-	-	2 days	1.1 Site Inspection Detail
B	A		14 days	2.1 Purchase Order / LOI
C	B		9 days	3.1 Internal Processes
D	C		78 days	3.2 Material Delivery

E	C	D	2 days	4.1 Work Permit & Site Access
F	E		18 days	4.2 In-House Installation, Assessment and Inspection
G	E		6 days	5.1 T&C of system
H	G		5 days	5.2 Project Handover (Signed Work Completion Report)
I	H		7 days	5.3 Project Invoicing

Figure 21*Critical Path of Project No. 3*

Note. Blue arrows are to illustrate the critical path, while Black arrows are non-critical paths.

4.6.4 Critical Task Delay Contribution of Project No. 3

Figure 22*Critical Task Delay Contribution of Project No. 3*

The Bar Chart in Figure 22 illustrates the prioritisation of delay impacts across critical path tasks, highlighting their contribution to the overall project timeline. The analysis shows that Task 3.2 (Material Delivery) was the primary contributor, accounting for 62% of total project delay.

The secondary critical tasks, Task 5.1 (T&C of system) and Task 5.3 (Project Invoicing), each contributed 30% to the actual total delay. These delays were largely related to client-side processes involving IT coordination and invoicing procedures.

Moreover, Task 3.1 (Internal Processes) contributed 8% to the overall delay. Although smaller in scale, it still influenced the overall project completion due to its relationship with procurement and installation tasks. The findings indicate that most delays were concentrated in the installation and handover phases, reflecting the cascading impact of client-side and administrative dependencies.

A detailed analysis of the delay contributions, risks, root causes, risk assessment and mitigation strategies follows in the next section.

4.6.5 Analysis of Delay Contribution to the Initial Planned Duration of Project No. 3

Figure 23

Project No. 3 Task Delay Comparison to Task As-Planned Duration

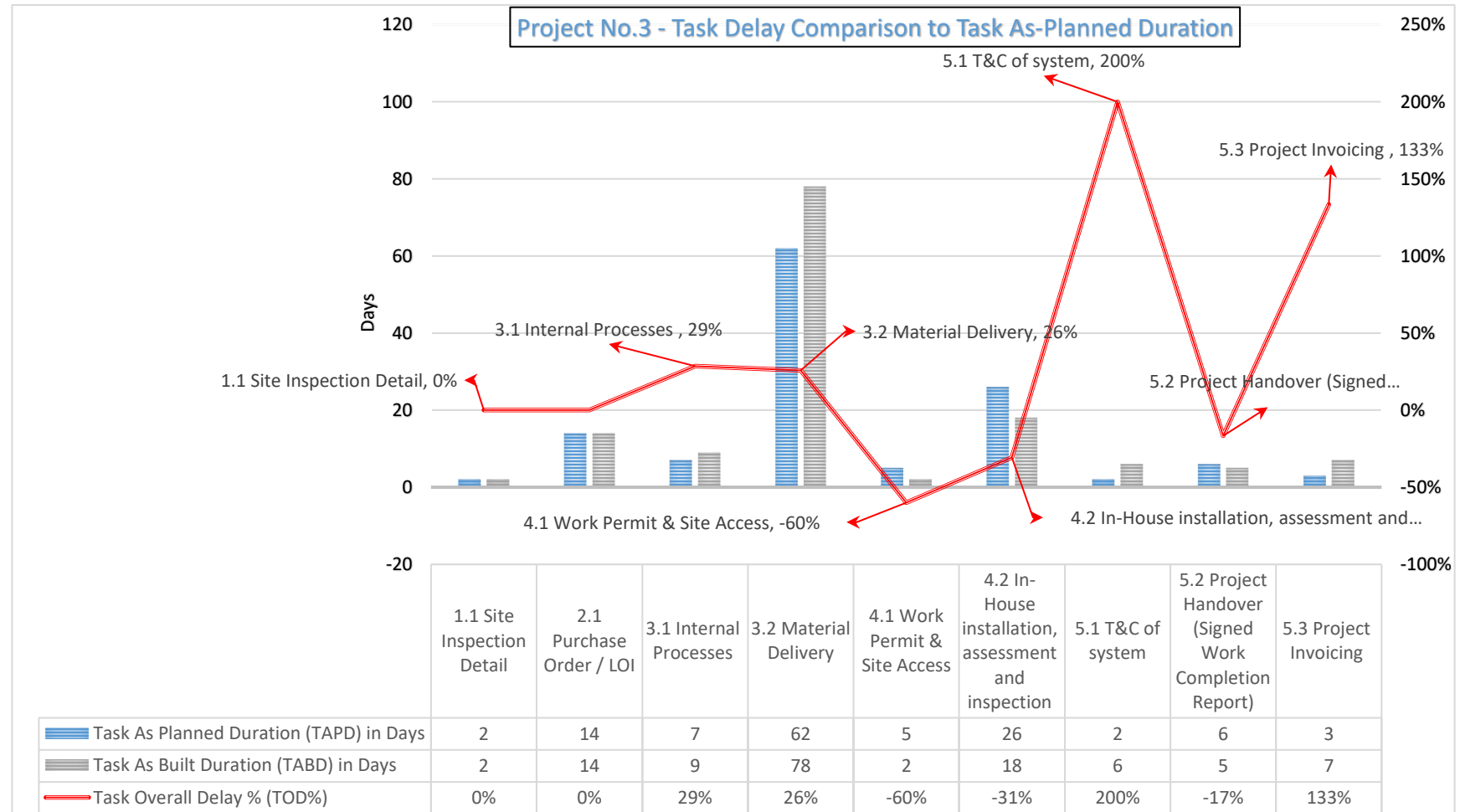


Table 17

Project No. 3 – Reasons for Delay and Delay Contribution to the Initial Planned Duration

Project Task	Task Contribution Delay %	Delay Category	Reason for the Delay
3.1 Internal Processes	7%	Internal Process Delays	Delayed due to internal budget approval procedures.
3.2 Material Delivery	7%	Procurement & Supply Chain Delays	Delay in the process of procurement for partial material delivery due to limited availability of specific items.
5.1 T&C of System	52%	Client-Related Delays	Delayed due to IT-related work dependencies from the client (Client's Process Delay).
5.3 Project Invoicing	34%	Client-Related Delays	Delayed due to extended client-side processing during the project invoicing phase.

Table 18*Delays by Category – Project No. 3*

Project No. 3 – Category Contribution Delay Percentage	
Delays as per Category	Category Contribution Delay %
Client-Related Delays	86%
Internal Process Delays	7%
Procurement & Supply Chain Delays	7%

Upon reviewing the data of the project and based on the analysis findings illustrated in Figure 23, Table 17 and Table 18, the results revealed that the following tasks contributed 14% to the delay in the initial planned project duration. The delays are categorised as follows:

- 1) Internal processes delays – Task 3.1 (Internal Processes): Delayed by 2 days, representing a 29% delay compared to the project’s planned baseline. The delay was caused by internal financial budget approval procedures.
- 2) Procurement and supply chain delays – Task 3.2 (Material Delivery): Delayed by 16 days, resulting in an impact of 26% delay against the project’s planned baseline. The delay occurred due to the unavailability of certain materials required for partial deliveries.

The remaining delays were attributed to client-related factors, which accounted for 86% of the total delay in the initial planned project duration, as detailed below:

- 1) Client’s Internal Process Delay – Task 5.1 (T&C of system): Delayed by 4 days due to the client’s IT Team requiring additional time to finalise IP configuration. This task

contributed 15% to the total project delay (as illustrated in Figure 23) and contributed 34% to the project's initial planned timeline delay (as shown in Table 17).

- 2) Client's Internal Process Delay – Task 5.3 (Project Invoicing): Delayed by 4 days, contributing 15% to the total project delay (as shown in Figure 23) and 52% to the delay in the initial planned timeline (as detailed in Table 17). The delay was due to extended client-side processing during the invoicing phase.

Furthermore, several tasks were completed ahead of the planned baseline, as follows:

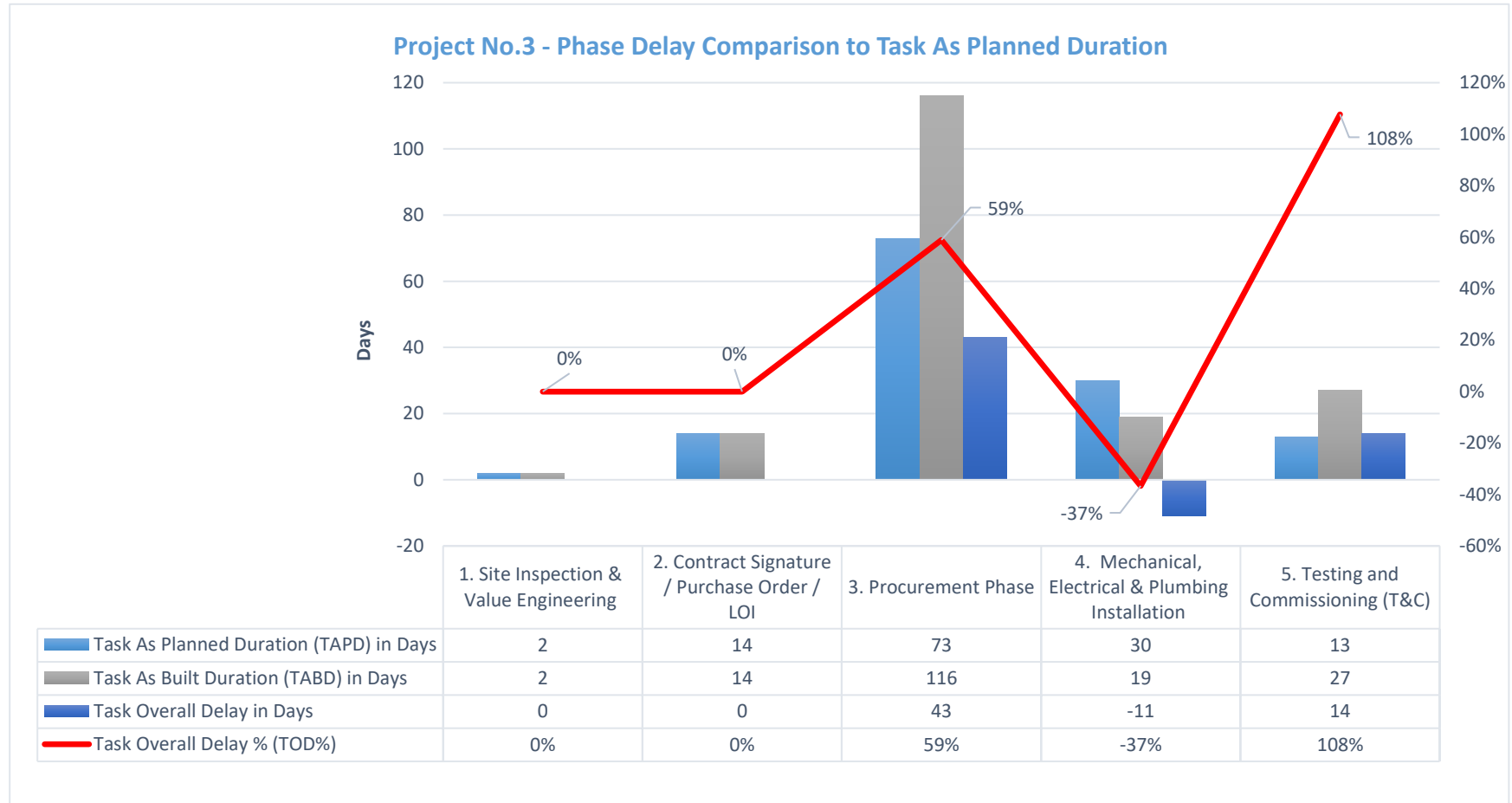
- Task 4.1 (Work Permit & Site Access): 60% ahead of project planned timeline.
- Task 4.2 (In-House Installation, Assessment and Inspection): 31% ahead of planned schedule.
- Task 5.2 (Project Handover): 17% ahead of planned schedule.

These early completions positively influenced the overall project performance by offsetting portions of the delay caused by client and process-related factors.

4.6.6 Comparison of Phase Delays of Project No. 3:

Figure 24

Project No. 3 Phase Delay Comparison to TAPD



Note. A negative value indicates that task was completed ahead of schedule, whereas a positive value represents a delay.

The highlighted delay phases compared to the TAPD of Project No. 3 are illustrated in Figure 24, and are as follows:

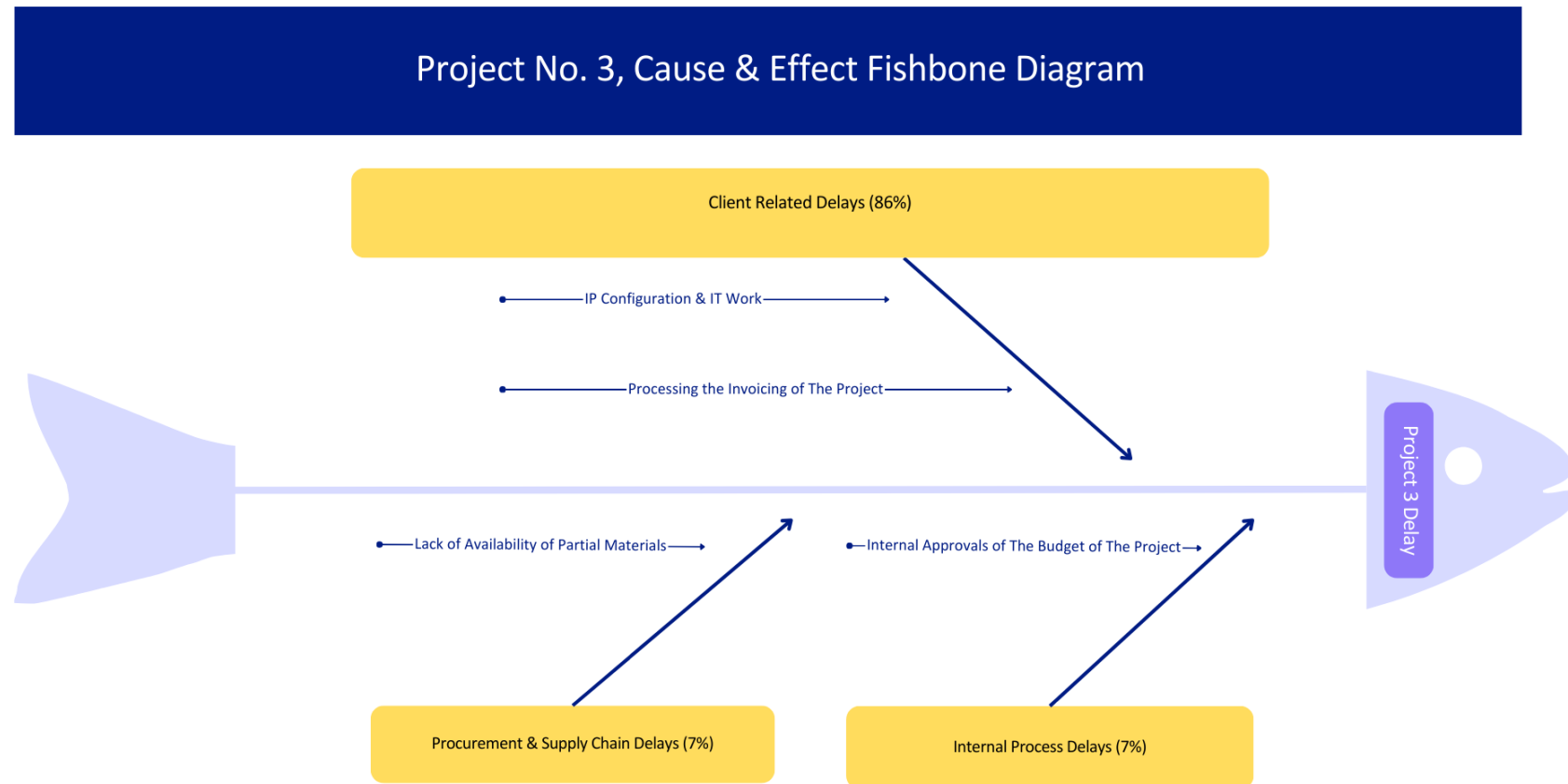
- 1) Contract Signature/Purchase Order Phase: Delayed by 26 days (Task Overall Delay Percentage = 289% above the planned baseline), as shown in Figure 24. This delay was entirely due to the client's internal procedures and the client's pre-budget approval process.
- 2) Procurement Phase: The planned duration for this phase was similar to Project No. 2; however, it was completed 29 days ahead of the planned schedule (Task Overall Delay Percentage = 40% below the planned baseline), as shown in Figure 24. This early completion has a positive impact on the overall project timeline performance.
- 3) Mechanical, Electrical & Plumbing (MEP) Installation Phase: Delayed by 50 days (Task Overall Delay Percentage = 89% above the planned baseline), as illustrated in Figure 24. This phase represents the most significant contributor to the critical path delay, accounting for 62% of the overall project delay.
- 4) Testing and Commissioning (T&C) Phase: Delayed by 23 days (Task Overall Delay Percentage = 164% above the planned baseline), as indicated in Figure 24. This phase formed the final critical path contributor, accounting for 30% of the overall project delay.

4.6.7 Analysis of Root Causes of Delays

Using an Ishikawa (Fishbone) Diagram, the root causes of delays are summarised in Figure 25. The Root Cause Analysis revealed that the primary source of project delay was client-related delays, which accounted for 86% of the total project delay. Additionally, internal process delays contributed 7%, while procurement and supply chain delays contributed another 7% to the overall project delay.

Figure 25

Ishikawa Diagram of Project No. 3



4.6.8 Risk Assessment and Mitigation Strategies of Project No. 3

Table 19

Project No. 3 Risk Assessment and Mitigation Strategies

Risk Category	Risk Identification	Impact of Risk	Likelihood	Mitigation Strategy
Internal Processes' Delays	Internal process's approvals of financial budget of project (Task 3.1)	High	High	Assign decision maker authority. Implement a quicker approval process. Increase frequency of review meetings to speed up the process.
Procurement & Supply Chain Delays	Stock unavailability of materials partially (Task 3.2)	High	High	Establish a strong relationship with several suppliers to ensure materials availability. Implement an advanced tracking system for procurement of needed materials.
IP Configuration – Client-Related	IT team of the mall's operation delayed the IP Configuration scope (Task 5.1)	Medium	Medium	Early coordination with the client's IT Team to include clear planned preparation in the project timetable; also define clear responsibility with deadlines for client teams.
Project Invoicing – Client-Related	Delayed invoicing processing by client (Task 5.3)	Medium	Low	Proactively manage client relationships to expedite the signatures of handing over documents.
Risk Rating Criteria:	Low	Medium	High	

Note. For more information on risk levels and likelihood or impact of risk, see Appendix E.

Chapter 5: Research Conclusion, Recommendations and Limitations

5.1 Research Conclusion

5.1.1 Task Delays in MEP/Energy Projects

Figure 26 presents an Area Chart that visualises the percentages of task delays compared to the Task As-Planned Duration (TAPD) across the three MEP/Energy projects that were successfully handed over. The chart demonstrates how different tasks experienced varying levels of delay throughout the project life cycle. A positive value in the chart indicates the estimated planned schedule was underestimated, while a negative value signifies that certain tasks were completed ahead of their planned timeline.

The data reveal that Project No. 2 experienced a significant delay in Task 2.1 (Purchase Order / LOI), recording a 289% increase compared with the planned timeline. This finding highlights the need for improvements in the procurement phase, and the development of strategies to mitigate future risks of delay.

By contrast, Project No. 1 and Project No. 3 demonstrated improvements in the same task (Purchase Order / LOI), with delays reduced to 90% and 0%, respectively.

Additionally, Task 4.2 (In-House Installation, Assessment and Inspection) in Project No. 1 showed the most significant delay, reaching 728% compared to the planned timeline, while in Project No. 2 the delay was reduced to 94%. These results indicate persistent challenges in the execution phase, particularly in site coordination and implementation efficiency.

Figure 26

Task Delay Comparison to Task As-Planned Duration for Three MEP/Energy Projects

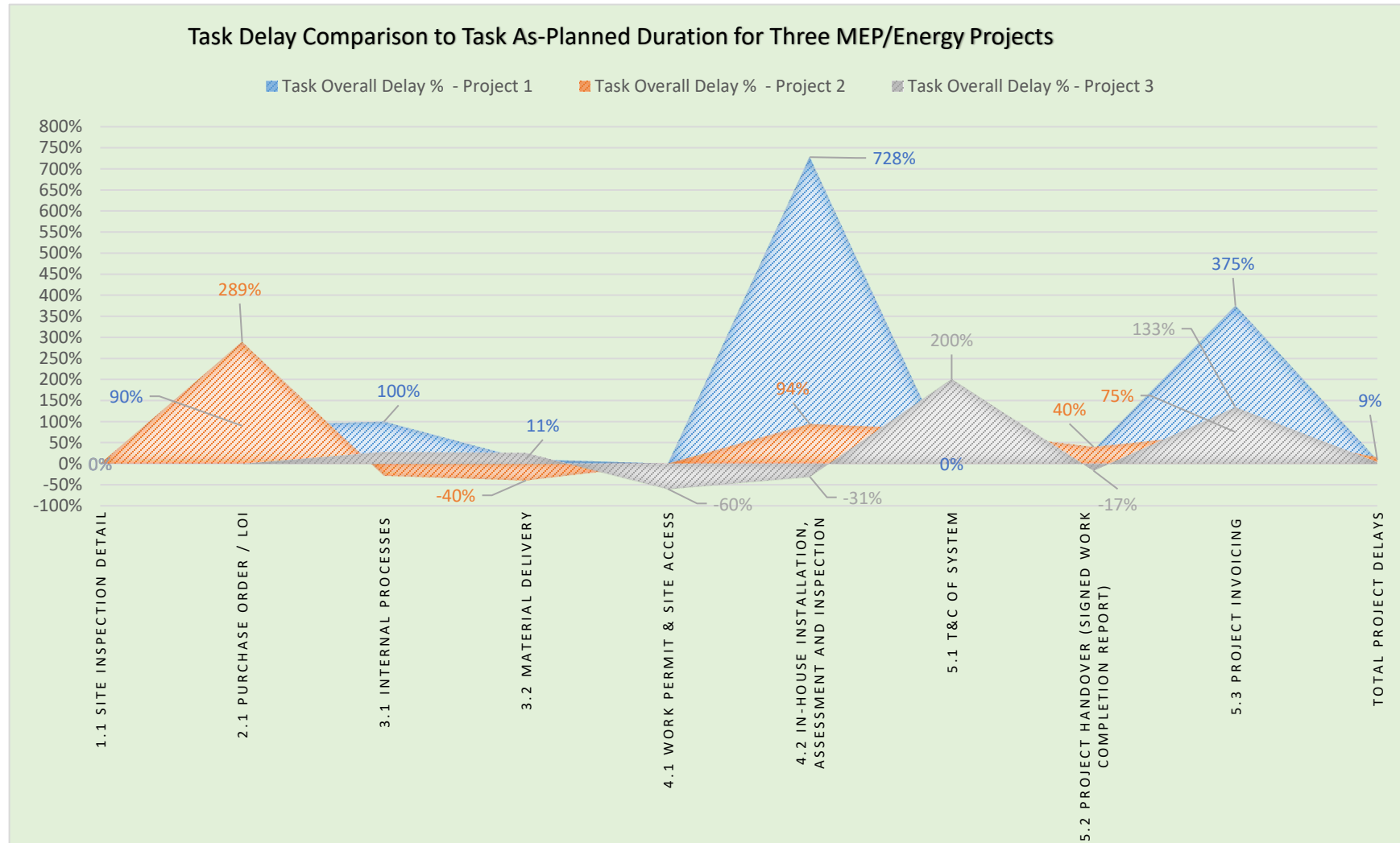


Figure 27 presents a Pareto Chart, a valuable project management tool used to identify the most significant factors contributing to project delays across three MEP/Energy projects successfully completed at a major retail landmark and one of the most vibrant shopping malls in the UAE. The key observations derived from the analysis are summarised below.

5.1.1.1 Major Delays. Task 4.2 (In-House Installation, Assessment and Inspection) experienced the most substantial delay of 791% compared to its planned timeline, followed by Task 5.3 (Project Invoicing) with a 583% delay, and Task 2.1 (Purchase Order / LOI) with a 379% delay. These three tasks collectively represent the most significant contributors to the overall project delays, as evident from the steep rises at the beginning of the cumulative Pareto Line in Figure 27. Given Task 4.2, Task 5.3 and Task 2.1, prioritising improvement efforts in these specific areas could substantially reduce overall project delay and enhance efficiency in future implementations.

5.1.1.2 Accumulative Impact of Delays. The cumulative percentage of delays, represented by the red Pareto Line in Figure 27, illustrates that a small number of tasks account for the majority of the project delays. This pattern reflects the Pareto Principle (80/20 Rule); where 80% of the impacts originate from 20% of the causes. In this context, a limited set of delay-prone tasks generated the majority contributors of the schedule overruns across all three projects.

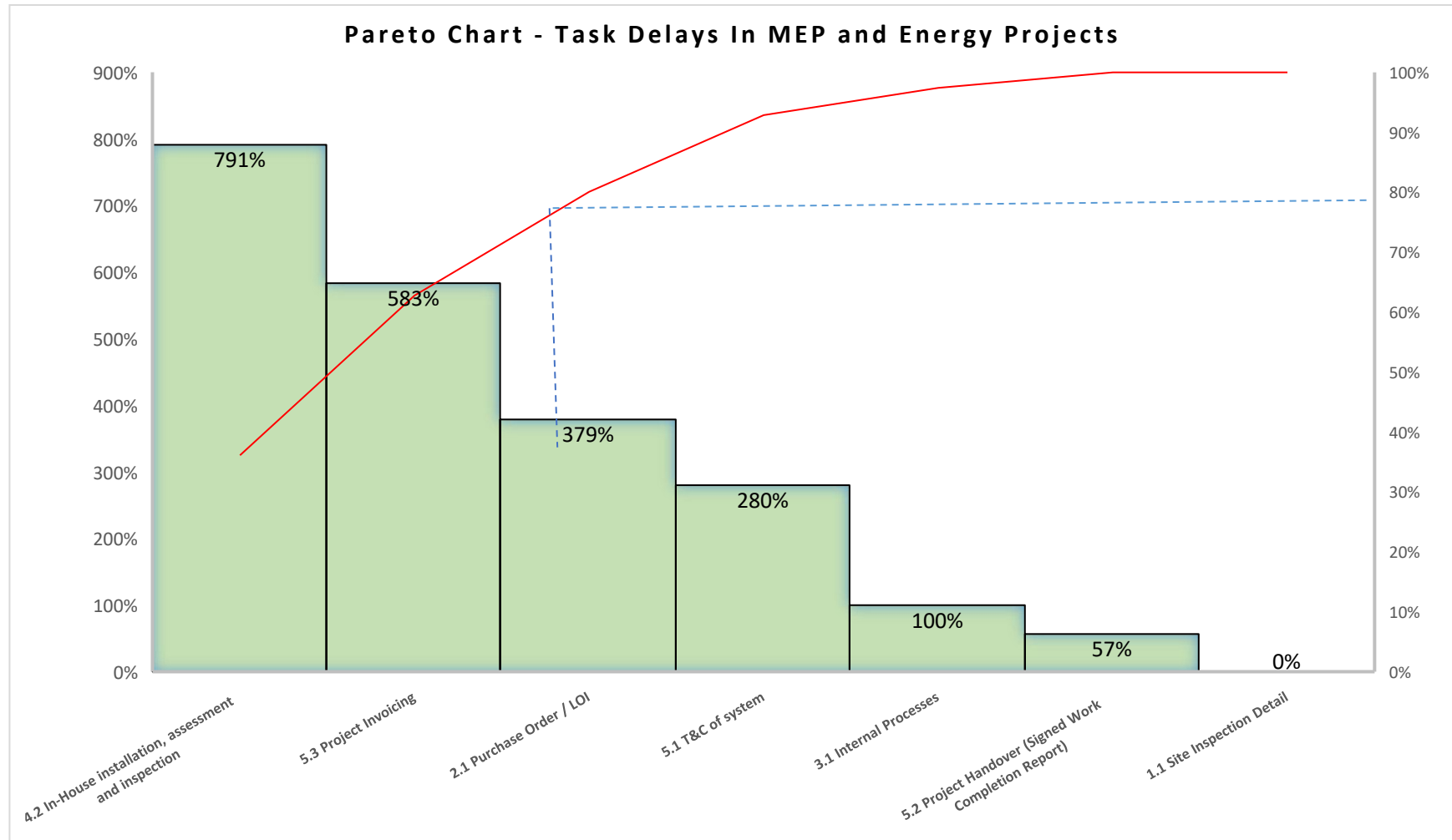
5.1.1.3 Minor Delays. Tasks such as Task 5.1 (T&C of system), Task 3.1 (Internal Processes) and Task 5.2 (Project Handover) exhibited minimal delays, indicating that these tasks were effectively managed and well-coordinated during project execution. These results suggest maturity and consistency in project control mechanisms for these process areas.

5.1.1.4 Process Improvement. Insights drawn from the Pareto analysis in Figure 27 highlight several targeted areas for processes improvement, particularly in the installation and execution phase and during the invoicing process. Key recommendations are below, and these focused interventions will strengthen project delivery efficiency, minimise recurring bottlenecks and contribute to more predictable project outcomes across future MEP and energy retrofit projects:

- Early coordination with client-side technical and administrative teams to mitigate approval-related delays.
- Proactive client relationship management to accelerate the invoicing cycle and documentation process.
- Enhanced site assessment and preparation protocols, particularly within client-managed retail spaces, to prevent access or safety-related disruptions.

Figure 27

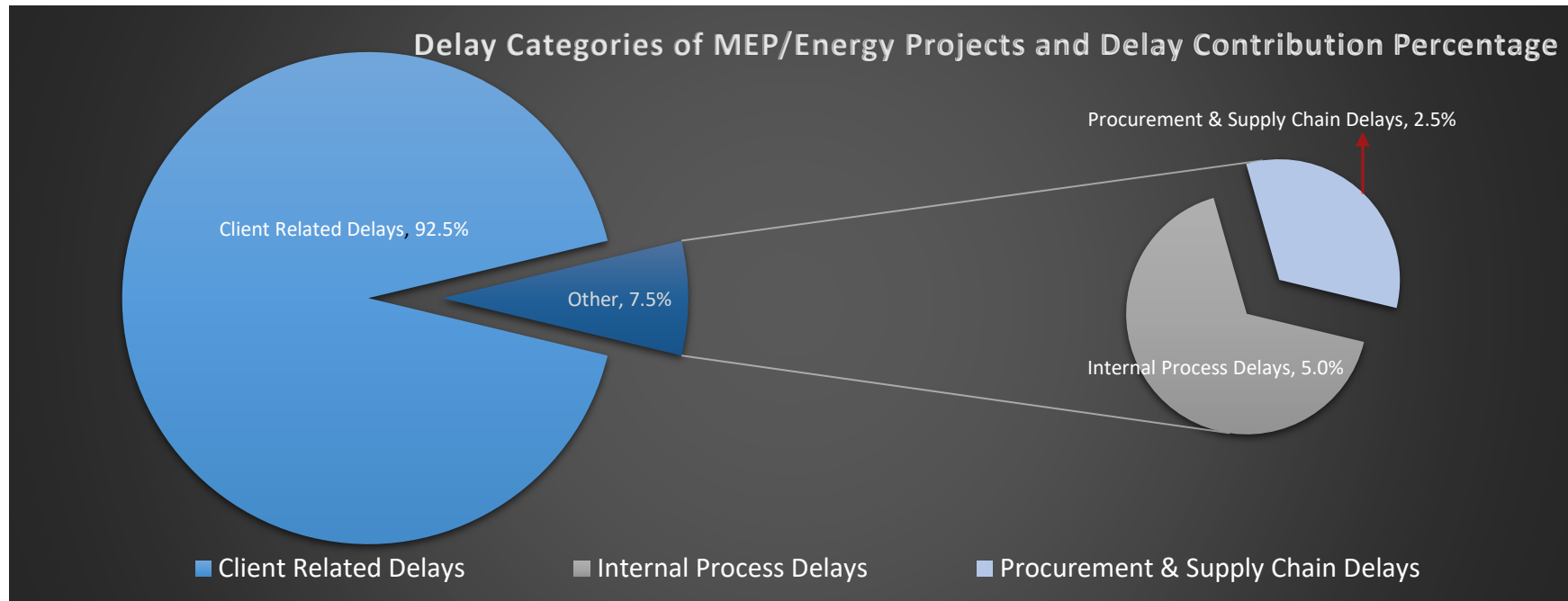
Pareto Chart: Task Delays in MEP/Energy Projects



5.1.2 Delay Categories of MEP/Energy Projects

Figure 28

Delay Categories of Energy/MEP Projects



The Pie Chart in Figure 28 effectively demonstrates the areas where project management efforts should be prioritised to minimise project delays, and showing the comparative impact of different delay categories or types within the engineering organisation.

The additional breakdown of the chart provides a clearer understanding of minor delays, which although smaller in percentage, still contribute significantly to overall delays in MEP/Energy projects. The findings are summarised below.

5.1.2.1 Client-Related Delays. Figure 28 indicates that client-related delays accounted for 92.5% of total project delays in MEP/Energy projects. These delays included: restricted site access, site equipment mishandling, improper planning, financial constraints, changes in work timings and slow approval processes. Such challenges highlight the dominant influence of external client factors on project timelines. Proactive communication, early coordination and robust contractual planning are essential to mitigate these types of delays.

5.1.2.2 Internal Process Delays. According to Figure 28, internal process delays contributed approximately 5% to the overall project delays. These delays suggest inefficiencies within internal workflows of the engineering organisation, particularly in approval and decision-making procedures.

Common issues include delays in internal approval chains, which can be mitigated by:

- Assigning clear decision-making authority to key personnel
- Implementing a streamlined approval process
- Conducting internal process audits to identify and address recurring inefficiencies

These corrective actions can strengthen organisational responsiveness and improve overall project control.

5.1.2.3 Procurement and Supply Chain Delays. These delays contributed only 2.5% to the total delay in MEP/Energy projects, representing a relatively minor impact. However, these delays can still affect project continuity if not managed proactively. To mitigate these

risks, it is recommended to build strong and reliable relationships with multiple suppliers, and implement an advanced material tracking system to enhance visibility and predictability in procurement operations.

5.1.3 Summary of Research Conclusion

The three analysed MEP/Energy projects represent part of a broader portfolio of seven concurrent projects executed with an operational shopping mall facility in Sharjah, where numerous external and internal factors critically influence project performance. The selected projects were chosen due to their data completeness, similarity in scope and relevance to the research objectives, which focus on quantifying and mitigating project delays within the engineering organisation.

In engineering sectors, customer satisfaction particularly is a fundamental determinant of long-term business growth, directly influencing repeat orders and client relationships. In this organisation, customer satisfaction is systematically monitored and evaluated as a key performance metric by both internal and external auditors through the Quality, Health, Safety and Environment (QHSE) Department.

However, delays in project delivery can significantly impact customer satisfaction, often leading to dissatisfaction and potential loss of future business opportunities. Such delays may arise from missed deadlines, increased costs or disrupted operational plans.

Accordingly, this research conducted a detailed quantitative delay analysis and developed data-driven mitigation strategies, focusing on:

- 1) Critical task path identification
- 2) Critical task delay contribution
- 3) Task delay contribution to the initial project plan

- 4) Phase delays compared to the initial project plan
- 5) Root Cause Analysis of delays
- 6) Risk management and mitigation strategies

The findings illustrated through Figures 26–28 provided a comprehensive overview of the magnitude and nature of delays across the projects. The Area Chart (Figure 26) showed that the execution and procurement phases (Task 4.2 and Task 2.1) were the most delay-prone, highlighting the need for enhanced site coordination and procurement management.

The Pareto Chart (Figure 27) confirmed that a limited number of critical tasks contributed disproportionately to total delays, validating the Pareto Principle (80/20 Rule). This emphasises the importance of focusing project improvement efforts on these few high-impact areas, particularly installation, invoicing and purchase order processes.

The Pie Chart (Figure 28) revealed that client-related factors accounted for approximately 92.5% of the total project delays. These delays included: restricted site access, slow approval processes of client, financial constraint and site equipment mishandling. Internal process delays contributed to 5%, while procurement and supply chain challenges represented 2.5% of the total delays.

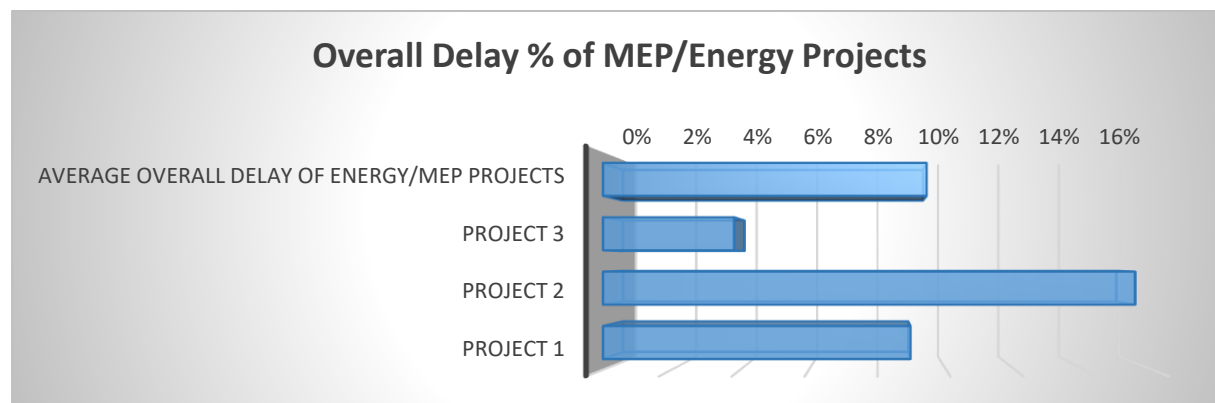
Figure 29*Overall Delay Percentage of Energy/MEP Projects*

Figure 29 indicates that the average overall delay across all Energy/MEP projects was approximately 9%, which reflects the cumulative impact of scheduling or planning inefficiencies and client-related factors identified previously. Among the three projects, Project No. 2 experienced the highest delay of 16%, attributed mainly to client-related delays. In contrast, Project No. 3 recorded a relatively low delay percentage of 4%, demonstrating improved project control and coordination measures.

Overall, Figure 29 illustrates that while moderate average delays are inherent to a complex retrofit environment, particularly within operational retail facilities, there remains substantial opportunity to minimise future delays through improved client coordination, process streamlining and strategic planning.

These insights not only serve to enhance project management practices but also act as an educational and transparency tool for clients, providing them with data-driven evidence of the causes and consequences of project delays on both client and vendor (service provider).

5.2 Research Limitation

This research was subject to both resource and methodological constraints, which impacted the depth and the scope of the analysis.

While Microsoft Excel was successfully utilised for the comparison between As-Planned and As-Built durations, delay quantification, critical path identification and the development of charts, tables and graphs, other analytical aspects were limited due to restricted tool accessibility within the engineering organisation. The primary limitations are summarised below:

1) **Manual Efforts and Limited Access to Advanced Project Management Tools:**

The unavailability of advanced project management software within the engineering organisation required reliance on publicly accessible online tools to generate the Gantt Chart and Ishikawa (Fishbone) Diagrams. This limitation required extensive manual data input to ensure accuracy, which likely affected the depth of analysis and increased the time required to complete the research.

Consequently, the absence of integrated digital tools (such as MS Project or Primavera P6) constrained the ability to perform real-time performance tracking and automated schedule variance.

2) **Gantt Chart Restricted to As-Built Durations:** The Gantt Chart was created using an online platform that displayed only the As-Built Durations, without visually illustrating the variance or deviation from the As-Planned Duration (baseline), which is a key element in evaluating schedule performance (PMI, 2017). Nevertheless, the comparison between As-Planned Duration and As-Built

Durations was accurately conducted using Microsoft Excel, ensuring that delay quantification remained valid despite this visual limitation.

- 3) **Unanalysed Interdependencies Between Overlapping Projects:** Project No. 1 and Project No. 2 shared overlapping timelines, as did Project No. 2 and Project No. 3. However, this study did not evaluate the interdependencies or cascading effects between these concurrent projects. In a multi-project operational environment, such missing data may limit understanding of systematic risks, resource conflicts and schedule interdependencies that can collectively influence project outcomes (PMI, 2017).
- 4) **Exclusion of Client-Requested Pauses in Delay Quantification:** Certain client-requested pauses between project tasks and phases, which were discussed in previous sections, were excluded from the delay quantification. Although these pauses extended both As-Planned and As-Built timelines, they were not incorporated into the Root Cause Analysis, thereby limiting the comprehensiveness of the findings. Including these pauses could have provided deeper insight into client-related procedural delays and their impact on overall project delivery performance.

In summary, while these limitations influenced the analytical depth of this research, they do not undermine the validity of its findings. Instead, they highlight areas where future studies could expand on the methodology by incorporating advanced project management systems, cross-project dependency analysis and integrated delay modelling to strengthen the reliability and scalability of results.

5.3 Research Recommendation

In light of the limitations and findings discussed in this research, several important recommendations are here proposed to guide future studies and to enhance project management practices within engineering organisations operating under similar conditions:

- 1) **Adoption of Integrated Advanced Project Management Tools:** Future studies should investigate the use of integrated and advanced project management software that provides real-time progress tracking, dynamic schedule variance analysis (As-Planned vs As-Built) and visualisation of concurrent projects. Such tools (MS Project, Primavera P6 or Oracle Aconex) would significantly improve analytical accuracy, reduce manual efforts and enable a more accurate assessment of interdependencies among overlapping projects.
- 2) **Analysis of Concurrent Project Interactions:** Given the overlapping timelines observed between Project No. 1, Project No. 2 and Project No. 3, future studies should model the cascading effects of delays across concurrent projects. Analysing these inter-project dependencies will allow for the identification of systemic risks, resource conflicts and bottlenecks, thus enabling the development of more resilient multi-project management strategies.
- 3) **Inclusion of Client-Induced Pauses in Delay Assessment:** To provide a more comprehensive and realistic analysis of project delays, future research incorporates client-induced pauses into quantitative assessments. Including such pauses, often related to financial approvals, design revisions or access restriction, would improve the transparency of delay impact and foster collaborative stakeholder engagement in refining planning and approval processes.

4) **Implementation of a Structured Feedback Loop for Continuous Improvement:**

Engineering organisations should develop structured systematic feedback mechanisms to capture and analyse lessons learned from completed projects. Such a feedback loop would contribute to continuous improvement, enhance the accuracy of project scheduling and help reduce the recurrence of similar delays. Integrating this practice within the organisational QHSE or project control framework would reinforce a culture of learning and accountability.

In conclusion, by implementing the above recommendations, future research can extend the scope of this study and overcome its identified limitations. These improvements will not only enhance delay mitigation strategies and optimise the project delivery outcomes, but also strengthen organisational resilience and adaptability within complex, multi-project environments.

References

- Al-Khalidi, A. B. (2022). Solar PV construction project delays and mitigation strategies to enhance projects timeline performance: A case study from Dubai's environment . In *The British University in Dubai*.
- Altalaa, W. H. (2017). Energy Optimization of an Existing Residential Villa in UAE Towards Net Zero Energy Building (NZEB) Concept . *The British University in Dubai*.
- Amoah, K. B. (2024). Construction delay analysis: Causes, impacts, and mitigation strategies. *Journal of Civil Engineering Research*, 14(1), 1–9. doi:10.5923/j.jce.20241401.01
- Anil Cherian. (2020, August). The Construction Industry in the Perspective of an Economic Boost of The United Arab Emirates (UAE). *International Research Journal of Engineering and Technology (IRJET)*, 273. Retrieved from <https://www.researchgate.net/publication/343547695>
- Ascione, F. B. (2016). Simulation-based model predictive control by the multi-objective optimization of building energy performance and thermal comfort. *Energy and Buildings*, 111, 131-144. doi:<https://doi.org/10.1016/j.enbuild.2015.11.033>
- ASHRAE. (2023). ASHRAE Handbook-HVAC Applications. *American Society of Heating, Refrigerating and Air-Conditioning Engineers*.
- Assaf, S. A.-H. (2006). Causes of delay in large construction projects. *International Journal of Project Management*, 24(4), 349–357. doi:<https://doi.org/10.1016/j.ijproman.2005.11.010>
- Baratta, A. (2006). The triple constraint: a triple illusion. *Project Management Institute*.

- Bas, D. A. (2022). Integrated design challenges of energy retrofit in non-residential buildings. *Renewable and Sustainable Energy Reviews*, 159, 112216.
- Blak Bernat, G. Q. (2023). Enhancing Sustainability in Project Management: The Role of Stakeholder Engagement and Knowledge Management in Virtual Team Environments. *MDPI* . doi:<https://doi.org/10.3390/su15064896>
- BMI, A. F. (2024). *United Arab Emirates infrastructure report: Q3 2024 to 2033 forecast*. BMI - A Fitch Solutions Company. doi:<https://www.fitchsolutions.com/bmi>
- Braimah, N. (2013). Construction delay analysis techniques - a review of application issues and improvement needs. *Construction Management and Economics*, 31(3), 174–183. doi:<https://doi.org/10.1080/01446193.2012.746728>
- Brewer, J. D. (2010). *Methods of IT Project Management*. New Jersey.
- Brown K.A. and Hyer, N. (2010). *Managing Projects*. New York.
- Brudermann, T. P. (2013). Smart governance for sustainable smart cities. . *Energy Policy*, 55, 308–316.
- Cabeza, L. F. (2022). Buildings. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. doi:10.1017/9781009157926.011
- Chaowarat Watanabe, W. S. (2024). *The impact of triple constraints on the project success, a moderating role of organizational support*. (Vols. 9 (2024) 73–84). *Journal of Project Management*, . doi:<https://doi.org/10.5267/j.jpm.2023.8.002>
- Drury, E. M. (2012). Residential photovoltaics market transformation via third-party ownership. *Energy Policy*, . 42, 681–690.

- Durdyev, S. &. (2020). Causes of delays on construction projects: A comprehensive review (Vol. 13, Issue). 13(1), 20-46. doi:<https://doi.org/10.1108/IJMPB-09-2018-0178>
- Enker, R. A. (2020). The potential contribution of building codes to climate change response policies for the built environment. 13(4), 789–807. . doi:<https://doi-org.buid.idm.oclc.org/10.1007/s12053-020-09871-7>
- Ghimire, B. R. (2019). Review of delay analysis methods used in construction industry, 5, 53–65. *Journal of Advanced College of Engineering and Management*. doi:<https://doi.org/10.3126/jacem.v5i0.27050>
- Goggins, J. K. (2020). The assessment of embodied energy in typical reinforced concrete building structures in Ireland. . 202, 109374. doi:<https://doi.org/10.1016/j.enbuild.2019.109374>
- Hane Hagström, M. B. (2023). BARRIERS FROM A SOCIO-TECHNICAL PERSPECTIVE TO IMPLEMENT DIGITALISATION IN INDUSTRIAL ENGINEERING PROCESSES - A LITERATURE REVIEW. 3, 737–746. doi:10.1017/pds.2023.74
- harpreet dhillon. (2018). *Medium*. Retrieved from <https://medium.com/@harpreet.dhillon/iron-triangle-triple-constraints-of-project-management-e818e631826c>
- Institute., P. M. ((2021).). *A guide to the project management body of knowledge (PMBOK® Guide) (7th ed.)*. Project Management Institute. Retrieved from <https://ibimone.com/PMBOK%207th%20Edition%20%28iBIMOne.com%29.pdf?utm>
- International AACE. (2011). AACE International Recommended Practice No. 60R-10 - EVM with S-Curves. *AACE*. Retrieved from <https://www.scribd.com/document/611094112/60R-10-Developing-the-Project-Controls-Plan-AACE-International>

- Ismail A., A. H. (2012). *Time and Cost Performance of Construction Projects in Southern and Central Regions of Peninsular Malaysia*. 12, 978-1-4673-4616. IEEE.
- Karakaya, E. &. (2015). Barriers to photovoltaic adoption: A state of the art review. . *Renewable and Sustainable Energy Reviews*, , 49, 60–66.
- Kim, K. J. (2022). Application Issues of Impacted As-Planned Schedule for Delay Analysis. . 12(9), 1442. doi:<https://doi.org/10.3390/buildings12091442>
- Koinegg, J. B. (2013). Prospects and barriers of building-integrated photovoltaics. *GAI - Ecological Perspectives for Science and Society*, 22(1), 39–45.
- Konior, J. &. (2020). S-curve modeling in project control: Application and interpretation. . *Scientific Papers of Silesian University of Technology. Organization and Management Series*, , (148), 165–175.
- Lekan, A. D. (2017). *Cost and Time Performance Information of Building projects in Developing Economy*. 8(10), 918-927. International Journal of Mechanical Engineering and Technology.
- Levine, H. A. (2005). *Project Portfolio Management: A Practical Guide to Selecting Managing Portfolios and Maximizing benefits*. . USA: Pfeiffer Wiley.
- Marzouk, M. M.-R. (2014). *Analysing delay causes in Egyptian construction projects*, 5(1). Journal of Advanced Research.
- Motaleb, O. &. (2010). *An investigation into causes and effects of construction delays in UAE*. Dubai: Association of Researchers in Construction Management. .
- Movilla, M. A. (2013). A system dynamics approach for the photovoltaic market in Spain. *Energy Policy*, 60, 142–154.

- Muhamad, M. I. (2016). Evaluation of construction delay analysis techniques: A case study of Malaysian construction industry. *MATEC Web of Conferences*, 66, 1–9.
doi:<https://doi.org/10.1051/matecconf/20166600053>
- Osei-Asibey, D. A. (2025). Impact of time-based delay on public-private partnership (PPP) construction project delivery: construction stakeholders' perspective. *Journal of Financial Management of Property and Construction*.
doi:<https://doi.org/10.1108/JFMPC-07-2023-0044>
- Palit, D. (2013). Solar programs for rural electrification: Lessons from South Asia. *Energy for Sustainable Development*, 17(3), 270–279.
- PMI. (2021). *PMBOK Guide, 7th Edition - Project Performance Domains*. Project Management Institute. Retrieved from <https://www.pmi.org/pmbok-guide-standards>
- PMI Phoenix Chapter, .. (2025). The triple constraint in project management: Managing cost, scope, and time. Retrieved from <https://pmiphx.org/presidents-corner/the-triple-constraint-in-project-management-managing-cost-scope-and-time>
- Pode, R. (2013). Financing LED solar home systems in developing countries. . *Renewable and Sustainable Energy Reviews*, , 25, 596–602.
- Project Management Institute. (2000). *A guide to the project management body of knowledge (PMBOK® Guide) (2000 ed.)*. Project Management Institute.
- Project Management Institute, p. (2021). *The standard for project management and a guide to the project management body of knowledge (PMBOK guide)*. PMI Seventh Edition July 2021.
- Rehman, G. U. (2015). *Causes of Delay in Construction Projects*. Dubai: The British University in Dubai.

- Reinertsen, D. G. (2009). *The Principles of Product Development Flow: Second Generation Lean Product Development*. *Celeritas Publishing*.
- Sambasivan, M. &. (2007). *Causes and effects of delays in Malaysian construction industry*. 517-526. *International Journal of Project Management*.
- Sargent, A. (2020). As-Planned Versus As-Built Method. *Vertex*. Retrieved from <https://vertexeng.com/insights/as-planned-versus-as-built-method/>
- Shah, R. K. (2016). An exploration of causes for delay in construction projects: A case study. *International Journal of Engineering Research and Applications*, 6(6), 84-96.
- The Official Portal of the UAE Government. (2024). UAE Energy Strategy 2050. *The Official Portal of the UAE Government*. Retrieved from <https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/uae-energy-strategy-2050>
- The PMBOK guide® – Seventh Edition Summary*. (2021, October 19). Retrieved from Project Times: <https://www.projecttimes.com/articles/the-pmbok-guide-seventh-edition-summary/>
- UAE Ministry of Energy and Infrastructure. (n.d.). Energy Strategies to Achieve Net Zero. . *UAE Ministry of Energy and Infrastructure*. Retrieved from <https://www.moei.gov.ae/en/about-ministry/energy-strategies-to-achieve-net-zero>
- Vasseur, V. K. (2013). Comparative innovation analysis of photovoltaic systems. *Innovation and Development*, 3(2), 241–257.
- Wasfy, A. &. (2022). Delay analysis methods and statements in construction projects. . pp. 14(4), 431. doi:<https://doi.org/10.1504/IJPOM.2022.127147>

Yang, J. B. (2012). Critical delay factors in construction projects . 28(3), 243–251.

doi:[https://doi.org/10.1061/\(ASCE\)ME.1943-5479.0000101](https://doi.org/10.1061/(ASCE)ME.1943-5479.0000101)

Zhang, X. S. (2012). Barriers to implementing green strategy in real estate. . *Journal of Cleaner Production*, 32, 96–103.

Appendices

Appendix A

Table 20

Analysis of Project No.1 or Case Study No.1

MEP Project Phases	As-planned Schedule - Phase Starting Date	As-planned Schedule - Phase Finishing Date	As-built Schedule- Starting Date	As-built Schedule - Finishing Date
1. Site Inspection & Value Engineering	Wednesday, 5 April 2023	Monday, 10 April 2023	Wednesday, 5 April 2023	Monday, 10 April 2023
1.1 Site Inspection Detail	Wednesday, 5 April 2023	Monday, 10 April 2023	Wednesday, 5 April 2023	Monday, 10 April 2023
2. Contract Signature / Purchase Order / LOI	Tuesday, 25 April 2023	Friday, 5 May 2023	Tuesday, 25 April 2023	Tuesday, 16 May 2023
2.1 Purchase Order / LOI	Tuesday, 25 April 2023	Friday, 5 May 2023	Tuesday, 25 April 2023	Tuesday, 16 May 2023
3. Procurement Phase	Tuesday, 16 May 2023	Tuesday, 8 August 2023	Wednesday, 17 May 2023	Monday, 4 September 2023
3.1 Internal Processes	Tuesday, 16 May 2023	Tuesday, 23 May 2023	Wednesday, 17 May 2023	Thursday, 1 June 2023
3.2 Material Delivery	Wednesday, 24 May 2023	Tuesday, 8 August 2023	Monday, 12 June 2023	Monday, 4 September 2023
4. Mechanical, Electrical & Plumbing Installation	Monday, 5 June 2023	Wednesday, 28 June 2023	Thursday, 8 June 2023	Friday, 1 December 2023
4.1 Work Permit & Site Access	Monday, 5 June 2023	Thursday, 8 June 2023	Thursday, 8 June 2023	Monday, 12 June 2023
4.2 In-House installation, assessment and inspection	Thursday, 8 June 2023	Wednesday, 28 June 2023	Monday, 12 June 2023	Friday, 1 December 2023

5. Testing and Commissioning (T&C)	Monday, 27 November 2023	Thursday, 7 December 2023	Wednesday, 29 November 2023	Friday, 29 December 2023
5.1 T&C of system	Monday, 27 November 2023	Wednesday, 29 November 2023	Wednesday, 29 November 2023	Friday, 1 December 2023
5.2 Project Handover (Signed Work Completion Report)	Thursday, 30 November 2023	Saturday, 2 December 2023	Saturday, 2 December 2023	Wednesday, 6 December 2023
5.3 Project Invoicing	Monday, 4 December 2023	Thursday, 7 December 2023	Friday, 8 December 2023	Friday, 29 December 2023
Total Project Delays	Wednesday, 5 April 2023	Thursday, 7 December 2023	Wednesday, 5 April 2023	Friday, 29 December 2023

Task As-planned Duration (TAPD) in Days	Task As-built Duration (TABD) in Days	Task Overall Delay in Days	Task Overall Delay % (TOD%)	Float (TAPD-TABD) in Days	Delay Occurrence?	Critical?	% Delay For the Critical Path Tasks
5	5	0	0%	0	No	No	0%
5	5	0	0%	0	No	No	0%
10	19	9	90%	-9	Yes, delayed phase	Yes, Critical	4%
10	19	9	90%	-9	Yes, delayed phase	Yes, Critical	4%
73	95	22	30%	-22	Yes, delayed phase	Yes, Critical	10%
7	14	7	100%	-7	Yes, delayed phase	Yes, Critical	3%
66	73	7	11%	-7	Yes, delayed phase	Yes, Critical	3%
21	152	131	624%	-131	Yes, delayed phase	Yes, Critical	57%
4	4	0	0%	0	No	No	0%
18	149	131	728%	-131	Yes, delayed phase	Yes, Critical	57%

10	27	17	170%	-17	Yes, delayed phase	Yes, Critical	7%
3	3	0	0%	0	No	No	0%
3	4	1	33%	-1	Yes, delayed phase	Yes, Critical	0%
4	19	15	375%	-15	Yes, delayed phase	Yes, Critical	6%
212	231	19	9%	-19	Yes, delayed phase	Yes, Critical	8%

Table 21

Category Task Contribution Delay % of Project No.1

Project No. 1 - Reasons of Delay and Delay Contribution to Initial Planned Duration				
Project Task	Actual Task Delay % (TOD%)	Category Task Contribution Delay %	Delay Category	Reason of the Delay
2.1 Purchase Order / LOI	90%	6.9%	Client-related Delays	Delayed because of Client's Budgetary Approvals
3.1 Internal Processes	100%	7.7%	Internal Process Delays	Delayed due to the internal approvals of the budget of the project
3.2 Material Delivery	11%	0.8%	Procurement & Supply Chain Delays	Delay in the process of procurement in the partial delivery due to the lack of availability of some materials.
4.2 In-House installation, assessment and inspection	728%	55.8%	Client-related Delays	Delayed due to: First) Site Access inside some specific shops was delayed (Client's Process Delay). Second) IP Configuration was delayed for more than 2

				months (Client's Process Delay). Third) Work Timings (initial agreement is during 9AM to 6PM) has been changed into night shift (12PM to 6AM), which delayed the project of total of 25days resulted in less manpower, less productivity, and less work duration (Client's Process Delay).
5.3 Project Invoicing	375%	28.8%	Client-related Delays	Delayed because of client processing the invoicing of the project.
Total Critical Delay	1303%	100%		

Table 22

Critical Task Delay Contribution of Project No.1

Project Task	Overall Critical Delay %	Task Contribution Delay %
2.1 Purchase Order / LOI	4%	5.33%
3.1 Internal Processes	3%	4.14%
3.2 Material Delivery	3%	4.14%
4.1 Work Permit & Site Access	0%	0.00%
4.2 In-House installation, assessment and inspection	57%	77.51%
5.3 Project Invoicing	6%	8.88%
Total Critical Delay	73%	100%

Appendix B

Table 23*Analysis of Project No.2 or Case Study No.2*

MEP Project Phases	As-planned Schedule - Phase Starting Date	As-planned Schedule - Phase Finishing Date	As-built Schedule- Starting Date	As-built Schedule - Finishing Date
1. Site Inspection & Value Engineering	Saturday, 29 April 2023	Monday, 1 May 2023	Saturday, 29 April 2023	Monday, 1 May 2023
1.1 Site Inspection Detail	Saturday, 29 April 2023	Monday, 1 May 2023	Saturday, 29 April 2023	Monday, 1 May 2023
2. Contract Signature / Purchase Order / LOI	Friday, 16 June 2023	Monday, 26 June 2023	Wednesday, 21 June 2023	Monday, 31 July 2023
2.1 Purchase Order / LOI	Friday, 16 June 2023	Monday, 26 June 2023	Wednesday, 21 June 2023	Monday, 31 July 2023
3. Procurement Phase	Monday, 31 July 2023	Monday, 23 October 2023	Tuesday, 1 August 2023	Wednesday, 20 September 2023
3.1 Internal Processes	Monday, 31 July 2023	Monday, 7 August 2023	Tuesday, 1 August 2023	Saturday, 5 August 2023
3.2 Material Delivery	Saturday, 5 August 2023	Monday, 23 October 2023	Friday, 4 August 2023	Wednesday, 20 September 2023
4. Mechanical, Electrical & Plumbing Installation	Thursday, 1 February 2024	Friday, 5 April 2024	Thursday, 1 February 2024	Monday, 3 June 2024
4.1 Work Permit & Site Access	Thursday, 1 February 2024	Monday, 5 February 2024	Thursday, 1 February 2024	Monday, 5 February 2024
4.2 In-House installation, assessment and inspection	Monday, 5 February 2024	Friday, 5 April 2024	Monday, 5 February 2024	Monday, 3 June 2024
5. Testing and Commissioning (T&C)	Wednesday, 1 May 2024	Thursday, 16 May 2024	Monday, 3 June 2024	Monday, 15 July 2024
5.1 T&C of system	Wednesday, 1 May 2024	Monday, 6 May 2024	Monday, 3 June 2024	Wednesday, 12 June 2024

5.2 Project Handover (Signed Work Completion Report)	Tuesday, 7 May 2024	Saturday, 11 May 2024	Friday, 28 June 2024	Friday, 5 July 2024
5.3 Project Invoicing	Monday, 13 May 2024	Thursday, 16 May 2024	Monday, 8 July 2024	Monday, 15 July 2024
Total Project Delays	Saturday, 29 April 2023	Thursday, 16 May 2024	Saturday, 29 April 2023	Monday, 15 July 2024

Task As-planned Duration (TAPD) in Days	Task As-built Duration (TABD) in Days	Task Overall Delay in Days	Task Overall Delay % (TOD%)	Float (TAPD-TABD) in Days	Delay Occurrence?	Critical?	% Delay For the Critical Path Tasks
2	2	0	0%	0	No	No	0%
2	2	0	0%	0	No	No	0%
9	35	26	289%	-26	Yes, delayed phase	Yes, Critical	7%
9	35	26	289%	-26	Yes, delayed phase	Yes, Critical	7%
73	44	-29	-40%	29	No	No	-8%
7	5	-2	-29%	2	No	No	-1%
68	41	-27	-40%	27	No	No	-7%
56	106	50	89%	-50	Yes, delayed phase	Yes, Critical	13%
4	4	0	0%	0	No	No	0%
53	103	50	94%	-50	Yes, delayed phase	Yes, Critical	13%
14	37	23	164%	-23	Yes, delayed phase	Yes, Critical	6%
5	9	4	80%	-4	Yes, delayed phase	Yes, Critical	1%
5	7	2	40%	-2	Yes, delayed phase	Yes, Critical	1%
4	7	3	75%	-3	Yes, delayed phase	Yes, Critical	1%

329	380	51	16%	-51	Yes, delayed phase	Yes, Critical	13%
-----	-----	----	-----	-----	--------------------	---------------	-----

Table 24*Pauses or Holds Discription of Project No. 2*

Pause or Hold Discription of Project No. 2	Starting Date	Completed Date	Total Days (Excluding Sundays)	Reason of the Pause
First Pause (task 1.1 Site Inspection Detail and task 2.1 Purchase Order / LOI)	Monday, 1 May 2023	Wednesday, 21 June 2023	43	Project No. 2 had faced some struggles that did not allow the project to run smoothly: First) Project No. 2 was paused between task (3.2 Material Delivery) was completed on Monday, 4 September 2023 and between the starting of task (4.1 Work Permit & Site Access) on Thursday, 1 February 2024, resulting in about 113days of paused work. The causes of the project pause are due to: a. The inability of getting enough site access inside retail shops as it was simultaneous work with project No.1. b. There was financial struggle from client side on pending due payments of other projects with more than 280days which affected the relationship with client; specifically deploying enough manpower to work project No.1 and No. 2. Second) The initiation Phase (1. Site Inspection & Value Engineering) of project No.1 and Project No. 2 were done simultaneously from the starting date on Saturday, 29 April 2023 and completed on Monday, 1 May 2023, but due the pre-budget approvals from client side and delays of payments, the project was paused from client side for about 43days. The project was continued on Wednesday, 21 June 2023 when the techno-commercial proposal was sent to client as per their request.
Second Pause (task 3.2 Material Delivery and task 4.1 Work Permit & Site Access)	Wednesday, 20 September 2023	Thursday, 1 February 2024	113	
Total Duration of Project No. 2 in Days			380	

Table 25*Critical Task Delay Contribution of Project No.2*

Project Task	Overall Critical Delay %	Task Contribution Delay %
2.1 Purchase Order / LOI	7%	30.59%
4.2 In-House installation, assessment and inspection	13%	58.82%
5.1 T&C of system	1%	4.71%
5.2 Project Handover (Signed Work Completion Report)	1%	2.35%
5.3 Project Invoicing	1%	3.53%
Total Critical Delay	22%	100%

Table 26*Category Task Contribution Delay % of Project No.2*

Project No. 2 - Reasons of Delay and Delay Contribution to Initial Planned Duration				
Project Task	Actual Task Delay % (TOD%)	Category Task Contribution Delay %	Delay Category	Reason of the Delay
2.1 Purchase Order / LOI	289%	50%	Client-related Delays	Delayed because of Client's Budgetary Approvals and internal processes
4.2 In-House installation, assessment and inspection	94%	16%	Client-related Delays	Delayed due to: First) Site Access inside some specific shops was delayed (Client's Process Delay). Second) The Field Server/Communication Gateway got faulty during the final installation and engineering phase, in which we had to re order from manufacturer the 2nd time and it took 65days from Wednesday, March 20, 2024 to Monday, 3 June 2024 (DLP and Warranty Period affected the next phases).

				Client's Site Mishandling) Third) IP Configuration was delayed for more than 2 months from Tuesday, April 23, 2024 to Wednesday, June 12, 2024 (Client's Process Delay).
5.1 T&C of system	80%	14%	Client-related Delays	Delayed due to IT Work related from client (Client's Process Delay).
5.2 Project Handover (Signed Work Completion Report)	40%	7%	Client-related Delays	Delayed due to the process of signing the completion report and work verification (Client's Process Delay).
5.3 Project Invoicing	75%	13%	Client-related Delays	Delayed because of client processing the invoicing of the project.
Total Critical Delay	578%	100%		

Appendix C

Table 27*Analysis of Project No.3 or Case Study No.3*

MEP Project Phases	As-planned Schedule - Phase Starting Date	As-planned Schedule - Phase Finishing Date	As-built Schedule- Starting Date	As-built Schedule - Finishing Date
1. Site Inspection & Value Engineering	Saturday, 29 April 2023	Monday, 1 May 2023	Saturday, 29 April 2023	Monday, 1 May 2023
1.1 Site Inspection Detail	Saturday, 29 April 2023	Monday, 1 May 2023	Saturday, 29 April 2023	Monday, 1 May 2023
2. Contract Signature / Purchase Order / LOI	Wednesday, 11 October 2023	Thursday, 26 October 2023	Thursday, 23 November 2023	Friday, 8 December 2023
2.1 Purchase Order / LOI	Wednesday, 11 October 2023	Thursday, 26 October 2023	Thursday, 23 November 2023	Friday, 8 December 2023
3. Procurement Phase	Friday, 8 December 2023	Friday, 1 March 2024	Tuesday, 12 December 2023	Wednesday, 24 April 2024
3.1 Internal Processes	Friday, 8 December 2023	Friday, 15 December 2023	Tuesday, 12 December 2023	Thursday, 21 December 2023
3.2 Material Delivery	Thursday, 21 December 2023	Friday, 1 March 2024	Thursday, 25 January 2024	Wednesday, 24 April 2024
4. Mechanical, Electrical & Plumbing Installation	Tuesday, 21 May 2024	Monday, 24 June 2024	Friday, 24 May 2024	Friday, 14 June 2024
4.1 Work Permit & Site Access	Tuesday, 21 May 2024	Saturday, 25 May 2024	Friday, 24 May 2024	Saturday, 25 May 2024
4.2 In-House installation, assessment and inspection	Saturday, 25 May 2024	Monday, 24 June 2024	Saturday, 25 May 2024	Friday, 14 June 2024
5. Testing and Commissioning (T&C)	Friday, 14 June 2024	Friday, 28 June 2024	Friday, 14 June 2024	Monday, 15 July 2024

5.1 T&C of system	Friday, 14 June 2024	Sunday, 16 June 2024	Friday, 14 June 2024	Thursday, 20 June 2024
5.2 Project Handover (Signed Work Completion Report)	Monday, 17 June 2024	Saturday, 22 June 2024	Wednesday, 3 July 2024	Monday, 8 July 2024
5.3 Project Invoicing	Wednesday, 26 June 2024	Friday, 28 June 2024	Monday, 8 July 2024	Monday, 15 July 2024
Total Project Delays	Saturday, 29 April 2023	Friday, 28 June 2024	Saturday, 29 April 2023	Monday, 15 July 2024

Task As-planned Duration (TAPD) in Days	Task As-built Duration (TABD) in Days	Task Overall Delay in Days	Task Overall Delay % (TOD%)	Float (TAPD-TABD) in Days	Delay Occurrence?	Critical?	% Delay For the Critical Path Tasks
2	2	0	0%	0	No	No	0%
2	2	0	0%	0	No	No	0%
14	14	0	0%	0	No	No	0%
14	14	0	0%	0	No	No	0%
73	116	43	59%	-43	Yes, delayed phase	Yes, Critical	11%
7	9	2	29%	-2	Yes, delayed phase	Yes, Critical	1%
62	78	16	26%	-16	Yes, delayed phase	Yes, Critical	4%
30	19	-11	-37%	11	No	No	-3%
5	2	-3	-60%	3	No	No	-1%
26	18	-8	-31%	8	No	No	-2%
13	27	14	108%	-14	Yes, delayed phase	Yes, Critical	4%
2	6	4	200%	-4	Yes, delayed phase	Yes, Critical	1%

6	5	-1	-17%	1	No	No	0%
3	7	4	133%	-4	Yes, delayed phase	Yes, Critical	1%
366	380	14	4%	-14	Yes, delayed phase	Yes, Critical	4%

Table 28*Pauses or Holds Discription of Project No. 3*

Pause or Hold Discription of Project No. 3	Starting Date	Completed Date	Total Days (Excluding Sundays)	Reason of the Pause
First Pause (task 1.1 Site Inspection Detail and task 2.1 Purchase Order / LOI)	Monday, 1 May 2023	Thursday, 23 November 2023	177	Project No. 3 had faced some struggles that did not allow the project to run smoothly: First) The first hold or pause of the project between two important tasks of the project. Since the request of holding the project was requested by client because of few financial struggles including allocating financial budget for this project, thus it resulted with a 177days of delay between task (1.1 Site Inspection Detail) which ended on Monday, 1 May 2023 and task (2.1 Purchase Order / LOI) which started on Thursday, 23 November 2023, thus it was not calculated in this analysis as a delay contributor. Second) The project was on second hold resulted in a 25days of delay between task (3.2 Material Delivery) which ended on Wednesday, 24 April 2024 and task (4.1 Work Permit & Site Access) which started on Friday, 24 May 2024. Also, this hold was requested by mall's operations due to the following reasons: a. Limited Site Access: difficulty in obtaining site access inside the retail shops from client side, which overlapped with Project No. 2. b. Financial Struggles: delays in payments from the client affected the progress of the project and the manpower deployment.
Second Pause (task 3.2 Material Delivery and task 4.1 Work Permit & Site Access)	Wednesday, 24 April 2024	Friday, 24 May 2024	25	
Total Duration of Project No. 3 in Days			380	

Table 29*Category Task Contribution Delay % of Project No.3*

Project No. 3 - Reasons of Delay and Delay Contribution to Initial Planned Duration				
Project Task	Actual Task Delay % (TOD%)	Category Task Contribution Delay %	Delay Category	Reason of the Delay
3.1 Internal Processes	29%	7%	Internal Process Delays	Delayed due to the internal approvals of the budget of the project
3.2 Material Delivery	26%	7%	Procurement & Supply Chain Delays	Delay in the process of procurement in the partial delivery due to the lack of availability of some materials.
5.1 T&C of system	200%	52%	Client-related Delays	Delayed due to IT Work related from client (Client's Process Delay).
5.3 Project Invoicing	133%	34%	Client-related Delays	Delayed because of client processing the invoicing of the project.
Total Critical Delay	388%	100%		

Table 30*Critical Task Delay Contribution of Project No.3*

Project Task	Overall Critical Delay %	Task Contribution Delay %
3.1 Internal Processes	1%	8%
3.2 Material Delivery	4%	62%
5.1 T&C of system	1%	15%
5.3 Project Invoicing	1%	15%
Total Critical Delay	7%	100%

Appendix D

Table 31*Overall Delay of Energy/MEP Projects*

MEP/Energy Project Phases	Task Overall Delay % - Project 1	Task Overall Delay % - Project 2	Task Overall Delay % - Project 3	Delay Weighted Average	Average Phase Delay Contribution
1. Site Inspection & Value Engineering	0%	0%	0%	0%	0%
1.1 Site Inspection Detail	0%	0%	0%	0%	
2. Contract Signature / Purchase Order / LOI	90%	289%	0%	126%	24%
2.1 Purchase Order / LOI	90%	289%	0%	126%	
3. Procurement Phase	30%	-40%	59%	16%	3%
3.1 Internal Processes	100%	-29%	29%	33%	
3.2 Material Delivery	11%	-40%	26%	-1%	
4. Mechanical, Electrical & Plumbing Installation	624%	89%	-37%	225%	44%
4.1 Work Permit & Site Access	0%	0%	-60%	-20%	
4.2 In-House installation, assessment and inspection	728%	94%	-31%	264%	
5. Testing and Commissioning (T&C)	170%	164%	108%	147%	29%
5.1 T&C of system	0%	80%	200%	93%	
5.2 Project Handover (Signed Work Completion Report)	33%	40%	-17%	19%	
5.3 Project Invoicing	375%	75%	133%	194%	

Total Project Delays	9%	16%	4%	9%	
----------------------	----	-----	----	----	--

Table 32

Compiled 3 Project Cases Delay Analysis

Compiled 3 Project Cases Delay Analysis				
Project Task	Delay Category	Reason of the Delay in Project 1	Reason of the Delay in Project 2	Reason of the Delay in Project 3
2.1 Purchase Order / LOI	Client-related Delays	Delayed because of Client's Budgetary Approvals	Delayed because of Client's Budgetary Approvals and internal processes	NA
3.1 Internal Processes	Internal Process Delays	Delayed due to the internal approvals of the budget of the project	NA	Delayed due to the internal approvals of the budget of the project
3.2 Material Delivery	Procurement & Supply Chain Delays	Delay in the process of procurement in the partial delivery due to the lack of availability of some materials.	NA	Delay in the process of procurement in the partial delivery due to the lack of availability of some materials.

4.2 In-House installation, assessment and inspection	Client-related Delays	Delayed due to: First) Site Access inside some specific shops was delayed (Client's Process Delay). Second) IP Configuration was delayed for more than 2 months (Client's Process Delay). Third) Work Timings (initial agreement is during 9AM to 6PM) has been changed into night shift (12PM to 6AM), which delayed the project of total of 25days resulted in less manpower, less productivity, and less work duration (Client's Process Delay).	Delayed due to: First) Site Access inside some specific shops was delayed (Client's Process Delay). Second) The Field Server/Communication Gateway got faulty during the final installation and engineering phase, in which we had to re order from manufacturer the 2nd time and it took 65days from Wednesday, March 20, 2024 to Monday, 3 June 2024 (DLP and Warranty Period affected the next phases). Client's Site Mishandling) Third) IP Configuration was delayed for more than 2 months from Tuesday, April 23, 2024 to Wednesday, June 12, 2024 (Client's Process Delay).	NA
5.1 T&C of system	Client-related Delays	NA	Delayed due to IT Work related from client (Client's Process Delay).	Delayed due to IT Work related from client (Client's Process Delay).
5.2 Project Handover (Signed Work Completion Report)	Client-related Delays	NA	Delayed due to the process of signing the completion report and work verification (Client's Process Delay).	NA
5.3 Project Invoicing	Client-related Delays	Delayed because of client processing the invoicing of the project.	Delayed because of client processing the invoicing of the project.	Delayed because of client processing the invoicing of the project.

Appendix E

Table 33

Level of Risks and Likelihood of Occurrence as per Existing QHSE Department of an Engineering Organization

Level of Risks			
Likelihood of Occurrence \ Risk Severity	1 Minor	2 Moderate	3 Major
	3 Often	6	9
	2 Likely	4	6
	1 Rare	2	3

LEGEND
High Risk
Medium Risk
Low Risk

Note: Medium and High ratings are significant risks but in all cases (whether low, medium or high risk), identified mitigation / treatment to be strictly followed / implemented