Mitigating Missed Order Due Dates in an Engineer-to-Order Environment: Evidence from Saudi Arabia

By

Mohammad Omar Hajeer

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Abstract

This research addressed the pressing issue of missed order due dates in the highly dynamic engineer-to-order (ETO) environments of AL DAR Company, a Saudi Arabian ETO manufacturer. Despite the common adoption of ETO approaches in several industries, a significant research gap existed regarding consensus on integrated planning and control systems designed for ETO manufacturing firms. Therefore, this research aimed to address this gap by evaluating the planning and control practices at AL DAR and investigating the impact of implementing a proposed integrated planning and control system on reducing missed order dates in the ETO environment of AL DAR and within the community of practice.

The research methodology combined a pragmatic philosophy and three Action Research Cycles, adopting a blend of data collection methods. These methods included five individual interviews and nine focus groups, with 45 participants instances selected for their extensive experience and diverse roles at AL DAR. Additionally, these qualitative methods were complemented by survey responses from 20 respondents, and statistical analyses were extracted from 147 project documents to enhance the robustness of the findings.

This first research Cycle identified four main characteristics of ETO environments: high customisation, the dynamic nature of its design phase, the complex nature of its procurement phase, and the need for high coordination. Additionally, this Cycle identified challenges in each process of the ETO project execution, from receiving the order to delivering the project to the customer, underscoring the inefficiencies in AL DAR’s processes and its lack of a robust planning and control system.

The second Cycle built on these findings to propose a new integrated planning and control system. This system incorporated elements borrowed from Lean Construction (LC) and traditional project management theories. The main theories or elements adopted were the Pull Planning Theory, the Work Breakdown Structure (WBS) principle, the Critical Path Method (CPM), Rolling Wave Planning, and the “5 Whys” technique for root cause analysis. This study challenged conventional approaches and provided a novel perspective on ETO operational efficiency by integrating LC principles with traditional project management theories. The proposed system aimed to address the identified deficiencies and was evaluated against ten Critical Success Factors for effective implementation that emerged from the focus groups and the theoretical insights.

The third and final Cycle implemented and tested the proposed system in a real-world setting. The results showed an enhancement in the estimated delivery time, thus mitigating the missed order due dates by 30%, as suggested by qualitative and statistical analyses pre- and post-implementation of the new system. Although the findings demonstrated the efficacy of the integrated system in addressing the challenges of the ETO environment, the system was further refined based on the implementation outcomes to optimise its performance and applicability.

This research contributes to operations management by providing a practical framework of an integrated and comprehensive planning and control system that mitigates missed order due dates in ETO environments. Additionally, it bridges the gap between academic theories and practical applications, offering valuable insights and a scalable solution for organisations facing similar challenges. However, its single-case design limits generalisability, suggesting avenues for further research with longer durations using diverse ETO environments and stakeholders.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

APM	Association for Project Management
ATO	Assemble to Order
BOM	Bill of Materials
CCPM	Critical Chain Project Management
CODP	Customer Order Decoupling Point
CPA	Critical Path analysis
CPM	Critical Path Method
ETO	Engineer to Order
ERP	Enterprise Resource Planning
EVM	Earned Value Management
IGLC	International Group for Lean Construction
LC	Lean Construction
LCI	Lean Construction Institute

LPS	Last Planner System
MTO	Make to Order
MPS	Master Production Schedule
MTS	Make to Stock
OM	Operations Management
PDCA	Plan-Do-Check-Act methodology
PERT	Project Evaluation and Review Technique
PMI	Project Management Institute
PMP	Project Management Professional
PO	Purchase Order
PPC	Percent Plan Complete
RFQ	Request for Quotation
TPS	Toyota Production System
WBB	Work Breakdown Structure

WIP	Work in Process
WLC	Workload control

CHAPTER 1: INTRODUCTION

Research Title: Mitigating Missed Order Due Dates in an Engineer-to-Order Environment: Evidence from Saudi Arabia

1.1 Research Background

Operations management (OM) is essential for organizations to achieve their objectives through efficient and effective resource utilization to produce goods and services (Jacobs, Chase and Aquiltrano, 2004; Erkan Bayraktar et al., 2007). In the realm of project management, Engineer-to-Order (ETO) projects stand out due to their characteristics related to their low volume and highly customized nature. Despite the wide application of ETO strategies in industries like manufacturing and construction, there remains a notable gap in having integrated planning and control systems to manage ETO projects effectively. This gap underscores the importance of systems that are crucial for achieving operational excellence and ensuring timely project completion.

AL DAR, a Saudi Arabian ETO company specializing in machinery, exemplifies this challenge related to the absence of an integrated planning and control system with a high rate of missed order due dates, leading to significant customer dissatisfaction potentially leading to lost revenue or reputational damage. This Research was conducted at AL DAR Company from February 28, 2023, to December 20, 2023. The research project received approval from AL DAR's top management and was guaranteed their full support. The study utilized Action Research, a methodology allowing for iterative testing and refinement of a proposed planning and control system specifically designed for ETO environments.

This approach was chosen due to its potential to directly impact and improve the existing systems by integrating qualitative methods with statistical analyses to strengthen findings.

The researcher was a member of Al Dar organisation, working as an Operations Planning Manager for AL DAR and a doctoral student and conducted this Action Research for two reasons: (1) to evaluate the current planning and control practices and (2) to explore the effect of proposing an integrated planning and control system on mitigating missed order due dates in an ETO environment at AL DAR Company and the community of practice. Through the iterative process of proposing, implementing, testing, and fine-tuning a planning and control system, the researcher sought to address the challenge of failure to meet deadlines by demonstrating how the combination of lean and non-lean planning and control elements could directly reduce missed order due dates.

1.2 Problem Statement

The study of Engineer-to-Order (ETO) environments, particularly within AL DAR, is critical due to the unique operational challenges presented by such settings. Despite the widespread implementation of ETO strategies in industries such as manufacturing and construction, there exists a significant research gap in the development of integrated planning and control systems specifically tailored for these complex environments (Adrodegari et al., 2015; Nakayama and de Mesquita Spinola, 2015). ETO projects, characterized by their low-volume nature, require highly specialized planning and control systems to manage the complexity and dynamism inherent in customized manufacturing. Existing systems often fall short, leading to frequent missed deadlines and significant customer dissatisfaction

(Bataglin et al., 2020), which in turn can result in lost revenue and reputational damage for companies like AL DAR.

The importance of this study lies in its potential to enhance operational efficiency and customer satisfaction through improved project delivery times and reduced missed order due dates, making a significant contribution to the field of operations management and the practices at AL DAR and similar companies. By integrating Lean elements like pull planning and Non-Lean elements like Work Breakdown Structure and Critical Path Method, this system aims to streamline operations, enhance coordination, and improve decision-making processes, thereby tackling the root causes of delays and inefficiencies in ETO project delivery. Addressing this gap not only advances academic knowledge but also offers practical solutions that can significantly impact the efficiency and success of ETO firms in the competitive global market.

1.3 Research Aim and Question

Accordingly, this research aimed to **evaluate the current planning and control practices and explore the effect of proposing an integrated planning and control system on mitigating missed order due dates in an ETO environment at AL DAR Company and the community of practice.**

Hence, the main research question was as follows:

What is the evaluation of the current planning and control practices, and what is the effect of proposing an integrated planning and control system on mitigating missed order due dates in the ETO environment at AL DAR Company?

1.4 Research Objectives

Research objectives allow the researcher to operationalise the research question to draw a roadmap toward answering the research question (Saunders, Lewis and Thornhill, 2019). Accordingly, the research objectives below were formulated:

1. **Research Objective 1**: To examine the theoretical underpinnings and shortcomings of the existing Lean and non-Lean planning and control systems used to deliver ETO projects in the ETO environments at AL DAR Company.

   Research Objective 2: To explore the Critical Success Factors to be incorporated into a proposed planning and control system to ensure its effective implementation.
2. **Research Objective 3**: To explore the effect of the proposed integrated project planning and control system on the on-time delivery of the projects in AL DAR Company's ETO environment.
3. **Research Objective 4**: Refine the proposed planning and control system based on the implementation outcomes.

1.5 Significance of the Research

This Action Research had several significances:

1.5.1 Practical Significance

The research addressed the pressing issue of missed order due dates in the ETO environment at AL DAR Company, leading to improved project performance, customer satisfaction, and profitability. As a result, the integrated planning and control system proposed through this research can serve as a practical framework for other ETO companies facing similar challenges.

1.5.2 Theoretical Significance

This research bridged the gap in the existing body of knowledge by proposing an integrated planning and control system designed explicitly for ETO operations to mitigate missed order due dates by integrating Lean and non-Lean elements.

1.5.3 Methodological Significance

This research employed a novel Action Research Framework (Figure 3-1) built by the researcher. It integrated previous perspectives of the Cyclical Process Model (CPM) proposed by Lewin, Susman, Evered, Moroni, Cohen, Manion and Morrison (1946; 1978; 2011; 2018) and the five principles articulated in the seminal study of Davison, Martinsons, and Kock (2004). This framework, depicted in Figure 3-1, aimed to enhance the Action Research's rigor and relevance through a systematic and structured approach that guided the implementation of the Action Research process.

1.6 Statement of Originality

This Action Research makes an original contribution to practice and theory in several areas. This project provides a significant opportunity to change organisational practice to enhance operational efficiency and effectiveness in the subject company and the community of practice by proposing, testing, and fine-tuning an integrated project planning and control system. It also aims to contribute to existing knowledge and theory by introducing a system for planning and controlling ETO projects with engineers. Additionally, this project can hopefully contribute to a deeper understanding of the late completion of projects by Action

Research that adopts qualitative methods (the focus of existing Action Research) and statistical analyses during the diagnosis of the problem and the assessment of the proposed solution.

1.7 Structure of the Thesis

This thesis is organized into five main chapters, each contributing uniquely to the overarching investigation of the impacts of an integrated planning and control system on mitigating missed order due dates in an engineer-to-order (ETO) environment. Following this introduction, Chapter 2 starts with the theoretical perspective of this action research and delves into a comprehensive literature review by assessing existing knowledge and identifying gaps, particularly in planning and control challenges in ETO settings. Chapter 3 describes the research design and methodology, detailing the choice of action research, and explaining the methods used for data collection and analysis within AL DAR Company.

The findings from the implementation of the integrated planning and control system are discussed in Chapter 4. This includes a detailed examination of the outcomes from each of the three action research cycles, highlighting the practical challenges encountered, the iterative refinements made, and the observed improvements in process efficiency and adherence to schedules. The final chapter synthesizes the research findings, discussing their theoretical, practical, and methodological implications. It concludes with reflections on the research process, limitations of the study, and recommendations for future research, emphasizing the potential for broader application of the system in similar ETO environments.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Operation Management (OM) is an organisational function that enables organisations to achieve their objectives by acquiring and utilising resources efficiently and effectively to produce goods and services (Jacobs, Chase and Aquiltrano, 2004; Erkan Bayraktar et al., 2007). Projects are one type of operation that is managed using a project management approach. ETO is one type of project characterised by low volume and highly customised products (Jacobs, Chase and Aquilano, 2004). Though ETO approaches as project-based projects have deployed widely in the manufacturing and construction industries (Vaidyanathan, 2003), companies still lack integrated planning and control systems that achieve operational excellence (Adrodegari et al., 2015; Dave et al., 2015; Nakayama and de Mesquita Spinola, 2015; Jünge et al., 2019) which is the same issue at AL DAR Company where this Action Research was conducted.

For this literature review, ETO project manufacturing was the primary research context. However, due to the similarities between ETO construction and ETO manufacturing (Vaidyanathan, 2003), this research was drawn from construction-related and manufacturing theories and approaches. Furthermore, improving the planning and control of ETO projects at AL DAR Company was the primary focus area of this research. Accordingly, OM, ETO projects, and project management were the context of this research. In contrast, the proposed project planning and control system, inspired by conventional and non-conventional project management approaches, was the practical context of the research. A summary of the research context is presented in Figure 2-1, which illustrates the focus area of this research and the practical context: a proposed project planning and control system, which was tested and improved to address the missed due dates of orders at AL DAR Company.

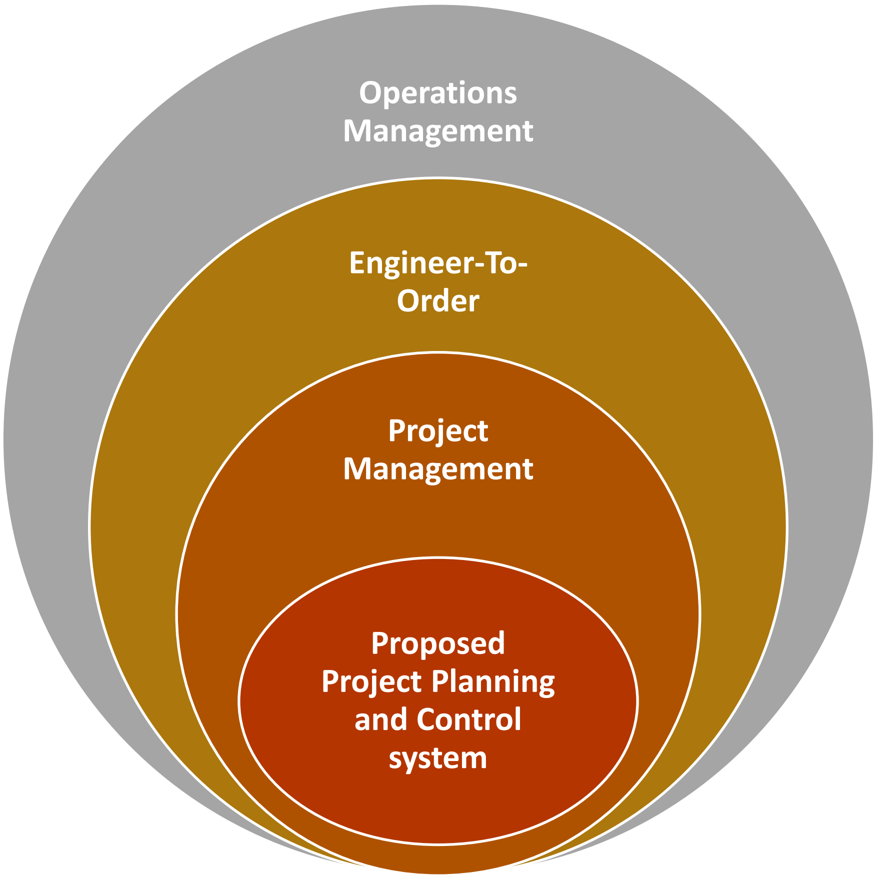

Figure 2-1: Research Context

According to the above research context, this literature review is divided into seven themes. The first theme is an introduction to the literature review followed by the theoretical perspective of this action research. The third theme briefly discusses OM theory, which is the general context of the research. The fourth theme is ETO characteristics of project-based projects to understand the unique characteristics of ETO environment projects and their implications for planning and control systems. Next, these planning and control systems are discussed in the context of traditional and Lean project management in the fifth and sixth themes, respectively. Then, the seventh theme presents the proposed planning and control system, after which the literature review is concluded by a summary of the findings.

2.2 Theoretical Perspective of This Action Research

As mentioned in this research methodology, theory is crucial in Action Research. It provides a framework that guides the problem identification, planning action, and evaluation stages of the Cyclical Process Model (CPM) discussed earlier (Susman and Evered, 1978). Without theory, Action Research is not considered research (McKay and Marshall, 2001), particularly in higher-degree studies (Mumford, 2001). However, Baker and Jayaraman (2012) argued that theorising before starting Action Research can be counterproductive and even unachievable as the researcher cannot define the exact theory to be used or developed before starting Action Research. Therefore, this research used the first two Action Research Cycles and literature review as a starting point towards explicating theory.

The interaction in these two Cycles with AL DAR's top management, department heads, and middle-level employees in the formal focus groups, individual interviews, and informal chatting revealed that AL DAR had been under tremendous pressure to enhance the efficiency and effectiveness of the operations process to address missed order due dates. Hence, the researcher needed to understand how AL DAR's process changed in response to the pressure to address the issue of missing due dates. Baskerville and Myers (2004) emphasised that theory should be explicated (i.e. clarified and elaborated) while conducting Action Research to guide the research process effectively before action is taken to avoid purposeless or meaningless action. Accordingly, the first theory was related to Lean manufacturing and LC theory, as discussed in the literature review. The rationale for adopting this theory was that the proposed planning and control system was based on borrowing elements of Lean theory.

Secondly, the researcher introduced a sociological theory – Institutional Theory – to be deployed in the context of this Action Research to provide the overarching framework for explaining how organisations like AL DAR respond to pressures from established norms, values, and systems, also known as institutional pressures (Lawrence and Shadnam, 2008). Dover and Lawrence (2010) concluded that integrating an Institutional Theory framework in Action Research could lead to new insights in answering Action Research questions. Institutional Theory is a theoretical framework used by organisational research that examines the institutions' role in changing and influencing behaviour and outcomes. The institution refers to the structures and mechanisms of social order, such as laws, norms, regulations, and routines, that govern individual organisational behaviours.

Five principles of Institutional Theory benefitted this Action Research by providing a framework for understanding, analysing, and influencing change at AL DAR. The first principle was related to the institutional isomorphism theory, as highlighted in the seminal study of DiMaggio and Powell (1983). According to DiMaggio and Powell (1983), isomorphism captures the constraining process that forces organisations to become more similar over time due to the same institutional pressures and environmental conditions. DiMaggio and Powell (1983) argued that institutional isomorphism theory is a valuable tool for understanding organisational behaviour and its change in responding to institutional pressures and environmental conditions. Ashworth, Boyne, and Delbridge (2009) examined institutional isomorphism in the public sector by analysing changes in the internal characteristics of 101 organisations in England between 2001 and 2004. They provided empirical evidence for the existence of isomorphic pressures in those organisations.

Three mechanisms promote institutional isomorphic change in organisations, referred to as three types of isomorphic pressures (DiMaggio and Powell, 1983). The first mechanism is coercive isomorphism, which refers to the pressure of forces from formal or informal external political sources, such as regulations or influential stakeholders, that force organisations to conform. This mechanism is an example of hiring accountants to meet law tax requirements (DiMaggio and Powell, 1983).

However, coercive authorities cause institutional isomorphism, so uncertainty could be a powerful force for organisations to copy or imitate successful peers or competitors (DiMaggio and Powell, 1983). This second type of mechanism is called mimetic isomorphism, which derives from uncertainty like a poor understanding of organisational technologies and ambiguous organisational objectives (DiMaggio and Powell, 1983). The third mechanism of institutional isomorphic change is normative isomorphism derived from the professionalisation that represents the collective struggle of occupation members while trying to define their practices to control the “production of the producers” (DiMaggio and Powell, 1983; Fang et al., 2019).

However, these three types cannot always be defined distinctly in understanding organisational behaviour and changes. This isomorphism classification system is a way to analyse organisations. Notably, these types are not always clearly separate in practice. For instance, an external entity may influence an organisation to follow the same practices (coercive isomorphism) as its peers (normative isomorphism) by making it necessary for them to perform a task and specifying the professionals responsible for it. Alternatively, changes in behaviour may occur due to uncertainties created by the environment (mimetic isomorphism). However, even though these three types often overlap in real-life situations, they typically arise from diverse conditions and can lead to different outcomes (DiMaggio and Powell, 1983).

The second principle is legitimacy, which refers to organisations seeking legitimacy to ensure their survival and success and gain stakeholder acceptance and support (Weidner, Weber and Göbel, 2019). The third principle is institutionalisation, which refers to organisations creating new routines or norms that everyone follows and become norms or routines within an organisation or society (Tolbert and Zucker, 1999). The fourth principle is decoupling, which refers to organisations with official policies but acting differently (Coburn, 2004). The last principle is institutional entrepreneurs, people or organisations working to change or create new societal norms and practices (Wahid and Sein, 2013).

Some studies have addressed the limitations of Institutional Theory. For example, Aksom and Tymchenko (2020) argued that while institutional isomorphism greatly influences highly institutionalised fields, it may not hold as much influence in technically dominated environments. Reflecting on this research field, AL DAR operates in institutionalised and technically dominated fields because AL DAR's operations focus on custom design and fabrication and should adhere to technical specifications. At the same time, AL DAR operates in the oil and gas sector, with its established norms, regulations, and standards exerting institutional pressures. Recognising this dual nature by applying Institutional Theory, this research ensured that the specific context and characteristics of AL DAR were considered. Hence, this strategy mitigated the risk of over-relying on institutional explanations where technical constraints also hold significant sway.

Institutional Theory has limitations when explaining why certain organisations embrace changes in response to institutional pressures while others do not, even if they operate within the same institutional environment (Juárez-Luis, Sánchez-Medina and Díaz-Pichardo, 2018). Additionally, the theory does not entirely explain owner-managers influence on legitimacy processes and how organisations within the field can differ (Juárez-Luis, Sánchez-Medina and Díaz-Pichardo, 2018). Therefore, this research focused on in-depth focus groups and discussions with key stakeholders within AL DAR, including owner-managers, to address these issues. By capturing the perspectives of those directly involved in decision-making processes, the research aimed to uncover specific reasons and motivations behind the company's responses to external pressures, going beyond what Institutional Theory would suggest to provide a more holistic understanding.

2.3 Operations Management (OM)

As shown in Figure 2-1 above and briefly discussed in the previous section, the overarching context of this research is OM, which has evolved significantly over the years (Chopra, Lovejoy and Yano, 2004). While OM originally referred to manufacturing production, it now permeates other functions such as accounting, logistics, engineering, information management, procurement, and human resources (Chopra, Lovejoy and Yano, 2004). This expansion of OM's scope has blurred its boundaries (Pilkington and Liston-Heyes, 1999; Hayes, 2000). According to this shifting in OM limits, Chopra, Lovejoy, and Yano (2004, p.10) defined OM as *“the design and management of the transformation processes that create value for society”.*

However, today, the core function of OM is manufacturing production, which encompasses the planning, organising, and controlling of manufacturing processes to achieve organisational goals (Jacobs, Chase and Aquilano, 2004). Five types of manufacturing processes exist based on the variety of products and production scale: batch, repetitive, continuous, job shop, and project (Stevenson, 2018). The latter is the practical context of this research. However, before discussing the project in this research context as a manufacturing process, a brief description of other manufacturing processes is provided to explain the unique characteristics.

A batch process example is the manufacturing/production of a moderate variety of products with small- to medium-volume products such as soft drinks and paint (Jacobs, Chase and Aquilano, 2004). A repetitive process is related to manufacturing a higher volume of standard products, such as the production and assembly lines for televisions, computers, and automobiles (Jacobs, Chase and Aquilano, 2004). In comparison, continuous processes relate to highly standardised products, such as sugar, steel, and salt, produced in a very high volume without various outputs (Stevenson, 2018). However, a job shop, called “jobbing production” (Porter et al., 1999), is related to manufacturing products with very low volume and often unique for a varied range of products as per customer requirements, which are typically not expected to produce them again. An example of jobbing production is the production of specific machine tools as per customer requirements (Stevenson, 2018).

Now, we turn back to the last type of manufacturing process, project manufacturing, which encompasses this research context. According to Porter et al. (1999), this type of production falls within the broad definition of a job shop or jobbing production. However, it is characterised by its large scale of inputs compared to jobbing production. It must be coordinated in engineering and procurement manufacturing to produce one-off and unique products per customer requirements (Porter et al., 1999; Little et al., 2000). One type of project-based operation or project manufacturing is ETO (Little et al., 2000; Strandhagen et al., 2018). Typical examples of ETO projects are construction, shipbuilding, oil and gas installation, and the manufacturing of customised equipment (Strandhagen et al., 2018; Jünge et al., 2019), which is the practical context of this research.

In contrast, other scholars classify manufacturing strategies into four categories: make-to-stock (MTS), assemble-to-order (ATO), make-to-order (MTO), and ETO (Olhager, 2003). This classification is based on the concept of the Customer Order Decoupling Point (CODP). The CODP, as defined by (Olhager, 2010), is the point in the manufacturing stages (i.e. engineer, fabricate, assemble, and deliver) where the product is tied to a specific customer order. For the ETO manufacturing strategy, CODP is located at the "engineer" stage (Olhager, 2003). Hence, the manufacturing firm starts the engineering phase only once the customer order is received, which is the case of AL DAR Company, where the Action Research is conducted. Hence, the COPD adds complexity to the characteristics of ETO projects (Gelders, 1991), determining the operational business processes of ETO manufacturing companies, including design, procurement, fabrication, assembly, and project management, and other ETO characteristics (Powell et al., 2014). These are discussed in the next theme to explore their implications on the proposed planning and control system.

2.4 ETO Environment Characteristics

As noted in the introduction of this literature review and depicted in Figure 2-1, the research context of this study was the ETO environment, where the researcher sought to investigate the potential impact of implementing a proposed integrated planning and control system on project lead time, operational performance, and key competitive criteria. The study eventually aimed to conclude by refining the proposed system at AL DAR Company to address the issue of missing the due date of the orders. Since the characteristics of the ETO environment had significant implications for the planning and control system and its implementation, it is crucial to examine these characteristics thoroughly to enhance the research outcomes.

One characteristic is the iterative and uncertain nature of the ETO environment. During the tender stage and early stage of the engineering work, the scope and the requirements of the ETO products, which are highly customised, are broadly defined and evolve iteratively as the project progresses (Bertrand and Muntslag, 1993; Little et al., 2000; Alfieri, Tolio and Urgo, 2012b). Moreover, customers may request design changes during the engineering and fabrication stages (Strandhagen et al., 2018). Consequently, new information should be reflected progressively in the initial planning document for each project. Based on this characteristic of uncertainty, a traditional linear approach is inadequate for the planning and control system of the ETO environment (Geraldi et al., 2008). Accordingly, several scholars have studied this phenomenon and highlighted the need for a flexible and adaptive planning approach (Geraldi et al., 2008; Sriram, Alfnes and Arica, 2012).

The second characteristic of the ETO environment is that ETO products are highly customised to customer requirements and produced in low volume, which requires a diversity of materials and components, some of which are high-quantity, long-lead, and highly customised items (Hicks and Braiden, 2000; Vaidyanathan, 2003). These requirements and materials need significant engineering and procurement activities to align with the customer's requirements and deliver them on the due date before starting the fabrication and assembly activities (Bertrand and Muntslag, 1993). As a result, ETO production includes only a physical stage (i.e. the fabrication and assembly) and a non-physical stage related to engineering and procurement activities (Bertrand and Muntslag, 1993).

The strong interaction between the physical and non-physical stages adds complexity to determining the progress and planning activities (Gelders, 1991). Nevertheless, planning and control practices in ETO projects focus only on detailed fabrication plans and lack an integrated approach to planning and monitoring engineering activities and procurement (Little et al., 2000; Adrodegari et al., 2015). Kjersem (2020) emphasised that the lack of an integrated approach to planning and monitoring engineering activities and procurement in ETO projects was an interesting gap in traditional and non-traditional project management literature. This gap highlighted the need for a comprehensive planning and control system that covers physical and non-physical stages of ETO production. Therefore, this research aimed to test and refine a proposed integrated system to bridge this gap and improve planning and control practices at AL DAR.

Thirdly, ETO products meet both definitions as project-based and manufacturing products. ETO products meet the Project Management Institute's (2017) definition of project-based as a unique and temporary effort due to the uniqueness of the customer's demands and requirements. On the other hand, ETO products are like manufacturing products since they are produced in a few units or single units. Accordingly, ETO products are called project manufacturing (Yang, 2013; Kozjek, Rihtaršič and Butala, 2018). Nevertheless, the ETO strategy involves executing multiple projects simultaneously, sharing the same resources at a different stage for each project (Fox et al., 2009). Thus, visualisation capabilities are needed to ensure the flow with minimum variability of these shared resources in the ETO planning and control system for better optimisation. Hence, Dave et al. (2015) concluded that based on a literature review and practice, a gap of missing flow visualisation from the schedule and the plan in the ETO projects needed to be bridged.

Fourthly, the ETO product structure is deep and complex, which requires a high level of coordination between the assembly processes and component supply (Hicks and Braiden, 2000). A comprehensive literature review by Gosling and Naim (2009) supported this concept. They emphasised that ETO products are generally associated with complex project environments in the manufacturing and capital goods sectors. This complexity was classified into five dimensions by Geraldi, Maylor, and Williams (2011) in their systematic review: 1) structural complexity related to the size, variety, and interdependence attributes of ETO products, 2) uncertainty related to the unavailability of information and the novelty attributes of ETO products, 3) dynamics related to changes in any element of the project especially at the beginning, 4) the pace related to urgency and limited timeframe attribute of ETO production, 5) and socio-political complexity related to emotional and political aspects involved based on the project's importance and transparency of its hidden agendas.

Accordingly, Caron and Fiore (1995) emphasised deploying an innovative system that integrates manufacturing and logistics with project management to deal with such complexity. Hicks and Braiden (2000) highlighted that the ETO products' complexity requires a high level of coordination between ETO project activities. Additionally, Mello, Strandhagen, and Alfnes' (2015) findings emphasised that essential factors influence coordination in ETO projects, requiring integrated planning of the engineering and production activities. Hence, an integrated planning and control system is needed.

In conclusion, these studies provided important insights into the main characteristics of ETO projects that make implementing a planning and control system challenging. The iterative and uncertain nature of ETO projects requires a flexible and adaptive planning approach (Bertrand and Muntslag, 1993; Little et al., 2000; Geraldi et al., 2008; Alfieri, Tolio and Urgo, 2012b). The highly customised nature of ETO products, with diverse materials and components, demands significant engineering and procurement activities to be planned and controlled without just focusing on the fabrication activities, adding complexity to the planning and control process (Hicks and Braiden, 2000; Vaidyanathan, 2003). The ETO product structure is deep and complex, requiring a high level of coordination between assembly processes and component supply (Bertrand and Muntslag, 1993). Finally, ETO products meet project-based and manufacturing product definitions and share the same resources, necessitating visualisation capabilities to ensure their flow (Yang, 2013; Project Management Institute, 2017; Kozjek, Rihtaršič and Butala, 2018). Therefore, this study aimed to refine the proposed integrated planning and control system at AL DAR covering the physical and non-physical stages of ETO production to address the issue of missing due dates and bridge the gap by enhancing planning and control practices in ETO production. This integrated planning and control system was inspired by management methods and approaches considering ETO characteristics and complexity mentioned in this theme, per Williams (2005).

Accordingly, the following themes cover the third and fourth layers of the research context related to project management and a planning and control system. These themes laid the foundation for the proposed planning and control system, considering the implications of the abovementioned ETO characteristics. This proposed planning and control system was implemented, tested, and refined in this Action Research at AL DAR.

2.5 Planning and Control in Traditional Project Management

2.5.1 Overview of Planning and Control in Traditional Project Management

Cleland and Ireland (2002) argued that comprehending the evolution and current state of project management, particularly its crucial planning and control aspects, is vital for proposing, implementing, and refining a planning and control system in ETO environments to tackle late project completion. Project management was developed in the Atlas and Polaris programmes in the 1950s (Williams, 2005). However, nowadays, its practices and “bodies of knowledge” are formulated and dominated by professional associations such as the Project Management Institute (PMI), the Association for Project Management (APM), the UK’s Office of Government Commerce (PRINCE2 standard; (Williams, 2005; Geraldi, Maylor and Williams, 2011), and the International Project Management Association ((Williams, 2005). These associations consider their “bodies of knowledge” as the core of project management.

Project planning is critical in project management (Cleland and Ireland, 2002; Project Management Institute, 2017). Effective project control is also essential for manufacturing firms (Porter et al., 1999). Slevin and Pinto (1988) found that planning and control processes were among the top ten Critical Success Factors in a survey of 418 project managers. In contrast, in their seminal empirical analysis, Dvir, Raz, and Shenhar (2003) investigated the relationship between project planning and project success. Their research revealed that, based on data from over 100 development and defence research projects, project success is insensitive to resources invested in the planning and project management process. Consequently, they recommended that project managers prioritise milestone planning over comprehensive project planning.

Scholars have disagreed on the relationship between project success and planning efforts, as mentioned in the previous paragraph, and have debated the meaning of the term “planning”, adding complexity to its comprehension. For example, Cleland and Ireland (2002) defined project planning as the process that carefully considers the project’s objectives, strategies, and goals that guide the project from start to finish. Turner and Müller (2005) expanded this idea by explaining that project planning entails the development of a comprehensive plan that outlines the project objectives, tasks, timelines, resources, and risks. The Project Management Institute (2017) also considered creating a WBS and developing a project schedule as part of project planning.

Laufer and Tucker (1987) suggested that project planning involves making decisions in advance of action to design a desirable future and identify effective ways to achieve it. However, Cicmil et al. (2006) emphasised the importance of stakeholder involvement in project planning to ensure that the project plan reflects the needs and expectations of all parties involved. Overall, project planning is a critical process in project management that involves a series of activities aimed at defining project objectives, developing strategies for achieving them, and allocating resources to various tasks (Anantatmula and Thomas, 2010; Project Management Institute, 2017).

Regarding project management, Laufer and Tucker (1987) argued that planning answers the following inquiries in more detail: What should be done (activities)? How do we perform these activities? Who should perform those activities? What are the resources needed to perform those activities? When should we perform those activities (sequence and timing)? Planning is a process that occurs at multiple levels and stages. While some consider it a hierarchical, systematic, and comprehensive process conducted in a top-down manner, as argued by Emery (cited in Laufer and Tucker, 1987), others have argued that planning that aims to facilitate execution, coordination, control, and forecasting is a multi-directional, incremental, and heterarchical process characterised by opportunism and conducted into several stages. (Laufer and Tucker, 1987).

Arditi and Koseoglu (1983) depicted these planning stages and described planning as transforming in three stages: normative, operational, and retrospective. The normative function aims to direct and initiate actions before they occur. In contrast, the operational function seeks to influence and regulate ongoing activities. Finally, the retrospective function is limited to reporting and forecasting after the fact to monitor and control progress.

However, Laufer and Tucker (1987) argued that five phases comprise the normative planning process. These phases include planning the planning process, gathering information, preparing plans, disseminating information, and evaluating the planning process. In the planning process and gathering information stages, the planner makes decisions regarding various aspects of the planning process, such as determining the effort and timing for each planning stage, the frequency of updates, the planning horizons and level of detail, and the degree of centralisation of planning and control. The planner may also decide on the selection of information to be gathered, the distribution method, and scheduling techniques.

The third stage is related to preparing the plans, followed by disseminating the plans per the user's needs. However, avoiding overwhelming users with too much information is critical since it can be as harmful as leaving them without the necessary information (Laufer and Tucker, 1987). Indeed, when users are presented with too much information, they can feel overwhelmed, making it difficult to process and comprehend the content effectively, eventually impacting their decision-making (Falschlunger, Lehner and Treiblmaier, 2016). Instead, planners should conduct a realistic assessment of what information each user requires and identify accompanying activities that can ensure the implementation of plans. The last phase is related to the periodic evaluation of the progress against the plans for further corrective action if needed. However, project planning in practice suffers from ignoring the first and last phases of the planning process, while the other three phases are carried out with significant deficiencies (Laufer and Tucker, 1987).

In conclusion, project planning is critical in project management. It involves a series of activities to define project objectives, develop strategies for achieving them, and allocate resources to various tasks. The planning process occurs at multiple levels and stages and addresses what should be done, how to perform the activities, who should perform them, and when they should be performed. Despite its importance, project planning is a complex topic with varying definitions and approaches, making it challenging to comprehend fully. However, understanding project management's evolution and current state can provide a helpful context for proposing, implementing, and refining planning and control systems to address late project completion in ETO environments and, more specifically, in the subject company where the research was conducted.

2.5.2 Shortcomings of Planning and Control in Traditional Project Management

Despite 932,720 Project Management Professional (PMP) – PMI's official certificate – holders as of August 2019 (PMI, 2019) and over 1 million certified PRINCE2 professionals (PRINCE2.com, n.d), projects still fail (Buchanan, 1991). This failure in achieving the targeted project output was supported by W G Morris and G H Hough (cited in Williams, 2005). They emphasised that based on the references of 33 databases, and despite the attention to project management, the project had suffered from poor performance in terms of time and cost. Additionally, Powner (2008) highlighted that based on a U.S. Government Accountability Office study, 778 IT projects were performed in 2008; 413 of them (53%) were either poorly performed, poorly planned, or both.

Since this Action Research eventually proposed, implemented, and refined a planning and control system to resolve the late completion of projects, this theme investigated reasons for the ineffectiveness of the planning and control process in traditional project management, as highlighted in the literature. For example, Macomber and Howell (2003) claimed that traditional planning and control approaches lack conversation in the planning process. Moreover, Emblemsvåg (2014) claimed that current planning approaches only manage the project at the macro level. De Reyck (2010) also claimed that projects are overrun due to a poor understanding of the planning phase, as supported by Eckert and Clarkson (2010). They argued that planning processes are complex and diverse, where several elements that need to be planned are not mapped onto each other directly.

Overemphasising control is another reason highlighted in the literature for the ineffectiveness of the traditional planning and control process since it can have negative impacts. Site managers may become annoyed by the perception of constant monitoring (Arditi and Koseoglu, 1983). Gilbert (1983) argued that excessive focus on producing a historical record of past problems can distract first-line supervisors from current and future tasks. Rather than improving plans for the future, supervisors may find it more beneficial to expend their mental energy justifying past decisions. This shift in emphasis from execution to control results in a diminished emphasis on prospective planning, which involves creating a desired future. Instead, efforts are redirected towards retrospective planning, which addresses deficiencies caused by past decisions (Laufer and Tucker, 1987).

Additionally, traditional planning and control techniques in project management have been criticised for their limited effectiveness in dealing with uncertainties, complexities, and dynamic environments (Winter et al., 2006; Kwak and Anbari, 2009). Špundak (2014) argued that traditional project planning and control methods are based on a linear and sequential approach that assumes a stable and predictable project environment, which is rarely the case in practice. Ju and Xu (2017) added that traditional techniques, such as Critical Path Analysis (CPA)and earned value management, focus mainly on cost and schedule performance, neglecting other critical aspects such as stakeholder engagement, risk management, and value creation.

In the same vein, Spalek (2016) noted that traditional planning and control methods are often too rigid and bureaucratic, limiting the flexibility and agility required to respond to changing circumstances. Kwak and Anbari (2009) argued that traditional approaches cannot capture and manage the complexity of modern projects characterised by multiple interdependent variables and non-linear relationships. Qiu (2011) further emphasised the limitations of traditional methods in managing uncertainty and risk, suggesting that more adaptive and dynamic approaches are needed. Finally, Winter et al. (2006) criticised traditional planning and control techniques for their narrow focus on delivering predetermined outputs, ignoring the broader goals of projects and their stakeholders.

2.5.3 Underlying Theories of Planning and Control in Traditional Project Management

Due to the low performance of traditional project management, questions have been raised about its underlying theories, as mentioned in the previous theme. For example, in their project management research spanning 40 years, Kloppenborg and Opfer (cited in Koskela and Howell, 2002) concluded that nothing could be reported on the project management theory. Moreover, in his systemic modelling, Williams (2005) argued that it is generally accepted that project management is based on a very narrow implicit theory or no theoretical basis and determines its underlying assumptions. Assumptions about project management are 1) the methods used in project management are self-evidentially, correct, and normative rationalist; 2) project management takes the positivist view of ontology; and 3) project management is about scope management by dividing the scope into manageable pieces and emphases on planning, conventional control model and decoupling the plan from the environment. Williams (2005) also emphasised that these underlying assumptions are reasons for the inappropriateness of traditional project management in complex projects.

On the other hand, in their seminal research, Koskela and Howell (2002) highlighted four underlying theoretical foundations of project management: transformation, management-as-planning, classical communication theory, and thermostat model theories. However, Koskela and Howell (2002) argued that these theoretical foundations are obsolete and deficient. Additionally, they argued that practising traditional project management is counterproductive for current complex, big, speedy projects, which are some of the ETO characteristics highlighted above. Adopting a similar position, Geraldi, Maylor, and Williams (2011) claimed that traditional project management performance improvement is elusive. Moreover, Geraldi et al. (2008) emphasised the need for a non-linear approach to deal with the complexities better. However, the next theme investigates traditional planning and control systems to explore which elements can be appropriate to be considered in the proposed planning and control system.

2.5.4 Traditional Planning and Control Systems

2.5.4.1 Materials Requirements Planning (MRP I and MRP II)

Material Requirements Planning (MRP I) is a traditional planning and control system, which is a push-based software that integrates the supply management system with organisations' inventories to estimate raw material quantities and develop a demand-driven production plan (Ramya, Chandrasekaran and Shankar, 2019). The main inputs for MRP are the bill of materials (BOM), the master production schedule, and the inventory status file. Accordingly, the MRP calculates the raw materials quantities and the needed-by dates for the manufacturing process (Ramya, Chandrasekaran and Shankar, 2019). Furthermore, MRP I has been expanded with greater functionality to manufacturing resource planning (MRP II) to consider the material and the resources to control the entire organisational system, including receiving the order, scheduling, controlling inventory, accounting, and finance. Additionally, MRP today includes Kanban, computer-integrated manufacturing, and just-in-time (JIT; (Jacobs, Chase and Aquilano, 2004; Stevenson, Hendry and Kingsman, 2005).

On the other hand, the popularity of MRP/MRP II needs to be questioned. Bertrand and Muntslag (1993) argued that the wide availability of MRP/MRP II drives organisations to choose it. Additionally, MRP/MRP II vendors embrace a universalistic approach instead of gearing MRP/MRP II to a particular manufacturing strategy or industrial sector. However, there is evidence that MRP/MRP II tends to suit manufacturing strategies with lower variety levels, such as mack-to-stock (MTS), rather than strategies with wider variety, such as ETO and assemble-to-order (ATO). Bertrand and Muntslag (1993) argued that MRP/MRP II had been implemented in many ETO organisations without success due to its functionality.

Exploring the underlying assumptions of MRP/MRP II is necessary for understanding the functionality problematic issues leading to such failure rates. Firstly, MRP/MRP II assumes that the production is standard; thus, the BOM is well-known in advance with the product routings (Bertrand and Muntslag, 1993).

However, in ETO products, the BOM cannot be generated unless the detailed design of the product is completed, which is also subject to modification in case of any design change as per the client's request (Stevenson, Hendry and Kingsman, 2005). Secondly, MRP/MRP II assumes that the future demand for the product can be forecasted, which cannot happen in the ETO environment, as reflected in the Master Production Schedule (MPS). This misconception leads to unrealistic MPS and can lead to a high inventory level and work-in-process (WIP). Accordingly, the uncertainty in the design and the forecast demand can severely impact the applicability of MRP/MRP II (Bertrand and Muntslag, 1993; Stevenson, Hendry and Kingsman, 2005)

In conclusion, MRP II is not the most valuable system in all manufacturing process strategies. For example, MRP can be most valuable for manufacturing products in batches using the same equipment or for assembly operations. In contrast, MRP is least valuable for operations involving fabrication, producing a few products, and design activities such as ETO. Thus, a network scheduling technique is needed for such operations (Jacobs, Chase and Aquilano, 2004; Alfieri, Tolio and Urgo, 2012a) or a combination of project management and MRP (Harhalakis and Yang, 1988; Caron and Fiore, 1995).

2.5.4.2 Enterprise Resource Planning

MRP/MRP II's shortcomings have led to further advanced technologies such as advance planning and scheduling, enterprise resource planning (ERP), and workflow management systems. Small and Chen (2003) defined ERP systems as a group of software modules that address the fragmentation problem of information across the entire business' functional areas. Although ERP systems have been widely used to manage ETO projects in many organisations to improve their operational efficiency and provide real-time information about project performance, implementing an ERP system in ETO projects is not without its challenges and limitations, as argued by several scholars (Kehoe and Boughton, 2001; Stevenson, Hendry and Kingsman, 2005).

Kehoe, Boughton, Muscatello, Small, and Chen (2001; 2003) argued that the progression from MRP/MRP II to ERP dominates production planning and control systems mindsets. Although modern ERP vendors are working on increasing the functionality capabilities of ERP systems and continue claiming that their software is widely applicable to meet any type of business (Aslan, Stevenson and Hendry, 2012), the planning and control module core assumptions underpinning these ERPs have been developing less promptly compared to another module (Stevenson, Hendry and Kingsman, 2005). Consequently, MRPs' underlying assumptions-related issues are still applicable to ERP systems.

One major limitation in implementing ERP as a planning and control system is the complexity of ETO projects. ERP systems are designed to handle standardised processes. Customising ERP systems to meet the complex characteristics of ETO can be difficult, time-consuming, and costly, resulting in a low success rate (Zhao and Fan, 2007). These factors can lead to delays and prolonged lead time in project delivery, as customisation is often necessary to meet customer requirements in ETO projects. In addition, ETO projects often require the integration of multiple systems. The integration of ERP systems with other systems can be challenging, mainly when different systems are used by different departments or suppliers (Zhao and Fan, 2007). In the same vein of MRP/MRP II implementation, Hong and Kim (2002) noted that ERP implementation reported a high failure rate and sometimes jeopardised the organisations' core operations based on their survey of 34 firms. Hong and Kim (2002) claimed that the main reason for this failure was ERP misfits in the organisation.

This assertion was supported by Aslan, Stevenson and Hendry's (2012) study, which questioned the effectiveness of ERP in dynamic environments like MTO, which is similar to ETO. In their contingency-based prospective study, based on their theoretical assessment of the applicability of ERP in such an environment, Aslan, Stevenson and Hendry concluded that there was a misalignment between the MTO requirement and ERP functionality and found a call for empirical research. Accordingly, a mixed-methods survey and case research study concluded that ERP does not suit the MTO environment's needs.

2.5.4.3 Critical Path Method (CPM)

In the late 1950s, Morgan R. Walker from DuPont and James E. Kelley from Remington Rand collaborated to create the CPM due to the inefficiencies of traditional planning and scheduling systems (Lenfle and Loch, 2010). In their seminal article, Kelley and Walker (1959) claimed that the CPM was developed to resolve issues related to coordinating many diverse activities required to complete projects. They highlighted that large construction or ETO projects involve numerous stakeholders with varied expertise focused on their specific tasks. Hence, managing the coordination of these interrelated activities is a fundamental aspect of management that can be addressed by adopting the CPM.

Moreover, Kelley, Walker, and Sayer (1989) argued that the potential applications of the CPM method could be limitless. In the same vein, Jaafari (1984) argued that project planning should be done using the CPM method despite the numerous criticisms considering tow main factors that affect its successful implementation. Firstly, the CPM should be fed with realistic productivity rates for the crews considering the job management efficiency conditions. Secondly, the CPM should include sufficient safety buffers (float) between dissimilar trades.

However, the role of the CPM in practice in traditionally managed projects has shifted from focusing on planning and studying alternative ways of performing work to controlling and scheduling at the expense of planning (Koskela et al., 2014). Accordingly, the management of projects follows a top-down approach by setting a schedule and ensuring compliance with contracts, as argued by Howell, Ballard, and Tommelein (2011). Therefore, the CPM method is utilised within this framework as a contract document for creating work orders and construction schedules, overseeing performance, assessing delays and change orders, and managing progress payments. While the actual means and methods used by the speciality contractors to complete the work are treated as "black boxes", safety and quality are regulated through inspections and enforcement measures (Koskela et al., 2014).

In the same vein, scholars have criticised the schedule resulting from the CPM since it has little value for site management. Additionally, planning is put aside before the work begins (Koskela et al., 2014). Seppänen and Aalto (2005) argued that the CPM technique concentrates solely on the activities' interdependence without focusing on achieving a stable continuous workflow (continuity principle) that can be achieved by adopting other methods, such as the line-of-balance method. Additionally, the CPM can identify productivity variances or schedule deviations and capacity waste very late, comparing the line-of-balance method, which even provides a better visualisation of such variances (Seppänen and Aalto, 2005).

In the same vein, Goldratt (1997) criticised the CPM for many shortcomings, firstly the misusing of activities' floats (i.e. safety buffers) that can account for any potential uncertainty for the actual completion of the activities, thus leaving the project team unprepared to start the next activity on the due date when the first activity finishes (Goldratt, 1997). In contrast, Goldratt (1997) argued for adopting the "theory of constraints", suggesting a different approach to dealing with activity buffers by strategically placing them in the project and focusing on finishing activities on time without grouping them. This approach can help ensure that activities are ready to start when needed and that completed activities are released as soon as possible without impacting the project's overall timeline.

Additionally, Sacks and Harel (2006) argued that traditional project management practices based on the CPM have resulted in a situation where all project stakeholders (including subcontractors) compete, creating adversarial relationships. Hence, project stakeholders make decisions based on their interests and goals rather than considering the planned dates generated from the CPM without aligning with the overall project's goal.

Overall, this section highlighted the fundamental shortcomings of the CPM in managing ETO projects. However, despite these issues with the CPM and its ability to manage project work effectively, it has surprisingly continued to be the dominant approach in construction and ETO projects for a long time and has been widely adopted and taught in the field of construction management as a technique used to plan, schedule, and control project activities to complete projects on time and within budget (Koskela et al., 2014). On the other hand, while some new methods, like the theory of constraints, line-of-balance, and critical chain, have been developed and promoted, they have not gained mainstream acceptance. One reason could be that critiques of the CPM have been presented as isolated arguments rather than a systematic evaluation of the method's validity (Seppänen and Aalto, 2005).

2.5.5 Evaluation of Traditional Planning and Control

Scholars have argued that ETO projects can utilise a pure traditional project planning system like the CPM (Porter et al., 1999) or a combination of project management and MRP (Harhalakis and Yang, 1988; Caron and Fiore, 1995). However, as highlighted above, many projects that adopted these planning processes were completed late (Kjersem, 2020).

However, the shortcomings of traditional project management mentioned above could justify that ETO companies still suffer from the lack of integrated planning and control systems, as reported in several research types. For example, in their case studies of three companies and literature review, Nakayama and de Mesquita Spinola (2015) claimed that ETO characteristics complicate planning tasks, resulting in missing the project deadlines. Additionally, in their empirical study of 21 ETO companies, Adrodegari et al. (2015) argued that they still suffer from the lack of comprehensive planning and control tools.

On the other hand, Ballard and Tommelein (2012) suggested that conventional or non-Lean management methods could be successful in projects with scope stability without any risk of change. In contrast, Williams (2005) argued that traditional project management methods are potentially disadvantageous for developing a planning and control system for complex, uncertain, and speedy ETO manufacturing. Thus, deploying a newer methodology in project management, such as “Lean” or “agile”, may be more appropriate (Williams, 2005).

Overall, these studies addressed the history of traditional project management and the poor performance of its practices. Additionally, the studies revealed that the underlying theoretical foundations of project management using the existing operations management theories are transformation, management-as-planning, classical communication theory, and the thermostat model (Koskela and Howell, 2002). However, based on evidence from practice and the literature, these theoretical foundations are obsolete and deficient and are the causes of the poor performance of its practices (Koskela and Howell, 2002). The traditional planning and control function has been discussed as an integral part of project management with its ineffectiveness reasons. Although MRP, ERP and CPM have been used as a tool for managing ETO projects, studies have highlighted that ETO firms still suffer from the lack of comprehensive planning and control tools (Adrodegari et al., 2015; Nakayama and de Mesquita Spinola, 2015).

Moreover, as Williams (2005) and other scholars suggested, the complexities of ETO manufacturing necessitate a move away from traditional paradigms towards more adaptive methodologies like agile. Agile, known for its flexibility and responsiveness, emerges as a promising alternative that can better meet the unpredictable demands of ETO projects so that ETO firms can potentially overcome many of the limitations observed with traditional project management practices. The next section discusses how agile may enhance planning and control in ETO environments.

2.5.6 Agile Response to Traditional Project Management Challenges in ETO Settings: Enhancing Responsiveness and Flexibility with Key Technologies

The aforementioned limitations of traditional project management approaches in handling the dynamic and customized nature of ETO projects necessitate the exploration of alternative approaches that can provide the necessary flexibility and responsiveness like agile. Agile approaches focus on four dimensions: people, technology that works well, working collaboratively with customers, and adapting to change (Yusuf et al., 2020). These dimensions are increasingly applied in project management, especially in environments like ETO where the ability to quickly respond to changing customer requirements and project conditions is crucial (Sońta-Drączkowska and Krogulec, 2024).

In ETO projects, the requirement for customization and the unpredictability of project scopes make agile approaches particularly relevant. By implementing agile practices, project teams can engage in continuous planning and frequent reassessment of project objectives, which aligns well with the iterative and uncertain nature of ETO projects. Furthermore, agile's emphasis on working in small, cross-functional teams with regular communication enhances collaboration and problem-solving, critical factors in managing the complexities of ETO projects (Olszewski, 2023).

To support agile practices, several technologies have been identified as enhancing agility in planning and control processes. Advanced Planning and Scheduling Systems (APS) and modern ERP systems integrated with real-time data analytics enable better flexibility in resource allocation and quicker response to changes in project dynamics. These systems provide the tools necessary for agile decision-making and resource management, thus supporting the agile philosophy of rapid adaptability (Uraon et al., 2023). However, although some ERPs support real-time data analytics, the planning and control module core assumptions underpinning these ERPs have been developing less promptly compared to other modules (Stevenson, Hendry and Kingsman, 2005)

The real-world application of agile methodologies within ETO settings offers insightful benefits and challenges. For instance, studies have shown that agile practices can reduce project lead times and improve stakeholder satisfaction by ensuring that planning and control processes are more adaptive to client feedback and project alterations (Piwowar-Sulej and Iqbal, 2024). However, the adoption of agile methodologies also requires significant cultural shifts within organizations. Transitioning from traditional, plan-driven approaches to a flexible, iterative approach often encounters resistance, necessitating strategic change management initiatives (Piwowar-Sulej and Iqbal, 2024).

Agility enablers are grouped into two categories: technology and management. The technology is related to the integration of information and computer-aided design and production. The management enablers include the lean approach (Vinodh et al., 2010 as cited in Yusuf et al., 2020).

In conclusion, while traditional project management methodologies provide a structured approach, they often fall short in environments characterized by high customization and uncertainty, as typical in ETO projects. Agile methodologies, with their emphasis on flexibility and responsiveness, may offer a practical element to the proposed planning and control system. Piwowar-Sulej (2021) recommended combining agile practices with traditional project management for ETO projects to take advantage of both. As we move on to discuss Lean project management, it'll become clear that combining agile responsiveness with traditional project management along with the efficiency of Lean as an enabler for agility might be a better way to manage ETO projects effectively.

2.6 Planning and Control in Lean Project Management

2.6.1 Lean Manufacturing and Lean Construction Theory

Due to the shortcomings of the traditional planning and control systems mentioned above, Lean-inspired elements may be used in the proposed and refined system tested at AL DAR Company, where this Action Research was conducted. Accordingly, this theme addresses Lean theory and systems and concludes by evaluating Lean planning and control. The International Motor Vehicle Program researcher John Krafcik coined the idea of Lean production, with the term “Lean” meaning producing more with fewer resources (Womack, Jones and Roos, 2007). Lean was developed from Toyota Production System (TPS) working practices, rooted in Henry Ford’s concepts related to continuous flow thinking (Powell et al., 2014). However, despite its widespread use, many practitioners and scholars do not understand Lean production’s theoretical foundations and philosophical principles (Koskela et al., 2019). The origins of Lean production are traced back to the TPS, which emerged from a series of unplanned and loosely related innovations and improvements (Fujimoto and Miller cited in Koskela et al., 2019).

However, several researchers have established different sets of Lean principles. In their book *Lean Thinking-Banish Waste and Create Wealth in Your Corporation*, Womack and Jones (1997) identified five principles or stages to eliminate waste:

1) the value to be defined by the customer, 2) the value stream to be identified as an activity required to produce the product, 3) creating a flow for added value activities and avoiding waste, 4) the customer pulling the product, and 5) seeking perfection. Liker JK (cited in Powell et al., 2014) extended Womack and Jone's five principles towards a more operationalised and general management philosophy by describing the TPS in *14 Management Principles to Achieve Lean*. Sobek and Smalley (2011) argued that the heart and the backbone of the TPS is the Plan-Do-Check-Act (PDCA) methodology (i.e. the Deming Cycle). Other Lean principles have been developed to be employed outside the automotive industry, such as those by Nightingale and Srinivasan, Powell et al., and Murman et al. (2011; 2014; 2016). However, one of the most relevant Lean thinking philosophies to this research context that addresses the one-of-the-kind (project) is Lean Construction (LC).

The starting point for the LC concept can be traced back to Koskela's seminal report (1992). Koskela (1992) reported the need to apply a new production philosophy to the construction industry, a type of ETO. His assertion on Lean implementation was due to the obsoleteness and several criticisms of traditional project management, as mentioned in the previous theme. In response to Koskela's report (1992), the International Group for Lean Construction (IGLC) was founded in 1993 with a vision of promoting LC practices among researchers and practitioners in architecture, engineering, and construction (IGLC.net, n.d). IGLC.net (n.d) claimed that LC emphasises theory compared to traditional methodologies. As a result of this initiative, research groups have been initiated, such as the Project Production Systems Laboratory (P2SL) at the University of California, Berkeley, USA (IGLC.net, n.d).

Professional organisations, institutes, and journals, such as the Lean Construction Institute (LCI), have also been founded, which initiated the *Lean Construction Journal*. LCI was founded in 1997 by Greg Howell and Glenn Ballard to develop and disseminate new knowledge concerning project management and, more specifically, project planning elements (Lean Construction Institute, n.d). LC principles that can be utilised while refining the proposed planning and control system, as identified in Koskela's report (1992, p.22), are as follows:

Reduce the share of non-value-adding activities, increase output value through systematic consideration of customer requirements, reduce variability, reduce the Cycle time, simplify by minimising the number of steps, parts, and linkages, increase output flexibility, increase process transparency, focus control on the complete process, Build continuous improvement into the process, balance flow improvement with conversion improvement and benchmark.

Biazzo, Panizzolo, and de Crescenzo (2016) systematically analysed scientific and management literature across various databases to understand the practices characterising the implementation of the aforementioned Lean principles in innovation processes. The authors independently analysed each publication to extract the methodologies, tools, and organisational solutions proposed in the literature for the Lean transformation of innovation processes. Based on this study, Biazzo, Panizzolo, and de Crescenzo (2016) identified 20 Lean innovation practices. One of the practices most related to this research is Visual Pull Planning.

Visual Pull Planning practice acknowledges the recent critiques of traditional project management and planning methodologies. These critiques reject the consideration of the project as a simple network of activities and instead emphasise the importance of understanding projects as networks of people (Biazzo, Panizzolo and de Crescenzo, 2016). To illustrate the practical applications of this approach, consider the case of a software development project where the project team adopted Visual Pull Planning. The team used a physical board with sticky notes representing tasks. As each task was completed, it was moved to the “done” column, which allowed the team to visually track progress and adjust plans in real-time, leading to improved collaboration, reduced lead times, and enhanced stakeholder satisfaction (Powell, 2018).

The key implications of this perspective are twofold. Firstly, the concept of Rolling Wave Planning, highlighted by the Project Management Institute (2017), should be considered. Based on this concept, planning and action cannot be separated, and planning out all activities from the start is not meaningful. Planning is an ongoing process that evolves gradually over time, allowing for adjustments as new information becomes available.

Secondly, since a project is a network of commitments and actions, planning must be collaborative and social activity. It involves conversations between activity leaders, who make mutual commitments to task implementation (Biazzo, Panizzolo and de Crescenzo, 2016). The temporal relationships between activities are negotiated rather than assumed, and the duration of each activity is also determined through negotiation based on downstream customer requirements. Pull planning is a coordination activity carried out by those who perform operational work. Plans must be simple and easily accessible, serving as a working tool rather than a reporting tool. A schedule with unnecessary details and excess information is considered waste and can create a false sense of control (Biazzo, Panizzolo and de Crescenzo, 2016).

This study incorporated feedback from project stakeholders into the refinement process to refine the proposed planning and control system during the implementation phase of the conducted Action Research. In addition, the proposed planning and control system was informed by Lean planning and control principles and innovations like Visual Pull Planning, which prioritises eliminating waste and maximising value through continuous improvement. The following paragraphs discuss specific Lean planning and control systems developed and found in the literature with potential drawbacks and limitations.

2.6.2 Lean Planning and Control Systems

2.6.2.1 Kanban

Numerous planning and control systems have been developed based on the Lean principles. One of those systems is the Kanban system. This Lean manufacturing methodology originated in the automotive industry and has been applied in other industries to eliminate waste and reduce lead times. The core principle of the Kanban system is a pull-based system, specifically Just In Time (JIT, where the production process is initiated only when demand for the product arises (Powell, 2018). The simplest form of the Kanban system in traditional manufacturing environments uses a visual board with cards or signals to indicate the status of production and inventory levels, ensuring that production is not delayed awaiting materials and maintaining inventory levels. The number of Kanban cards informs strategic decisions related to flow times, balancing Work In Process (WIP), and utilisation (Stevenson, Hendry and Kingsman, 2005; Powell, 2018).

Kanban is most effective in repetitive or mass manufacturing when certain conditions are met, such as maintaining a continuous flow or using large batches, limiting the number of parts involved, minimising the number of setups required, and keeping demand variability low (Stevenson, Hendry and Kingsman, 2005). However, implementing Kanban in the ETO sector poses challenges. JIT, which is the core of Kanban, requires extensive advanced planning, which is a rare commodity in the ETO sector (Tardif and Maaseidvaag, 2001). Moreover, the implementation of JIT requires reform and reorganisation of the manufacturing process, including the reduction of set-up time and lot sizes and the use of cellular manufacturing (Zäpfel and Missbauer, 1993). Similarly, Fowler, Hogg, and Mason (2002) argued that implementing Kanban is challenging at best. Hence, some companies have developed a derivative approach suited to their particular situation, while others have abandoned it. Therefore, the conventional Kanban system was unsuitable for addressing the routing variability and lack of repetition prevalent in ETO manufacturing.

Contrary to previously published studies, several studies have investigated the applicability of the Kanban system on ETO projects with successful stories. For instance, Powell (2018) conducted two case studies applying the simple visual technique of the Kanban system to the fabrication and assembly activities. Drawing on these cases, he concluded that visualising and materialising the workflow of the ETO fabrication activities reduced the lead time by 50%. However, Powell (2018) overlooked the other activities impacting the lead time, such as engineering and procurement. The study would have been relevant if the research had also studied Kanban's application in engineering and procurement activities. In the same vein, Abdul-Nour, Lambert, and Drolet (1998) observed that small firms encountered difficulties when implementing JIT due to high upfront costs, insufficient influence over suppliers and a lack of materials. Based on their study on small-sized ETO organisations, they claimed that adapting the JIT philosophy and the Kanban technique along with the CPM could increase productivity and quality and reduce the lead time by 66%.

Hence, the traditional Kanban system was unsuitable for ETO manufacturing with high variability and infrequent repetition. Kanban is a decentralised shop floor signalling system that lacks control at various stages, including customer inquiry, job entry, and job release. It may be possible, however, to use Kanban combined with a higher-level planning tool like workload control (WLC) or the CPM, although it would still require a way to handle product variation. The WLC job release function can control the shop floor through simple priority dispatching without using Kanban signals. While Kanban cannot effectively plan and control in a non-ETO environment, some aspects of the JIT philosophy and Lean thinking approach can be adopted, such as reducing waste and stockholding. However, SMEs may face practical challenges in implementing JIT production. Therefore, there are reservations about using Kanban in ETO.

2.6.2.2 Last Planner System

Besides Kanban, other Lean planning systems are employed in ETO construction and manufacturing. One of the most popular in literature is the Last Planner System® (LPS), which some scholars have claimed to be successful (Ballard and Howell, 1998; Macomber and Howell, 2003; Emblemsvåg, 2014). The LPS was developed by Ballard and Howell (1998) and received other developments in the innovative and seminal work of Ballard's Ph.D. thesis (Ballard, 2000). The LPS has been deployed in the ETO industry and, more specifically, in construction (Dave et al., 2015) and shipbuilding (Emblemsvåg, 2014) across the world since 1992

(Ballard and Howell, 2003). It was developed to address the shortcomings and gaps found in traditional project management (Dave et al., 2015) highlighted above.

Since the proposed planning and control system is based on borrowing some elements from the LPS and to be fine-tuned and tailored for ETO manufacturing/project manufacturing considering the documented LPS shortcomings, the following is a brief description of the LPS system.

The LPS is divided into four phases: SHOULD, CAN, WILL, and DID, as illustrated in. What SHOULD be done, when, and by whom is determined by the master planning and phase planning performed collaboratively with the LPS (the activity's performer) using a pull planning approach (Ballard, 2000). Next is the CAN phase, preparing the Lookahead schedule. All possible blockages or interruptions called constraints (e.g. labour, material, space, prerequisite work, space, equipment) are identified (Ballard and Howell, 2003). These constraints are analysed in this phase. Activities that WILL be done in the plan period are those only with removed (satisfied) constraints and form the "commitment plans" or assignments that are considered reliable promises. Comparing the activities planned in the WILL phase with those completed in the DID phase helps identify the plan failures using some matrices like the Percent Plan Complete (PPC) for further investigation (Ballard and Tommelein, 2016).

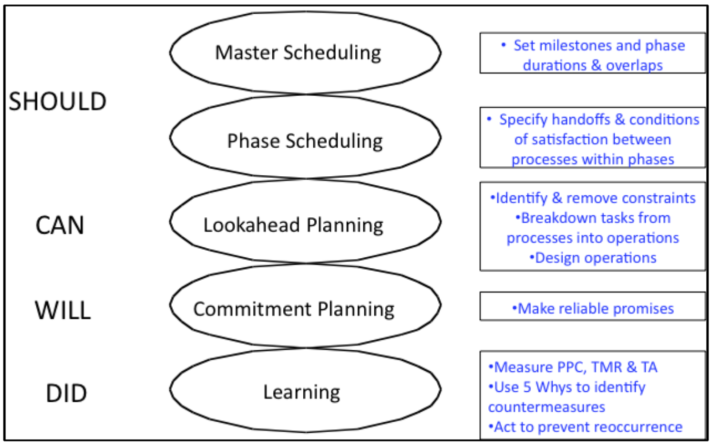

Figure 2-2: The Last Planner System®: SHOULD-CAN-WILL-DID (Ballard and Tommelein, 2016).

However, despite the reported success of the LPS (Ballard and Howell, 2003; Bortolazza and Formoso, 2006; Alarcón et al., 2011), the LPS has recently been challenged by several studies demonstrating that its full potential is rarely achieved (Dave et al., 2015; Aslam, Gao and Smith, 2020) due to various shortcomings. The first shortcoming is the lack of an integrated system, as argued by Dave et al.; Aslam, Gao, and Smith; and Dave et al. (2015; 2020). They argued that the implementation of the LPS overlooks many areas. More specifically, they emphasised missing links between the high-level and detailed plans in the LPS and suggested identifying the information flow between all plan levels. However, this Action Research aimed to introduce an integrated system for planning and control projects. The second shortcoming that this research aimed to address was the non-performance of the constraint analysis. Dave et al. (2015) claimed that though the LPS involves constraints analysis, its scheduling system (e.g. Excel sheets and Post-It notes) does not support this analysis. Similarly, Bortolazza, Formoso, and Daniel’s (2006; 2017) empirical study highlighted that constraint analysis is inadequately or not implemented in some projects.

The third shortcoming is the lack of visualisation. Based on a literature review and practice, Dave et al. (2015) argued the need to bridge the gap of missing the visualisation flow from the schedule and the plan. The fourth shortcoming is the missing procurement planning and the procurement planning meeting in the LPS, which is considered an interesting gap in the literature (Kjersem, 2020). Several authors have highlighted this gap. For example, in their empirical analyses of 164 plants, Salvador et al. (2001) suggested bridging this gap with a planning system that facilitates the material flow to enhance the project's time-related performances. In their four-year Action Research study on ETO delivery, Elfving, Tommelein, and Ballard (2005) argued that the procurement phase significantly impacts other project phases like design and manufacturing, consequently affecting the product lead time. Collectively, these studies emphasised the need for an integrated planning and control system that fills the abovementioned gaps.

2.6.3 Evaluation of Lean Planning and Control

The studies concerning this theme have collectively outlined the history of Lean production, Lean project management, and LC. Several researchers have set different Lean principles for various sectors, including ETO manufacturing. However, in this research, the proposed planning and control system took elements from LC due to the similarities between construction and ETO manufacturing challenges, as highlighted in Koskela's report (1992). The LPS is the most used planning system discussed in the literature; some authors have claimed it to be successful. However, despite its reported success, the LPS has recently been challenged by several studies demonstrating that its full potential is rarely achieved (Daniel, 2017; Aslam, Gao and Smith, 2020). Accordingly, four shortcomings were highlighted and are addressed in the proposed planning and control system: the lack of an integrated system, the non-performance of the constraint analysis, the lack of visualisation, and missing procurement planning.

However, caution should be exercised while implementing Lean principles as “going too Lean” could harm employees’ creativity, productivity and organisational systems, as claimed by Chen and Taylor (2009). Therefore, in this research, the researcher balanced Lean-inspired and non-Lean-inspired theories and systems by fine-tuning the proposed planning and control system to achieve the research objectives.

2.7 Proposed Planning and Control System

According to the evaluation of traditional and non-traditional planning and control systems, the researcher proposed initially the planning and control system below (Figure 2-3) with Lean-inspired and non-Lean-inspired elements.

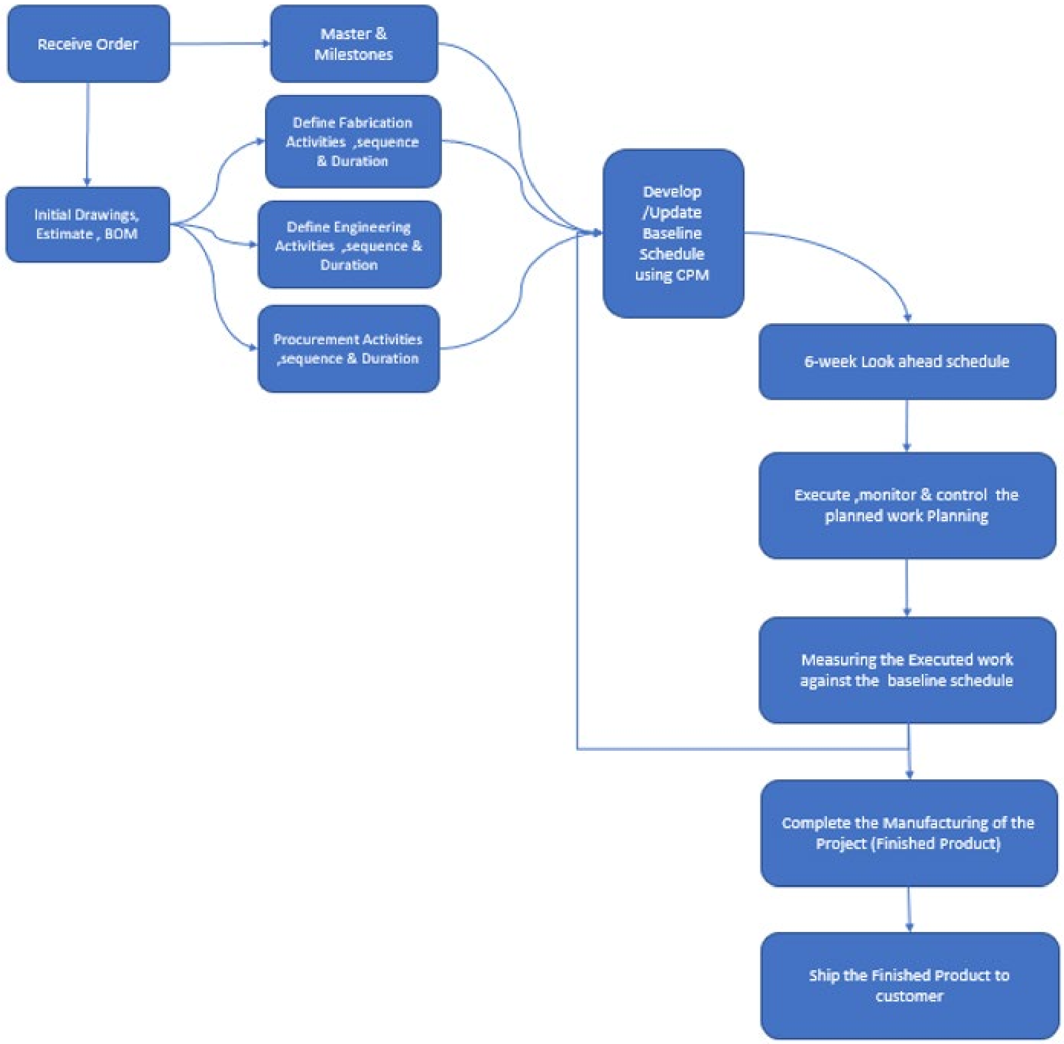

Figure 2-3: Initial Proposed Integrated Planning and Control Model

The proposed model begins with the receiving order, which generates these deliverables: a master schedule, a milestone schedule, basic engineering, an estimate, and the initial BOM. Accordingly, engineering, procurement, fabrication, and manufacturing activities are defined along with the sequence and duration. Then, a baseline schedule is developed using the CPM, a non-Lean-inspired theory. During the execution of the project, a six-week Lookahead schedule, a Lean-inspired element, is generated and communicated with the project team for further execution. Then, progress is monitored, controlled against the baseline schedule, and updated accordingly. The steps are repeated from a six-week Lookahead schedule generation until the manufacturing is completed and the finished product is shipped to the client.

2.8 Summary

This literature review briefly summarises the literature related to the planning and control of ETO projects. It started with a broad context: OM, the most crucial function in any organisation. Projects are one type of operation managed using project management approaches. ETO is one type of project. ETO characteristics were examined to determine their implications for the proposed planning and control. ETO projects are delivered using project management approaches, which are either traditional or non-traditional (Lean) approaches. Each approach was examined in terms of theory, the most popular systems, and an overall evaluation. Traditional project management theoretical foundations were found to be obsolete and deficient. Thus, practising traditional project management would be counterproductive based on evidence from practice and the literature (Koskela and Howell, 2002). Instead, Lean project management was initiated to overcome traditional project management deficiencies. However, examining Lean-inspired systems revealed shortcomings.

The literature indicated no consensus on an integrated planning and control system to manage ETO projects. Some authors have argued that ETO projects can utilise a pure traditional project planning system like the CPM (Porter et al., 1999) or a combination of project management and MRP (Harhalakis and Yang, 1988; Caron and Fiore, 1995). However, other authors have challenged traditional project management approaches by adding other elements from LC (Ballard and Howell, 2003; Elfving, Tommelein and Ballard, 2005; Powell et al., 2014). Nevertheless, based on the abovementioned ETO characteristics and the shortcomings of the current approaches, adopting a hybrid planning and control system from the previous concepts considering Lean- and non-Lean-inspired elements was optimal. Accordingly, an integrated planning and control system was proposed for further implementation and fine-tuning using Action Research.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Research Design and Methodology Introduction

This chapter overviews the research design and methodology employed in the study to evaluate AL DAR's current planning and control practices and explore the impact of an integrated planning and control system on mitigating missed order due dates in its ETO environment. The outline of this chapter is based on Saunders, Lewis, and Thornhill's research design onion (2019)

This chapter begins with the research philosophy, followed by the research approach to theory development. Next, this chapter discusses the research methodological choice and its rationale, which was crucial for effectively addressing the research questions.

Subsequently, this chapter presents the research strategy. Then, this chapter explores the data collection and analysis methods to achieve each objective. Lastly, the research design and methodology limitations are discussed before summarising the chapter.

3.2 Research Philosophy – Pragmatism

In the context of research design and methodology, exploring research philosophy has three significant benefits, as argued by Easterby-Smith et al. (cited in Crossan, 2003). Firstly, it allows the researcher to refine and specify the research methods, research strategy, evidence types, how to interpret these evidence types, and how they contribute to answering research questions. Secondly, it helps researchers evaluate different methods and methodologies, enabling them to identify limitations and avoid inappropriate approaches. Thirdly, exploring philosophy can foster creativity and innovation in selecting methods unknown to the researcher. Similarly, Saunders, Lewis, and Thornhill (2019) argued that the researcher should determine a consistent, well-considered, credible research philosophy to start with a coherent research project. The research philosophy encompasses the researcher's assumptions about the realities (i.e. ontology), human knowledge (i.e. epistemology), and the influence of personal values on the research process (i.e. axiology; (Saunders, Lewis and Thornhill, 2019) as explained in the below subsections.

3.2.1 Ontological Assumptions

Pragmatism as a philosophical stance in this study suggests that reality is not a static entity to be observed but is continuously shaped through interactions within the community of practice. This view aligns with the nature of Action Research, which actively engages with the subject environment—in this case, AL DAR, an ETO manufacturing company in Saudi Arabia. The dynamic and constructed nature of reality in pragmatism supports the iterative process of developing, implementing, testing, and refining the planning and control system within the company (Saunders, Lewis and Thornhill, 2019). This ontological perspective acknowledges that realities are multiple and viewed differently by different stakeholders within the company.

3.2.2 Epistemological Assumptions

Epistemological pragmatism assumes that the specific context and settings determine the practical meaning of the knowledge. These knowledge and theories are deemed acceptable and considered true if they successfully resolve the community of practice issues (Saunders, Lewis and Thornhill, 2019). In this research, the final shape of the proposed planning and control system was not only influenced by but also tailored to, the unique operational environment of AL DAR Company. The iterative testing and refinement of this system within the company's context ensured that the knowledge generated was directly applicable and practically beneficial, thus validating its theoretical and practical effectiveness.

3.2.3 Axiological Assumptions

Concerning axiological assumptions, pragmatism recognises that research is influenced by the researcher’s beliefs, values, and doubts (Elkjaer and Simpson, 2011). In this study, the researcher’s role as an Operations Planning Manager and his extensive experience in the ETO manufacturing context deeply influenced the research perspectives and priorities. While efforts were made to manage preconceptions and preunderstandings suing the unlearning technique as advised by Coghlan, Coughlan and Shani (2019), the researcher’s beliefs, values, and doubts inevitably shaped the research.

Accordingly, the pragmatist philosophy underpinning this research justifies the methodological choices made, including the iterative cycles of Action Research and the engagement with stakeholders at AL DAR. It supports a flexible yet systematic approach to exploring the effects of new practices on operational realities, which is crucial for the practical and theoretical contributions of this study to the field of operations management.

3.3 Research Approach to Theory Development – Abductive Reasoning

In his seminal work, Morgan (2007) argued that pragmatic philosophy relies on the abductive approach to theory development, moving back and forth between inductive and deductive approaches achieved through Action Research Cycles, as outlined in this research strategy. According to Morgan (2007), abduction starts with observations converted into theory, which in this study refers to the proposed planning and control system assessed through action. This approach aligned with the main steps in the Action Research Cycles described in the research strategy. Furthermore, Morgan (2007) argued that the specific version of abductive reasoning includes evaluating the results. This evaluation step was a crucial aspect of this research, forming the primary focus of the Action Research Cycles.

Therefore, this study's research approach to theory development was abductive reasoning. This approach, moving between induction and deduction, aligned with the principles of pragmatic philosophy and the Action Research Cycles outlined in this research strategy.

3.4 Research Methodological Choice – Mixed Methods

Hanson (2008) argued that the best methodological choice helps the researcher answer questions while considering validity: "*Validity – seen as the relationship between theory and method – is the paramount criterion for judging the legitimacy of a method*".

Since this research involved understanding a complex real organisational problem to implement a proper planning and control system, qualitative methods were adopted as commonly associated with an Action Research strategy (Queirós, Faria and Almeida, 2017). Additionally, qualitative methods were integrated with statistical analyses to strengthen the qualitative findings.

3.5 Research Strategy – Action Research

Johansson and Lindhult (2008, p.95) concluded that pragmatic philosophy is well suited for this research context mentioned in the research philosophy section above, where immediate action is needed to resolve organisational issues. They stated (2008, p.95) that *"the pragmatic orientation is well suited for contexts where concerted and immediate action is needed*". Additionally, studying organisational issues thoroughly in real-world settings is essential for effectively identifying the variables that impact resolving these issues (Prybutok and Ramasesh, 2005). Action Research is a commonly employed strategy for addressing organisational issues to answer how and why questions related to variables that are difficult to observe directly, thereby overcoming observational limitations (Prybutok and Ramasesh, 2005; Chakravorty and Hales, 2008). Unlike other research strategies, such as case studies, where case researchers act as independent observers, Action Researchers are participants (Prybutok and Ramasesh, 2005). Argyris (cited in Prybutok and Ramasesh, 2005) emphasised the need for fostering participative collaboration between academia and managers by adopting an Action Research strategy to enhance understanding of the real world, improve practice, and facilitate the development of theories.

According to Kemmis and McTaggart (cited in Chakravorty and Hales, 2008), Action Research is suitable for achieving two objectives aligned with these research objectives. Firstly, Action Research focuses on learning to inform changes in practice. Therefore, this research defined the objective of proposing, testing, and refining a planning and control system at AL DAR. The participants were managers, shop floor employees, and the researcher, an Operations

Planning Manager at AL DAR. Secondly, Action Research does not seek to exercise control over behavioural elements. Instead, it relies on reflection and active involvement of the participants to assess phenomena (Kemmis and McTaggart cited in Chakravorty and Hales, 2008). This approach was applied through the cyclical process of this Action Research, as explained in the subsequent sections.

Similarly, Coughlan and Coghlan (2002) asserted that Action Research is valid and relevant for the OM field and has dual aims of taking action and creating theory or knowledge about that action while addressing the operational realities that managers experience. This approach aligned with the overall context of this research within OM. Furthermore, various OM researchers have identified Action Research as a suitable approach for overcoming limitations associated with observation (Westbrook, 1995; Coughlan and Coghlan, 2002).

Considering the main research objective of proposing an integrated planning and control system to mitigate missed order due dates in the ETO environment at AL DAR Company, we turned to the definition of Action Research provided by Coghlan and Shani (2018, p.4) to conclude that the most suitable research strategy to answer the research question and achieve the stated aim and objectives was Action Research. The definition, according to Coghlan and Shani (2018, p.4), is

An emergent inquiry process in which applied behavioural science knowledge is integrated with existing organisational knowledge and applied to address real organisational issues. It is simultaneously concerned with bringing about change in organisations, developing self-help competencies in organisational members and adding to scientific knowledge. Finally, it is an evolving process that is *undertaken in a spirit of collaboration and co-inquiry.*

Accordingly, the Action Research project emerged by confronting organisational issues, unfolding a series of events, and reaching a resolution through Action Research Cycles (Coghlan, Coughlan and Shani, 2019).

While Action Research has been recognised for its relevance to the real world (Baskerville and Wood-Harper, 1996; Bradbury, 2015), concerns have been raised regarding its level of rigour (Cohen, Manion and Morrison, 2018). In response to these concerns, scholars have articulated principles and guidelines for conducting rigorous scientific Action Research (Melrose, 2001; Davison, Martinsons and Kock, 2004). Therefore, this Action Research adhered to the five principles articulated in the seminal study of Davison, Martinsons and Kock (2004) to maximise rigour and relevance. These authors proposed a set of criteria for each principle to ensure its effective application. The application of these principles and criteria was evaluated as specified in *the 4.4 Evaluation of This Action Research's Quality* section, providing evidence for their effective implementation. These principles and criteria are illustrated in the next few paragraphs.

The first principle of Action Research emphasises the importance of establishing an agreement between the researcher and the client, which is foundational to the entire process (Davison and Martinsons, 2002). This agreement facilitates the collaboration between the client and the researcher during the Action Research journey. Davison, Martinsons, and Kock (2004) proposed five criteria to ensure an effective agreement. Firstly, establishing a shared understanding that Action Research is the appropriate approach for addressing the company's situation is crucial. Secondly, the research objectives and evaluation measures should be specified, as Mumford (2001) advised. Thirdly, the research project requires a clear commitment from the client. Fourthly, the roles and responsibilities of the client company and the researcher should be explicitly defined (Davison and Martinsons, 2002). Fifth, data collection and analysis methods should be explicitly outlined (Davison and Martinsons, 2002).

The second principle of Action Research centres on the Cyclical Process Model (CPM) of Action Research that guides the implementation of Action Research activities following the establishment of the researcher-client agreement. Various scholars have proposed different models outlining the steps of the Cyclical Process Model in Action Research. For instance, Lewin (1946) advocated that Action Research should be conducted in four steps for each Cycle: planning, acting, observing, and reflecting. If the outcomes are unsatisfactory, the reflection step leads to a new Cycle of the same four steps. Piggot-Irvine, Rowe, and Ferkins (2015) argued for no clear ending to Action Research since completing one Cycle leads to a new one.

In line with different perspectives on the Cyclical Process Model in Action Research, Susman and Evered (1978), in their seminal study, presented five steps for a specific Cyclical Process Model: diagnosing, action planning, action taking, evaluating, and specifying learning. Other scholars like Moroni (2011) codified Action Research into five steps: the diagnosis of a problem, planning an intervention, action, assessment, and critical reflection and communication of the learning. Cohen, Manion, and Morrison (2018) proposed a framework for Action Research consisting of eight steps: problem identification, possible interventions to address the problem, deciding on a particular intervention, planning intervention with success criteria, implementing the intervention, monitoring and recording the implementation's effectiveness, reviewing and evaluating the intervention, and generally assessing how well the intervention solved the problem. Based on previous perspectives of the Cyclical Process Model proposed by Lewin, Susman, Evered, Moroni, Cohen, Manion, and Morrison (1946; 1978; 2011; 2018) and the five principles articulated in the seminal study of Davison, Martinsons, and Kock (2004), the researcher built an Action Research Framework shown to maximise the rigour and the relevance of Action Research. This framework, depicted in Figure 3-1, provides a systematic and structured approach to guide the implementation of the Action Research process.

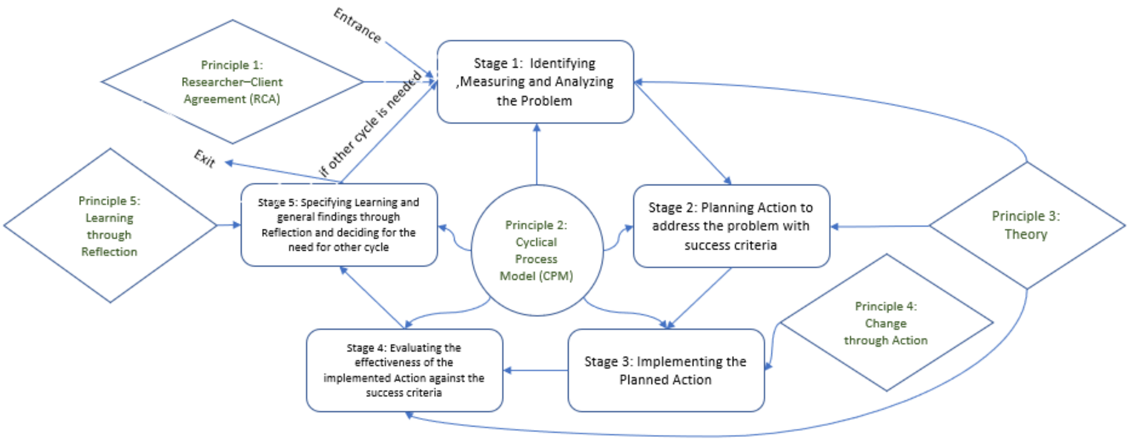

Figure 3-1: Action Research Framework

As shown in Figure 3-1, the first stage of the Cyclical Process Model identifies, measures, and analyses the company's problem. In this step, the researcher collects and analyses relevant data to clearly understand the organisational issue. Coughlan and Coghlan (2002) categorised data into hard and soft categories. In the context of this research, the hard data consisted of operational statistics about the comparison between the project's actual duration and the project's contractual duration (actual vs planned). These data points were extracted from the project documents available. Conversely, the soft data were gathered through interviews and workshops during the researcher's involvement in the day-to-day activities related to the Action Research project. By adopting a collaborative approach, as Coghlan, Coughlan, and Shani (2019) recommended, the researcher engaged with the client system to analyse the data collectively, fostering a deeper understanding of the organisational issue and its underlying dynamics.

The second stage of the Cyclical Process Model, as shown in Figure 3-1 is related to planning action to address the identified problem by specifying the success criteria. During this step, the researcher collaborated with the participants to explore alternative courses of action, develop an Action Research project management plan, and consider various tools and methodologies contributing to formulating the planning and control system elements.

The third stage collaboratively implemented the planned action developed in the previous stage, resulting in intervention and change within the client system until the final (fine-tuned) proposed planning and control system was implemented. Baskerville and Wood-Harper (1996) argued that various intervention strategies can be employed in Action Research. For instance, the intervention may adopt a directive approach, where the research actively guides the change process, or a non-directive approach, where the change is pursued indirectly by recruiting knowledgeable individuals from outside the organisation.

The fourth stage of the Cyclical Process Model focused on evaluating the effectiveness of the implemented action against the success criteria established in the second stage. During this step, the researcher evaluated and studied the consequences of the action with the participants regarding its weaknesses and strengths (Mumford, 2001). This evaluation examined the impact of applying the proposed project planning and control system in ensuring the on-time completion of the ETO projects.

Regarding the specified learning stage and the general findings through reflection, although it is listed as the final stage in the Cyclical Process Model, this step is an ongoing process (Baskerville and Wood-Harper, 1996). Baskerville and Wood-Harper (1996) argued that this step involves communicating the knowledge acquired in the Action Research to three distinct audiences, regardless of whether the action resulted in success or failure. Firstly, communicating the acquired knowledge involves restructuring organisational norms to reflect the new knowledge gained during the research (Baskerville and Wood-Harper, 1996). Secondly, in cases where the change efforts were unsuccessful, the additional knowledge obtained can serve as a foundation for diagnosing and preparing for further Action Research Cycles. Finally, whether the proposed intervention resulted in success or failure, the insights gained from the Action Research provide valuable contributions to the scientific community, guiding future research endeavours in similar settings (Baskerville and Wood-Harper, 1996; Davison, Martinsons and Kock, 2004).

As discussed, the second principle relates to the Cyclical Process Model of Action Research in the last few paragraphs. Now, the discussion turns to the third principle to maximise the rigour and the relevance of this Action Research corresponding to the theory (Davison, Martinsons and Kock, 2004), which is crucial in Action Research because it provides a framework that guides the problem identification, planning action, and evaluation stages of the Cyclical Process Model discussed earlier (Susman and Evered, 1978) Without theory, Action Research is not considered research (McKay and Marshall, 2001), particularly in higher-degree studies (Mumford, 2001).

Furthermore, the theory serves as a basis for evaluating the effectiveness of the implemented actions. It can be revised or supported based on this evaluation (Susman and Evered, 1978). Baskerville, Pries-Heje, and Mumford (1999; 2001) highlighted the importance of theory in the problem identification stage in providing a benchmark for comparing post-implementation outcomes. In cases where a grounded theory does not naturally emerge from the problem identification stage, explicit theorising becomes essential during the planning stage (Baskerville and Pries-Heje, 1999).

The fourth principle for maximising the rigour and relevance of this Action Research was the "change through action" principle (Davison, Martinsons and Kock, 2004). Several criteria were considered to apply this principle effectively. Following Davison, Martinsons, and Kock's (2004) recommendations, the researcher addressed six criteria during the Action Research process. Firstly, the client and the researcher were motivated to improve the situation, aligning with the importance of motivation emphasised by Baskerville and Wood-Harper (1996). Secondly, the organisational issue and its hypothesised cause(s) were specified during the problem identification stage (Foster, 1972). Thirdly, the planned action was tailored to address the identified hypothesised causes (Davison, Martinsons and Kock, 2004). Fourthly, the client approved the planned action before implementation, ensuring its involvement and agreement. Fifthly, the organisation's situation was assessed before and after the intervention, allowing for a comparison of the impact of the action taken (Dickens and Watkins, 1999). Lastly, all actions taken were thoroughly documented, capturing the process and outcomes (Martinsons cited in Davison, Martinsons and Kock, 2004). The researcher reported implementing these criteria, supported by evidence, in the 4.4 Evaluation of This Action Research's Quality" section, providing transparency and validity to the research process.

Finally, we come to "learning through reflection". Seven criteria were applied throughout this research to achieve this principle. Following Davison, Martinsons, and Kock's (2004) recommendations, the researcher ensured that the client and organisational members were updated on the project status and outcomes, reflecting the first three criteria. Clear and comprehensive communication played a crucial role in meeting these criteria. The remaining criteria related to the reflection and learning principle focused on research implications for further action in the subject company, the research domain and community, and the general applicability, which were carefully considered. The researcher sought to identify improvement and further development opportunities by examining the Action Research outcomes.

Additionally, the general applicability of the research findings to similar contexts was explored to contribute to the broader knowledge and understanding of the field. Throughout the research process, the researcher paid special attention to these criteria, ensuring that reflection and learning were integral components of the Action Research. The research aimed to maximise the study's rigour and relevance by adhering to these principles. Please note that the "4.4 Evaluation of This Action Research's Quality" section provides detailed evidence and insights into applying these criteria, offering a comprehensive assessment of this Action Research's reflection and learning process.

To conclude, conducting rigorous scientific Action Research requires applying a well-defined methodology. In this study, the researcher employed the Action Research methodology based on the seminal work of Davison, Martinsons, and Kock (2004). These scholars (2004) articulated five key principles as the foundation for rigorous Action Research: 1) researcher-client agreement, 2) the Cyclical Process Model, 3) theory, 4) change through action, and 5) learning through action. The researcher built a Cyclical Process Model based on the seminal research of Lewin, Susman, Evered, Moroni, Cohen, Manion, and Morrison (1946; 1978; 2011; 2018). This model consisted of five stages. The first stage involved identifying, measuring, and analysing the problem. The second stage focused on planning action to address the problem with clearly defined success criteria. In the third stage, the participants implemented the planned actions collaboratively. The fourth stage entailed evaluating the effectiveness of the implemented actions against the predetermined success criteria. Finally, the fifth stage emphasises reflecting on the learnings and general findings, thus leading to further Action Research Cycles.

The Action Research Framework, as depicted in Figure 3-1, visually represented these five stages and principles and provided a clear roadmap for conducting rigorous and relevant Action Research, guiding the researcher and the client system throughout the process.

By adhering to the principles and stages outlined in the Action Research Framework, the researcher strived to maximise the rigour and relevance of this study. The researcher-client agreement facilitated collaboration, ensuring the research approach aligned with the company's needs. Incorporating theory provided a solid foundation for problem identification, planning, and evaluation. Change through action drove interventions, resulting in tangible outcomes. Learning through reflection allowed for continuous improvement and the dissemination of knowledge to different stakeholders.

Hence, this study applied a rigorous scientific approach to Action Research. By integrating the principles and stages of the Action Research Framework, the researcher undertook a systematic and comprehensive investigation of the organisational issues. The outcomes and insights from this research can contribute to the context and wider field, providing valuable knowledge for future Action Research endeavours.

3.6 Research Data Collection and Data Analysis Methods

In this section, we describe the methodology employed in this research, specifically focusing on how each chosen method—qualitative and quantitative—supports the investigation's aims. The selection of mixed methods is crucial for a holistic understanding of the phenomena under study, allowing for a robust analysis of complex, multi-faceted project environments within the engineer-to-order (ETO) sector.

The selection of the data collection technique should consider the quality of the data generated that serves the research aims and objectives and the application's economic and feasibility aspects. Thus, considering these aspects with the balance between advantages, disadvantages, cost, and the researcher's skills (Coenen et al., 2012) for this Action Research, a combination of qualitative and quantitative methods were employed to complement each other and provide a comprehensive understanding of the research topic.

3.6.1 Qualitative methods

Qualitative data were primarily collected through semi-structure interviews and focus groups. Semi-structured interviews allowed for in-depth exploration of participants' experiences, believes, values and perspectives. Semi-structured interviews were appropriate for the researcher with experience in the field being researched (Alsaawi, 2014). Five semi-structured interviews were conducted with two Business Unit Managers, a Project Manager and two Project Engineers. This purposive sampling approach was adopted to select the interviewees to acquire as much data as possible to answer the research question thoroughly and trustily (Campbell et al., 2020). The rationale behind selecting them was based on their involvement in all project stages and their extensive experience and diverse roles.

On the other hand, nine focus groups were conducted with 45 participants instances as a valuable supplementary method to enhance achieving the research aims and objectives. Focus groups offered the opportunity for group interactions, generating diverse viewpoints and ideas that might not be easily accessible through individual interviews alone. The flexibility of focus group discussions was tailored to the specific research needs, and measures were taken to mitigate logistical issues, optimise group dynamics, and encourage equal participation. Those measures suggested by Easterby-Smith, Thorpe, and Jackson (2015) are: obtaining trust; being aware of social interaction; using the appropriate attitude and language; getting access; choosing the location for the interviews; and recording interviews.

The semi-structured nature of the interviews and focus groups allowed for open-ended responses and ensured participants shared insights beyond the predefined scope. The questions were related to current planning and control practices to understand their efficiency and effectiveness.

The researcher obtained consent (Appendix A) from the participants to ensure that the ethical research principles were upheld. Additionally, the participants were provided with a project information sheet. At the beginning of the interview, they were assured of confidentiality and anonymity (Saunders, Lewis and Thornhill, 2019). Moreover, the researcher assured the interviewees that they were free to withdraw at any time during the interview, and the sole use of the data would be for the DBA thesis, to which the interviewees agreed. Accordingly, the interviews were conducted, and audio recorded. These ethical considerations and measures not only adhere to ethical research standards but also enhance the credibility and reliability of the collected data.

Qualitative data analysis was conducted using inductive thematic analysis, a general approach to analysing qualitative data that provides an explanation, detailed descriptions, and theory (Saunders, Lewis and Thornhill, 2019). Although thematic analysis can offer a flexible, systematic, and accessible technique for analysing qualitative data, the author acknowledged its shortcomings, mainly related to the risk of the possibility of poorly conducted analyses or ill-suited research questions (Braun and Clarke, 2006). To mitigate these issues, the author rigorously conducted inductive thematic analysis within the constructionist framework, believing that the interviewer and interviewees were involved in developing the co-constructing meaning (Silverman, 2014).

Additionally, analysis was performed according to steps articulated by Braun and

Clarke's seminal research (2006), as summarised in Figure 3-2. Moreover, the analysis process was evaluated against the 15-point checklist of criteria for good thematic analysis stipulated in Braun and Clarke's (2006) seminal articles (see Appendix A) . While the steps below are shown linearly, they were performed in several iterative Cycles, as described by (Braun and Clarke, 2006).

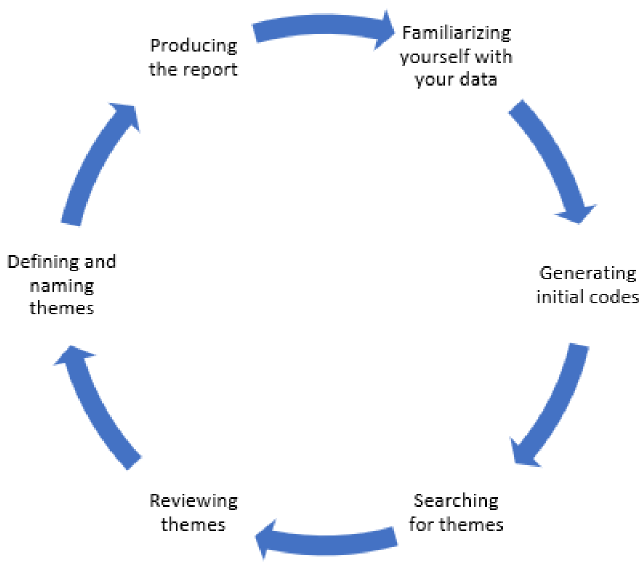

Figure 3-2: Phases of Thematic Analysis (Braun and Clarke, 2006)

As shown in Figure 3-2, as Braun and Clarke (2006) recommended, the first step of inductive thematic analysis is to become familiar with the data. Accordingly, the data were transcribed. However, as Saunders, Lewis, and Thornhill (2019) emphasised, the transcription focused on what was said and how it was said, including the tone and non-verbal signs, to avoid missing data. Then, the transcription data were reread several times, cleaned by rechecking for any errors, and sent to the interviewees for final review. Finally, after receiving the interviewees' acceptance of the transcriptions, they were saved as a word-process file and imported into one of the most effective computer-assisted qualitative data analysis software, NVivo (Feng and Behar-Horenstein, 2019). Therefore, the researcher became familiar with the data, as Braun and Clarke (2006) recommended.

Per Braun and Clarke (2006), the second step was coding the collected data. Therefore, the researcher reread the transcription data several times. Data with similar meanings relevant to the research question were categorised or labelled using codes for further analysis. During the coding process, the word counts generated from Nvivo gave some indication about the codes expected to emerge, which improved the rigour of the analysis as recommended by Feng and Behar-Horenstein (2019). Appendix F, Appendix G, Appendix L, Appendix M, Appendix Q and Appendix R show the word frequency tables and visualizations for all Action Research Cycles.

3.6.2 Quantitative methods

Complementing the qualitative insights, quantitative methods involved the analysis of project documents to measure existing project execution delays before (via analysing 118 project documents) and after the implementation (via analysing 29 project documents) of the newly proposed system. This approach operationalized through the calculation of schedule variance percentages, allows for empirical validation of the qualitative findings. Statistical analyses, including descriptive and inferential statistics, were performed to assess the impact of the newly implemented planning and control system, thus providing a quantitative basis for evaluating system effectiveness.

The schedule variance % variable, calculated as (Contractual Duration – Actual Duration) / Contractual Duration * 100.

The inferential analysis included 147 projects and utilized tests such as the Chi-Square test of independence, continuity correction, Likelihood Ratio, and Fisher's Exact test, followed by Cramer's V to evaluate the strength of associations. This statistical analysis was integrated through triangulation with qualitative findings, enhancing the research's robustness and validity (Denzin, 2015). Additionally, in 20 surveys we communicated with participants to analyse the cause and effect of missing due dates. This approach ensures that conclusions drawn are well-supported by diverse data sources, addressing the research questions from multiple angles. The below table summarises the data collection methods.

Table 3-1: Data Collection Summary

SN	Data Type	Interview ID	Method	Interviewee/Data Source	Sample size
1	Qualitative	01-01	Semi-Structure Individual	Business Unit Manager 1	1 Participant
2	Qualitative	01-02	Semi-Structure Individual	Project Engineer 1	1 Participant
3	Qualitative	01-03	Semi-Structure Individual	Project Engineer 2	1 Participant
4	Qualitative	Interview 02-01	Semi-Structure Focus	Project Engineer, Designer, Procurement Engineer	3 Participants

SN	Data Type	Interview ID	Method	Interviewee/Data Source	Sample size
			Group		
5	Qualitative	Interview 02-02	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager, Factory Manager & Logistics Manager	6 Participants
6	Qualitative	Interview 03-01	Semi-Structure Focus Group	CEO, Deputy CEO & Operation Manager	3 Participants
7	Qualitative	Interview 03-02	Semi-Structure Individual	Business Unit Manager 2	1 Participant
8	Qualitative	Interview 03-03	Semi-Structure Individual	Project Manager	1 Participant
9	Quantitative	N/A	Document analysis	Project Documents	118 Documents
10	Quantitative	N/A	Survey (Cause and Effect)	Top Management, Department Heads, and Engineers	20 Respondents

SN	Data Type	Interview ID	Method	Interviewee/Data Source	Sample size
11	Qualitative	Interview 04-01	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager, Factory Manager & Logistics Manager	6 Participants
12	Qualitative	Interview 04-02	Semi-Structure Focus Group	5 Project Engineer	5 Participants
13	Qualitative	Interview 05-01	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager, Factory Manager & Logistics Manager	6 Participants
14	Qualitative	Interview 05-02	Semi-Structure Focus Group	5 Project Engineer	5 Participants
15	Qualitative	Interview 06-01	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager,	6 Participants

SN	Data Type	Interview ID	Method	Interviewee/Data Source	Sample size
				Factory Manager & Logistics Manager	
16	Qualitative	Interview 06-02	Semi-Structure Focus Group	5 Project Engineer	5 Participants
17	Quantitative	N/A	Document analysis	Project Documents	29 Projects

The methodology outlined in this section is designed to address comprehensively the research questions posed in this study. Through a balanced application of qualitative and quantitative methods, this research captures both the depth and breadth of planning and control practices in the ETO environment, aiming to contribute valuable insights to the field and suggest practical improvements

3.7 Summary of Research Design and Methodology

This chapter presented the research design and methodology employed in the study, which aimed to evaluate the current planning and control practices and explore the impact of an integrated planning and control system on mitigating missed order due dates in the ETO environment at AL DAR Company. The study followed a pragmatic research philosophy, combining qualitative and statistical analysis to strengthen the findings.

The research approach to theory development in this study was abductive reasoning. This approach, characterised by moving between induction and deduction, aligned with the principles of pragmatic philosophy and the Action Research Cycles outlined in the research strategy.

In terms of research methodology, qualitative data were collected through semi-structured interviews and focus group discussions, allowing for in-depth exploration of participants' experiences and perspectives. Statistical analysis strengthened the qualitative data to facilitate a comprehensive understanding of the research topic.

The research strategy employed the Cyclical Process Model of Action Research, involving collaboration with the client, establishing a research agreement, and measuring existing delays in project execution and delivery. This strategy aimed to generate practical insights for improving planning and control practices in the ETO environment at AL DAR Company.

The research time horizon was defined to assess the impact of the proposed integrated planning and control system within a specific timeframe, considering available resources and the project's scope.

The figure below shows a summary of the research design and methodology.

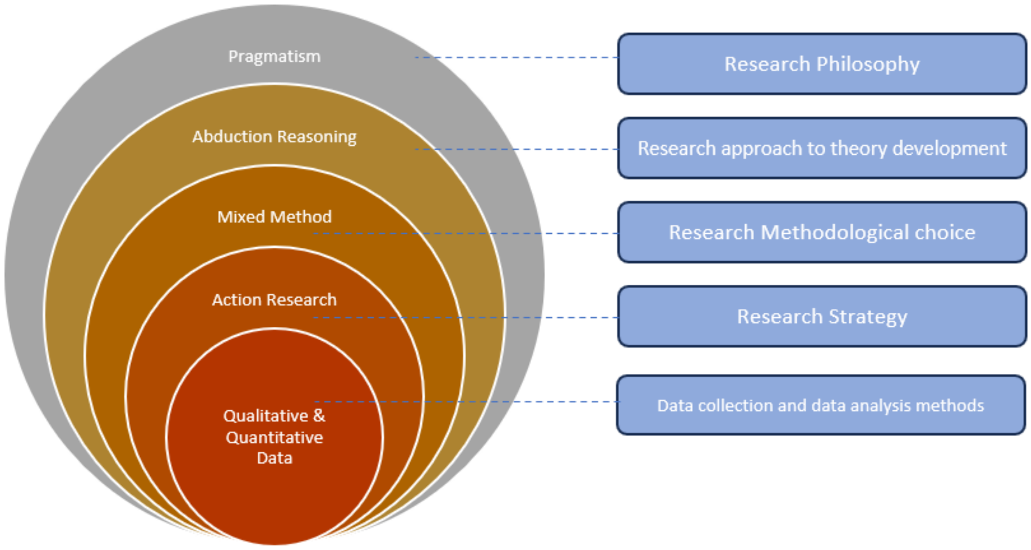

Figure 3-3: Summary of Research Design and Methodology Developed by the Researcher

CHAPTER 4: DISCUSSION AND FINDINGS OF THE ACTION RESEARCH CYCLE

4.1 Action Research Cycle 1

4.1.1 Action Research Cycle 1 Introduction

Action Research Cycle 1 is discussed in the following sections guided by the Action Research Framework illustrated in Figure 3-1, which the researcher constructed based on Susman, Evered, Moroni, Cohen, Manion and Morrison's (1946; 1978; 2011; 2018) seminal studies. The first section addresses the first stage outlined in the Action Research Framework for identifying, measuring, and analysing the company's problem. This stage involved the application of data collection and analysis methods mentioned in 3.6 Research Data Collection and Data Analysis Methods. Then, a findings and discussion section follows, underscoring the main themes that emerged from the data analysis. Subsequently, the four stages outlined in the Action Research Framework are discussed: planning action, implementing the planned action, evaluating the effectiveness of the implemented action, and the last stage related to specifying learning and general findings through reflection. Lastly, a conclusion section summarises Action Research Cycle 1.

4.1.2 Identifying, Measuring, and Analysing the Problem

4.1.2.1 Application of Data Collection Methods

Following the "Research Data Collection and Data Analysis Methods" section described in 3.6 section, this cycle involved the data collection and analysis of the three focus groups, five interviews, 20 surveys, and 118 project documents. These data aimed to define the problems the organisation encountered and associate them with the current planning and control system practices affecting the business's success. Additionally, data collection in this stage aimed to establish the client-researcher agreement, serving as the foundation for the entire process (Davison and Martinsons, 2002). Accordingly, the researcher collected two types of data as categorised by Coughlan and Coghlan (2002): hard and soft data, as summarised in the table below.

Table 4-1:Summary of Data Collection Methods and Sample Sizes for Action Research Cycle 1

SN	Data Type	Interview ID	Method	Interviewee/Data Source	Sample size
1	Qualitative	01-01	Semi-Structure Individual	Business Unit Manager 1	1 Participant
2	Qualitative	01-02	Semi-Structure Individual	Project Engineer 1	1 Participant
3	Qualitative	01-03	Semi-Structure Individual	Project Engineer 2	1 Participant
4	Qualitative	02-01	Semi-Structure	Project Engineer, Designer, Procurement	3 Participants

SN	Data Type	Interview ID	Method	Interviewee/Data Source	Sample size
			Focus Group	Engineer	
5	Qualitative	02-02	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager, Factory Manager & Logistics Manager	6 Participants
6	Qualitative	03-01	Semi-Structure Focus Group	CEO, Deputy CEO & Operation Manager	3 Participants
7	Qualitative	03-02	Semi-Structure Individual	Business Unit Manager 2	1 Participant
8	Qualitative	03-03	Semi-Structure Individual	Project Manager	1 Participant
9	Quantitative	N/A	Document analysis	Project Documents	118 Documents
10	Quantitative	N/A	Survey (Cause and Effect)	Top Management, Department Heads, and Engineers	20 Respondents

As shown in the above table, Soft data were gathered through three focus group interviews and five semi-structured interviews using distinct interview structures (1, 2 and 3) detailed in Appendix C, Appendix D and Appendix E. The focus groups were composed of different levels of personnel from AL DAR. The first focus group interview was conducted with AL DAR's top management (i.e., the CEO, deputy CEO, and operations manager), the second focus group was conducted with department heads, and the third focus group was conducted with the Project Engineer, the designer, and the Procurement Manager. In contrast, the three semi-structured individual interviews were conducted with two business unit managers, two Project Engineers, and the project manager. A purposive sampling approach was adopted to select the interviewees to acquire as much data as possible to answer the research question thoroughly and trustily (Campbell et al., 2020). The rationale behind selecting them was based on their involvement in all project stages. Additionally, participants from the top management were decision-makers since the researcher aimed to ensure the client's commitment to this project before starting the research project.

In contrast, hard, quantifiable, and objective data from 118 project documents were retrospectively collected to analyse and measure existing delays in the execution and delivery of projects at AL DAR. This dataset represented all projects for which proper records were available over the past three years. Due to the unavailability of comprehensive records for all projects executed during this period, the sample encompassed all projects with adequate documentation and similar complexity. Consequently, the improvement results at the end of the research were measured against this sample, which served as a robust baseline.

4.1.2.2 Application of Data Analysis Methods

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4.1.2.3 Findings and Discussion

4.1.2.3.1 Theme 1: ETO Environment Definition and Characteristics

4.1.2.3.1.1 Introduction To Theme 1

The project's initial objective was to examine the theoretical underpinnings and shortcomings of the existing planning and control system used to deliver ETO projects in the ETO environment at AL DAR. Understanding the characteristics of ETO projects and their implications on the proposed planning and control systems was crucial. The insights from Institutional Theory guided this understanding by acknowledging the broader institutional environment's potential influence on the characteristics and dynamics of ETO projects.

4.1.2.3.1.2 Subtheme 1-1: ETO Environment Definition

The first theme that emerged from interview structure 1 (Appendix B) in this Cycle was related to the definition and characteristics of the ETO environment. The participants shared a common understanding and definition of ETO and mainly emphasised the unique nature of its products in contrast to pure or mass manufacturing. For example, one participant stated: *"Each product is unique"*. Another stated, *"It's a unique requirement for each product".*

Two participants contrasted the ETO environment with pure or mass manufacturing. One explained, *"Pure manufacturing . . . is a lot easier*", while the other said, *"Mass manufacturing . . . is pretty standardised".*

These definitions of ETO products aligned with Dallasega and Rauch (2017), who explained that ETO companies produce products according to specific customer orders, making each product unique and different.

4.1.2.3.1.3 Subtheme 1-2: Customisation in ETO Environments

Participants also emphasised the uniqueness of ETO products because the standardisation in ETO production is almost impossible due to the high customisation. The participants expressed this high customisation characteristic of ETO. One said, *"All my projects are customised".* Another responded that the *"level of customisation is high . . . Customisation comes in as part of the manufacturing process".*

In this light, the high customisation characteristic of ETO, as noted by the participants, can be seen as a response to technical requirements and institutional pressures, validating the application of Institutional Theory in this context.

4.1.2.3.1.4 Subtheme 1-3: Dynamic Nature of ETO Design Phase

Another characteristic of ETO products highlighted by participants with implications for the planning and control system is the dynamic nature of the ETO design phase. This phase is not static or predetermined but is an evolving and iterative process stretching longer than planned and observed in other manufacturing paradigms. It is marked by frequent client interactions, iterative changes based on their feedback, and the pressing need for a keen eye for detail.

The testimonies from the participants provided insightful evidence. They spoke of *"a much longer design phase"* and "*there's a lot more detail that goes into engineering to order*". The design process does not solidify immediately; it *"continues to evolve",* so any "*changes after the design is frozen . . . cause further delays*".

These quotes demonstrated that while ETO projects offer flexibility in the design phase to tailor products closer to client specifications, they also come with challenges. The freedom to adjust and realign with the client's needs sometimes becomes a bottleneck, especially when changes are suggested after the design freeze stage. These changes are not minor. They can lead to re-procuring long-lead items previously procured, rescheduling manufacturing activities, and, unfortunately, significant time and cost overruns.

However, Haug, Ladeby, and Edwards (2009) highlighted the advantages and problems of the dynamic nature of the ETO design phase. They argued that while customer involvement in the design phase and the customisation can lead to shorter delivery times and faster manufacturing, extensive customisation, and design change options available in ETO can be a potential pitfall that leads to a complex design process and time overruns.

4.1.2.3.1.5 Subtheme 1-4: Procurement Complexities in ETO Environments

The complex world of ETO products presents many challenges, not just in design but also in component procurement. Institutional pressures, such as regulatory requirements or industry standards, can further complicate this procurement process. ETO environments are a complicated ballet of coordination, timing, and resource management as per the participants' shared experiences that illuminated the associated challenges.

A recurring aspect is the unpredictability of delivery timelines for critical components. One participant noted the time frame for component delivery as *“three to nine months maybe or less”*, with an added caveat that materials *“either come late or early”.* Such unpredictability can severely impact the production process. A product delayed due to a missing component can lead to bottlenecks, idle machinery, and wasted workforce hours. On the other hand, components arriving early may seem like an advantage. However, they can equally increase the inventory level or tie up capital if payment terms are based on the full delivery of the finished product.

The nature of component procurement made the issue more apparent. One participant highlighted, *“If you’re talking about pumps and valves, most pumps and valves are non-standardised”.* Non-standard components, by their very nature, require longer lead times, as they may be tailored to specific requirements and cannot start their fabrication at the supplier facility unless the client approves its detailed design. The participant stated that this process took longer than the planned duration. One participant said, *“Manufacturing clearance to start component fabrication takes too much time to be given to suppliers after signing the contract with them”*.

This scenario is further compounded when suppliers, while committed to their delivery timelines, are not necessarily aligned with the project’s broader timelines. As observed, *“We know how long suppliers have given us duration for delivery, but this is not in line with the finished product contractual delivery time”.* Such misalignments can be detrimental, especially when the final product’s delivery is contingent on these components.

A reflection on the existing literature provided further insight. Mello, Strandhagen, and Alfnes (2015) elaborated on procurement challenges in ETO environments, emphasising the need for better supplier coordination, real-time tracking of component deliveries, and flexible production schedules to adapt to such unpredictability while avoiding delays.

Moreover, the voices from the ground also illuminated the ground realities. As noted by one of the participants, *“The individual pumps don’t arrive on time, or the individual valve also doesn’t arrive on time”.* Such testimonies underlined the daily practical challenges, demanding innovative solutions and integrated processes to address such issues and eventually address the late deliveries of ETO products.

4.1.2.3.1.6 Subtheme 1-5: Coordination Challenges in ETO

With their complex design and procurement process aspect highlighted above, ETO products necessitate another crucial element for successful execution – coordination – because the coordination thread holds together the relationship between the design, procurement, and execution. This relationship can be seen while exploring the participants’ feedback that frequently echoed the sentiment that the ETO environment requires a *“high level of coordination between all phases”.* This feedback was not just a casual observation but a critical insight. By their very nature, ETO products are tailored to meet specific requirements. As such, there is no one-size-fits-all approach. As highlighted in the previous aspect, the design team may have a vision that needs specific components. However, procuring the components and assembling them on time requires careful coordination.

The emphasis on coordination was intense, with participants reiterating that *“coordination is essential”.* This coordination is not just internal but extends externally. One participant said, *"We need to coordinate with the design team and the customer".* This statement highlighted another aspect of the ETO environment. The client is often not just a passive recipient but an active participant, so the input, feedback, and requirements shape the product. Hence, ensuring the vision aligns with the finished product mandates high coordination.

Reflecting on existing literature, Gosling and Naim (2009) elaborated on the pivotal role of coordination in ETO projects. Their research emphasised that coordination, especially in ETO environments, is about managing resources and aligning visions – the vision of the design and procurement team and the customer's expectations.

4.1.2.3.1.7 Subtheme 1-6: Implications for Planning and Control Systems

ETO environmental characteristics mentioned in this theme had significant implications for the proposed planning and control system. The uniqueness of products, a high level of customisation, the dynamic nature of its design phase, and the intricate procurement process necessitated a comprehensive and agile planning and control system. As highlighted by the participants, the ETO model's inherent challenges underscored the need for a robust planning and control system to address the late deliveries of ETO products, the eventual practical aim of this research.

The uniqueness of each ETO product required a planning system that began with a broad vision, allowing for adjustments as more details become available. As the participants observed, the *"early stage of the project is more time-consuming"* because "*we don't have a concept of how long it's going to take*". The iterative nature of ETO projects, where the design evolves, and client requirements can shift, means there is often "*no time concept at the beginning of the project*". This observation aligned with Cigolini et al.(2022) and Jünge et al. (2023), who emphasised the importance of iterative planning in ETO environments to accommodate the evolving nature of projects.

High customisation, another hallmark of ETO, further complicates the planning process. Each product is tailored to meet specific client requirements, making standardised planning approaches less effective. This tension was reflected in the participant's statement that the *"client is always wanting a shorter schedule",* indicating the pressure to expedite projects while maintaining customisation.

The dynamic design phase, characterised by potential changes even after the design freeze, presents another challenge. As one participant noted, the *"time frame expands"* because of the ever-evolving nature of ETO projects. This unpredictability underscores the need for *"innovative planning practices"*, as another participant highlighted. In the realm of ETO, planning cannot be static; it must be an evolving process that can accommodate design changes, procurement challenges, and coordination complexities.

Procurement, particularly in the ETO context, is not just about obtaining components but ensuring they fit into the larger design tapestry. This process is complicated because many components are non-standardised, leading to varying lead times. Therefore, as highlighted by Stevenson and Spring (2007), the procurement process in ETO environments requires more than just sourcing; it demands intricate coordination, synchronisation, and integration into the broader project timeline.

Coordinating these multiple moving parts is no small feat. As one participant emphasised, *“Planning is an absolutely essential part of the overall production of this*”. This sentiment aligned with Haug, Ladeby, and Edwards’ (2009) assertion that coordination in ETO is not just about managing resources but also about aligning visions – the vision of the design team, the timelines of the procurement team, and the expectations of the customer.

However, as many participants emphasised, these overwhelming challenges are not unbeatable. The key lies in innovative planning practices that allow for flexibility and adaptability. As one participant rightly put it, *“We’ve got to factor in the uncertainties”,* suggesting that planning for ETO projects should begin at a high level and become more detailed gradually.

In conclusion, the unique characteristics of ETO products, their high customisation, the dynamic nature of their design phase, and the challenges of procurement necessitated a planning and control system that is robust and adaptable. The sentiments of the participants, combined with insights from the literature, underscored the importance of iterative, flexible, and innovative planning practices to navigate the complexities of the ETO environment.

4.1.2.3.1.8 Reflecting on Limitations and the Scope of Further Research Cycles

Nonetheless, certain limitations existed. First, the findings were based on a limited number of participants, predominantly from AL DAR Company, which might not have captured the full breadth of experiences across the entire ETO sector. This limitation could have introduced a potential bias, as the challenges and intricacies these participants faced might be unique to their specific organisational setting. Additionally, while effectively distilling key insights, the thematic analysis approach relied heavily on the subjective interpretation of qualitative data, with an inherent risk of overlooking nuances or overemphasising certain themes. Lastly, the research did not delve deeply into the quantitative aspects, such as the exact time delays caused by design changes or the financial implications of procurement challenges. Therefore, in the following themes, the researcher adopted a mixed-methods approach combining qualitative insights with quantitative data to understand the ETO environment comprehensively.

4.1.2.3.2 Theme 2: Inefficiencies and Deep Dive into the ETO Process and Challenges

4.1.2.3.2.1 Introduction to Theme 2

This theme emerged from three focus groups and three individual interviews using semi-interview structures 2 and 3. These interviews aimed to explore the execution processes of each phase of the ETO projects, from receiving the order to delivering the projects. They also aimed to explore the main obstacles and challenges for each phase to explore the root causes of the delays or the primary input that highly impacted on-time delivery. Inefficiencies in key processes were explored in this theme, underscoring internal obstacles that hampered project timelines and overall operational performance. Through the lens of Institutional Theory, these inefficiencies were examined in relation to the coercive, mimetic, and normative pressures that shape organisational behaviour. These inefficiencies surfaced mainly in relation to design, inventory, and Work-In-Process management, procurement, and communication. When delving deeper into this theme, it became evident that operational bottlenecks within the company impacted more than one area. This phenomenon created a domino effect, where inefficiencies in one area rippled through to others, amplifying their detrimental impact on project outcomes.

4.1.2.3.2.2 Subtheme 2-1: The Initial Hurdles of Order Receiving

The first process for executing the ETO project in Al DAR is receiving a customer's purchase order (PO). As per the established procedure in the company, the expected output from this process is the issuance of a project memo that represents the project kick-off by the CEO, which should be within one week of receiving the PO. One participant summarised this process as *"receive a PO; send out a project memo".* However, as straightforward as it may seem, this process is fraught with challenges.

As highlighted by the participants, one of the prominent challenges is the ambiguity or incompleteness of the POs. As one participant expressed, *"Ambiguous or incomplete POs often lead to back-and-forth communication with clients, which can significantly delay the memo issuance by more than a week at times".* This observation was critical. The initial step, though seemingly straightforward, can be delayed more than one week than the planned duration due to ambiguities, setting a precedent for subsequent delays in the project life cycle.

Moreover, the participants emphasised the importance of client requirements or the lack thereof. One participant noted, *"Sometimes, clients' requirements are not sufficiently clear, which leads to assumptions that could result in rework if incorrect"*. This issue becomes especially critical in ETO projects where each product is customised to meet client needs. Making assumptions in such scenarios can lead to deviations from client expectations, requiring revisions and additional work, ultimately causing delays and increased costs.

Reflecting on the existing literature, scholars such as Baldauf et al. (2020) have discussed the challenges associated with the initial stages of ETO projects. They emphasised the criticality of clear client requirements and the importance of effective communication to mitigate ambiguities. Asiedu and Adaku (2020) further asserted that such ambiguities may disrupt the planning process, causing delays and overruns. Therefore, the planning and control system should account for additional contingency duration to address such ambiguities that cause uncertainties while developing the master schedule. Jan and Ho (2006) identified this first process in the proposed planning and control system, as discussed in the second Cycle.

4.1.2.3.2.3 Subtheme 2-2: Design and Engineering: The Core of ETO Execution

After receiving the PO, the subsequent phase in the ETO project life cycle is to "perform the design and engineering work". This phase is arguably the backbone of any ETO project. The input of this process is tools and resources, which are client requirements, designers, software, procurement officers, work instructions, and quotations. The objective is to produce a series of outputs: the issuance of basic engineering within two weeks, the request for quotation (RFQ) within three weeks, and the approval of quotations within five weeks. The deliverables further stretch to detailed design and fabrication drawings over two months, culminating in the issuance of a material request in three months.

Despite the clear objectives, the participants highlighted a series of challenges. The first challenge was the delays in getting quotations from suppliers. One participant mentioned, *"Delays in receiving quotes from procurement can also* *cause time loss".* This quote highlights the complicated interplay between design and procurement. The other challenge in the design phase was reliance on external information: *"Technical information from sources, such as suppliers, is essential for our design and construction drawings. If they are late in providing this information, it can impact our project timeline*". This statement showcased the dependence on external entities and how their delays can significantly affect the project. The third challenge was client-induced changes: *"When clients request design changes, it can sometimes feel like starting from scratch".* Such changes can upend weeks or even months of work, leading to significant delays and potential cost overruns. It seems possible that these results are due to poor design management and, more specifically, a poor planning and control system that can adequately manage the design activities, as stated by one of the participants, "*We must think of advanced planning techniques that do not merely include fabrication processes but consistently weave in design and procurement activities into our planning activity stream*". This interesting finding was also reported by Little et al. (2000). Based on their research on 13 study cases, they argued that planning and control practices in ETO projects have primarily focused on detailed production plans while neglecting an integrated approach encompassing engineering activities. As Little et al. (2000, p.553) concluded,

> *In addition, the research identified a number of key generic issues for the ETO sector identified by the case study companies during the interviews . . . Lack of design planning and monitoring. Whilst production is typically planned in detail, design planning is largely ignored.*

4.1.2.3.2.4 Subtheme 2-3: Procurement: A Critical Link in ETO Execution

As highlighted by the participants, the third process in ETO projects at AL DAR is the procurement phase. The procurement phase is not just a sequence of purchasing tasks but a pivotal stage that can dictate the success or delay of the entire project. It is the backbone, ensuring every design is complemented with the right materials and components at the right time. Essential tools and resources, such as work instructions, RFQs, material requests, budgets, and schedule plans, are vital to ensure this stage progresses without difficulties. Per the Procurement Manager, the outputs of the procurement process are to

> *. . . provide engineering with quotations within two weeks from receiving the RFQ, issuing POs within three days of the material request or three days of approving the quotation, getting NMR from the supplier within two weeks from PO and despite all the challenges we have to get the material delivered on time and for sure those to be aligned with the work procedure in our company.*

However, the procurement process in ETO environments has numerous challenges. The interdependence of departments needed to perform the procurement process in ETO projects in AL DAR adds another layer of complexity. Indeed, if one part fails, the whole machine stops. A participant emphasised this relationship and remarked, *"When the engineering team falls behind schedule, it significantly impacts our department in many ways".* One participant referred to one main activity that interfered with the engineering department. First, delays in receiving an RFQ can lead to further delays downstream. As noted by another participant, *"Delays in receiving RFQ cause a domino effect leading to delays in* *the process".* Such observations reiterated the interdependence of the various processes in ETO environments. This interdependence can also be a potential pitfall, as delays or misalignments in one process can ripple through the entire project life cycle. Those on-ground observations were supported by the study of Mello, Strandhagen, and Alfnes (2015), who highlighted the domino effect of delays in ETO environments, where one delay can cascade and impact the subsequent processes.

As another participant highlighted, unpredictability can also mess up the best-laid plans: *"Despite having schedules in place, unexpected early or delayed arrivals disrupt our plans".* This unpredictability, coupled with challenges like machine malfunctions, insufficient staff training, and inadequate communication, can compound the challenges of the procurement process. These challenges, as indicated by Willner et al. and Mustonen and Harkonen (2013; 2022), necessitate a robust integrated planning and control system, which is the eventual aim of this research to address the late deliveries of ETO projects in AL DAR.

Another critical observation from the participants revolved around the late issuance of manufacturing clearance to let the supplier start manufacturing the component material. The statement *"Late manufacturing clearance is the main issue that impacts component delivery"* underscored the importance of timely issuance of manufacturing clearance in the ETO process. The participant noted that without these clearances, *"Suppliers might put the purchase orders on hold and further worsening delays*".

Moreover, another layer of complexity is added when interdepartmental collaboration comes into play when the component material is not delivered on time. One of the participants shed light on this by noting, *"Collaborating with departments presents another challenge. For instance, if materials don't arrive punctually or if projects face delays, it disrupts our schedule and frequently necessitates renegotiating terms with clients".* This disruption emphasises the interconnectedness of processes within the ETO environment. A delay or disruption in one process has a cascading effect, impacting subsequent processes and, ultimately, the overall project timeline.

Further emphasising the inefficiencies, the interviewees shared concern over delays in sourcing materials on time and the lack of synchronisation of production schedules in the procurement processes. One participant offered, *"Our procurement process is causing significant delays . . . We are not able to source materials on time".* Another participant continued, *"I have concerns about the synchronisation of production schedules with supplier deliveries. Delays in getting raw materials typically disrupt our plans and lead to missed due dates".*

This quote pointed towards procurement inefficiencies and confirmed the lack of synchronisation highlighted by Dallasega and Rauch (2017). However, although the interviewees did not link procurement inefficiencies with inventory and WIP levels, some scholars have argued that the procurement process in the ETO environment can also impact inventory levels (Gosling, Hewlett and Naim, 2021). Gosling, Hewlett, and Naim (2021) emphasised that choice of suppliers, lead times, and order quantities could all affect inventory levels, while adversarial relationships and a lack of collaboration with suppliers could lead to higher inventory levels.

Conclusively, inefficiencies and a lack of synchronisation in the procurement process led to production bottlenecks, emphasising the need for a robust, synchronised approach to address these challenges.

4.1.2.3.2.5 Subtheme 2-4: Inventory and WIP Management: Overlooked yet Crucial

The fourth process is related to receiving materials at the warehouse, a pivotal process serving as the foundation upon which subsequent manufacturing process is built. However, the ETO environmental complexities and unique dynamics can make this seemingly straightforward process challenging. Delving into the experiences shared by the Warehouse Manager at AL DAR offered a deep dive into the challenges of this phase:

> *While receiving material process inputs are only schedule plans, the procurement officer and work instruction the output, which inventory level is a very important aspect for company owner. The main issue we face is the high level of inventory due to poor planning*.

The Warehouse Manager’s statement underscored a fundamental issue within the ETO environment at AL DAR. He adequately summarised the core challenge of the receiving material process, emphasising the role of the current planning system in worsening the inventory problem.

For instance, concerning inventory and WIP level issues, a participant mentioned, *“Our inventory is always overstocked, we are not able to forecast accurately, and this is taking a toll on our storage and cost management . . . we should have a very low Work In Process level".*

Participants’ comments on inventory and WIP levels revealed how inaccurate forecasting led to cost and time overruns. Through the lens of Institutional Theory, this observation indicated the company's alignment with institutional norms and pressures.

This view was echoed by another participant who argued the need for keeping a very low inventory: *"We should keep a very low inventory level".* This comment revealed the extent to which inaccurate forecasting has led to cost and time overruns.

This result agreed with Dallasega and Rauch's (2017) and Smith's (1999) findings, highlighting that the issue of high levels of inventory in the ETO environment is a complex problem that requires careful consideration of various factors because ETO manufacturing involves the production of unique products based on specific customer needs and requirements (Dallasega and Rauch, 2017). Dallasega and Rauch (2017) argued that one factor contributing to high inventory and WIP levels in ETO environments is the lack of synchronisation between different stages of project execution. This issue was highlighted in the procurement phase.

The conversation about inventory and WIP challenges seamlessly led to another underlying issue: communication inefficiencies. An interviewee highlighted this issue by stating, *"Our communication processes are not effective enough... there are many instances where information is lost in the process".*

Although interviewees did not link communication inefficiencies with inventory and WIP levels, Gosling, Hewlett, and Naim (2021) argued that improving collaboration and communication between organisations in the supply chain could help reduce inventory levels. Petersen, Ragatz, and Monczka (2005) argued that improving collaboration and communication, thus the performance of the supply chain, could be done through collaborative planning activities between supply chain partners.

Similarly, Sanders and Premus (2002) highlighted that "*central to collaboration is the exchange of large amounts of information along the supply chain, including planning and operational data, real-time information, and communication*". These perspectives underscored the imperative for an advanced, cohesive planning and control framework to tackle such challenges, thus addressing the delays in project deliveries, which is this study's ultimate goal.

4.1.2.3.2.6 Subtheme 2-5: Manufacturing and Assembly: Bridging Design and Delivery

Following the procurement and inventory management trail, we arrived at the manufacturing and assembly process, a critical phase where the conceptualised design is brought to life. The Factory Manager's insights provided a valuable window into the complexities and challenges faced during this phase and the potential solutions that could streamline operations.

When the Factory Manager said, *"Our department consolidates all the preceding steps"*, he correctly described the manufacturing department's role. This activity places the department in a unique position where it manages internal processes while bearing the impact of delays or inefficiencies from upstream processes. This interconnectedness emphasises the need for an integrated planning and control system – the eventual aim of this research – where delays in one phase do not cascade down and magnify in subsequent phases.

While the inputs for the manufacturing process – detailed design and fabrication drawings, schedule plans, and materials – are foundational, the Factory Manager's observations revealed that the true challenge was in managing these inputs efficiently, most importantly, *"having a proper schedule that all team is adhering to* *is the most important thing"*. The proper schedule for the Factory Manager seemed flexible and integrated and could deal with the dynamic nature of ETO projects, as reflected in the Factory Manager's mention of "*last-minute design changes".* This sentiment directly fed into Research Objective 3, focusing on how the proposed integrated planning and control system would affect the project lead time.

Jiang, Hu, and Xi (2019) also emphasised the importance of proper scheduling in managing the fabrication and assembly process. The study highlighted the duration of tasks in the ETO fabrication. The findings showed that assembly processes could be minimised by having a well-defined schedule to which all team members adhere.

Considering the research objectives, particularly Research Objective 1, these insights reinforced the need to critically evaluate the existing planning and control system addressed in the next Cycle. The Factory Manager emphasised the importance of an integrated schedule aligned with this research's broader aim: to develop an integrated planning and control system to mitigate missed order due dates in ETO environments.

Furthermore, reflecting on Research Objective 3, understanding the impact of implementing the proposed system on the project lead time was crucial. As the Factory Manager highlighted, delays in the manufacturing phase could have cascading effects on the entire project timeline. Therefore, an integrated system to address these challenges head-on could significantly improve project lead times, ensuring that AL DAR Company delivers its projects on schedule, thereby meeting client commitments.

4.1.2.3.2.7 Subtheme 2-6: Delivery and Logistics: The Final Milestone

Delivering the finished product to the customer is the last process that culminates all the efforts put into the ETO process at AL DAR Company. It is a phase where the company's contractual timelines are tested. The Logistics Manager's insights illuminated the complexities and challenges of this last step.

As the Logistic Manager highlighted, *"Ideally, we receive the finished products from the factory and deliver them to the end user"*. However, the reality is often more complex. Challenges arise from unpredictable factors, often external but sometimes even internal. The Logistic Manager's mention that *"we just receive an email from the Factory Manager to ship the finished product urgently to the end user without any well advance notice"* indicated the ad hoc nature of current planning practices.

In light of the research objectives and integrating Institutional Theory, these inefficiencies caused more than mere delays in project execution. They also added unnecessary costs, thereby limiting the company's profitability. If left unaddressed, the systemic nature of these operational issues would threaten the company's long-term competitiveness and legitimacy in the face of institutional pressures. Hence, the need for planning and control system improvement was justified, as addressed in the following theme. The inefficiencies in key processes catalysed the need for a robust planning and control system, demonstrating a complementary relationship between the themes. Additionally, this theme, analysed using Institutional Theory, contributed to a broader research conversation by adding empirical evidence to the argument that even when a company is engaged in highly customised projects requiring specialist skills, common operational inefficiencies can pose significant barriers to successful project delivery.

4.1.2.3.3 Theme 3: Pre-Implementation Project Delays

The third theme, pre-implementation project delays, was crucial to the company's current situation. The issues that emerged primarily concerned the delays in project completion, which seemed to be a common occurrence. The interviewees provided ample evidence of this issue. For instance, one participant mentioned, *"We consistently miss deadlines. It feels like we're always firefighting, never proactively managing projects".* Another said, *"Delays have become the norm, not the exception. It's affecting our reputation with clients".*

These statements resonated with an extensive sense of frustration and highlighted the depth of the problem, indicating a reactive rather than proactive approach to project management and the need for drastic changes.

Complementing these personal perspectives, a comprehensive analysis of project schedule variances further substantiated the issue. The research calculated the schedule variance % for 118 projects to define and measure objectively the company's problem. The table below shows brief statistics about the schedule variance % extracted from SPSS V28.

Table 4-2: Pre-Implementation Schedule Variance Statistics

Statistics

Schedule Variance %

N	Valid	118
	Missing	0
Mean		-65.8105%
Median		-50.5119%
Mode		-50.51%
Std. Deviation		53.83518%
Range		224.36%
Minimum		-211.20%
Maximum		13.16%

The above table shows that the schedule variance % was calculated for 118 projects. Since this variable was an interval, we used the mean, median, and mode as central tendency measures (Bryman, 2012). The mean value for the schedule variance was –65.8%, suggesting that projects typically took 65.8% longer to complete than initially planned. In other words, a project with a contractual duration of 100 days was typically extended to 165.8 days. The median was 50.5%, meaning half of the values were less, and half were greater. The mode, representing the data's most commonly occurring schedule variance, was –50.5%. These stark statistical data confirmed the sentiments expressed by the interviewees.

On the other hand, the delays could have reflected mimetic pressures contributing to project delays. Mimetic pressures in the lens of instructional theory refer to organisations copying or imitating successful peers or competitors (Fang et al., 2019). An example could be using software or tools in a planning and control system that does not fit AL DAR, leading to delays. However, the subsequent Action Research Cycle elaborated on the limitations and the aspects of the current planning and control practices.

Furthermore, the analysis found considerable variability in the schedule performance, as indicated by the standard deviation of 53.8%, which indicated that the schedule variances could deviate from the mean by approximately 53.8%. The top-performing project had a 13.16% schedule variance, while the lowest-performing project was –211%.

A visual analysis of data was conducted using a histogram chart generated from SPSS to visualise the number of projects belonging to each schedule variance %, as shown in the chart below.

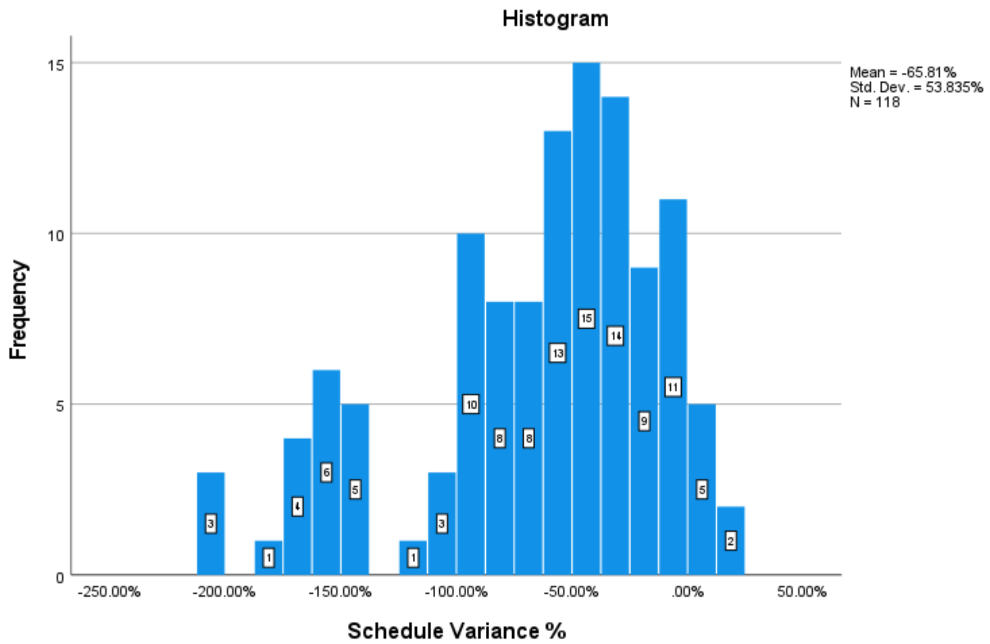

Figure 4-1: Schedule Variance % Histogram

As shown in the above chart, 15 projects had a schedule variance of –50%, confirming the mode mentioned in Table 2. Additionally, the histogram shows that the schedule variance data were skewed towards negative values, with the most common variances falling between –50 % and 75%, confirming the spread measures mentioned in Table 2.

The schedule variance data analysis provided valuable insights into the projects' schedule performance. The general trend of negative schedule variance suggested that delays were more common than early completions. However, the variability in the schedule performance, as indicated by the standard deviation and range, pointed to the presence of other influencing factors, potentially including institutional pressures other than mimetic pressures. These were explored in other Action Research Cycles to understand better and improve the projects' on-time completion.

These project delays were not isolated issues, but a symptom of other systemic organisational problems closely linked to previous themes – inefficiencies in critical processes and the need for improved planning and control systems. These factors seemed to contribute to the issue of project delays, making it a complex problem to address.

Linking these observations to broader research in the field and considering the Institutional Theory framework, scholars have similarly identified that project delays in an ETO environment often point towards deeper organisational issues. For instance, Kerzner (2018) acknowledged that delays often stemmed from systemic issues, emphasising that improvements in project management strategies could significantly impact the timely completion of projects.

4.1.2.3.4 Theme 4: Need for Planning and Control System Improvements

The fourth theme emerging from the analysis was the "need for planning and control system improvements". This theme provided an understanding of the challenges faced by the company. By examining it through the lens of Institutional Theory, the analysis of this theme explored how institutional pressures and norms have shaped the perceived need for improvement in the planning and control systems at AL DAR. The company seemed to deal with issues concerning specific processes and the overall planning and control system. This theme was also intrinsically connected with the theme of inefficiencies and a deep dive into the ETO process and challenges. Both pointed to problems affecting the whole company and highlighted the lack of synchronisation between departments.

The interviews revealed a consensus among employees that a robust planning and control system was necessary. One interviewee said, *"Our plans often go off track. We don't have a strong control system to keep things in order".* When viewed through the lens of Institutional Theory, this sentiment highlighted the company's response to external coercive and normative pressures to conform to industry standards and practices.

Moreover, a few individuals interviewed indicated that enhancing the interconnectedness of the planning and control system could effectively facilitate collaboration among operational components, leading to improved overall efficiency. One person said, *"We really need a control system that can bring our planning and doing together effectively".*

Applying Institutional Theory illuminated mimetic pressure, revealing how the successes and practices of industry peers shaped the company's aspirations for a cohesive system. This viewpoint also aligned with the previous theme, highlighting the lack of synchronisation between different departments.

Delving deeper into the ETO environment process at AL DAR revealed that a well-structured integrated planning and control system was pivotal for ensuring on-time delivery. More specifically, some participants highlighted the need for planning and control system improvement for specific processes mentioned in the previous theme. For example, the design process was linked with the procurement process and the need for an advanced planning system. One participant stated,

We must think of advanced planning techniques that do not merely include fabrication processes but consistently weave in design and procurement activities into our planning activity stream . . . We have been doing very well with the production, but unfortunately what, we're having a hard time with design and procurement.

Another participant stated, *"We're taking too long in the design phase".*

These statements showed the absence of a planning and control approach to address design and procurement activities adequately. Additionally, they highlighted the absence of planning and control of engineering and procurement activities, revealing the influence of institutional pressures on organisational practices from the lens of Institutional Theory. This issue was highlighted by Little et al.'s (2000) research based on 13 study cases. They argued that planning and control practices in ETO projects primarily focused on detailed production plans while neglecting an integrated approach encompassing engineering activities (Little et al., 2000, p.553):

> *In addition, the research identified a number of key generic issues for the ETO sector identified by the case study companies during the interviews . . . Lack of design planning and monitoring. Whilst production is typically planned in detail,*

design planning is largely ignored.

In the same vein, Kjersem (2020, p.276) highlighted that planning of procurement activities still presented an interesting gap in the literature:

> *Planning of procurement activities in ETO projects is also an interesting gap within the studied literature. While project management approaches procurement activities from the perspective of handling relationships with the suppliers, there is little or no recommendations on how to plan these activities.*

Hence, the company was not just dealing with problems in individual areas since broader issues caused delays in project delivery. In terms of the research objectives, the company needed to improve its overall planning and control system, not just individual processes. Similarly, Tefera and Hunsaker (2020) argued that conforming to institutional norms per Institutional Theory could drive systemic improvements, such as this research's integrated planning and control system.

These findings aligned with other researchers' findings, like Zwikael and Globerson (2006), who argued that planning and control systems are essential for companies that work on a project basis. Similarly, in their empirical study of 21 machinery-building ETO companies, Adrodegari et al. (2015, p.925) argued that the ETO firms suffered from the lack of comprehensive planning and control tools; hence, the researchers called for a new framework for other ETO industries: *"Considering both the practitioners' and researchers' points of view, further investigations are required to tailor the framework to other real cases, even involving other ETO industries".*

Overall, having a proper planning and control system is the cornerstone of ensuring timely project delivery, especially in complex ETO environments like that of AL DAR Company. As shown above, the extensive insights from the company's key department heads illuminated the sophisticated processes and challenges faced in each phase of the ETO projects, from receiving the order to delivering the final product. Thus, while each department had unique challenges, the overarching theme was the need for an integrated planning and control system.

Considering the research objectives, especially Research Objective 1, the insights from the department heads reinforced the pressing need for an integrated planning and control system to address the challenges in each phase and ensure that AL DAR delivers on its commitments, aligning with the broader aim of the research to develop an integrated planning and control system to mitigate missed order due dates in the ETO environment. The findings provided a solid foundation for the next Cycle to discuss the current system's shortcomings while highlighting the urgent need for an integrated approach.

4.1.2.3.5 Theme 5: The Client's Commitment to the Action Research Project

The final theme in the first Action Research, the client's commitment to the Action Research project, did not just stop at expressing willingness or enthusiasm for the Action Research project. The commitment showed itself tangibly, as seen in the interviewees' comments.

The company went beyond verbally affirming its support for the Action Research. It backed up its words with actions, as the CEO declared, *"OK, we will be allocating necessary planning and scheduling resources like Primavera P6 software tool for effective scheduling".* The deputy CEO reinforced this idea: "*We will assign* *personnel from relevant departments – IT, supply chain, and operations – to work collaboratively with research teams for a successful project outcome".*

This kind of commitment from the top management signalled a proactive approach, an understanding of the practicalities of Action Research, and the willingness to invest necessary resources. Including relevant department personnel showed an understanding of the project's interdisciplinary nature. It also underlined the willingness to involve internal stakeholders to ensure the project's success and demonstrated an alignment with institutional expectations and norms regarding research collaboration and organisational improvement.

Total commitment to the Action Research process is critical to its success, per Coughlan and Coghlan (2002). The clients' active participation ensured access to the essential data, sites, and personnel needed to thoroughly analyse the root causes of project delays (Gummesson, 2000). It also allowed interventions to be tested on real projects while collecting feedback (Coghlan and Brannick, 2005). Hence, this commitment provided much-needed support for implementing recommended process changes (Greenwood, 2007).

Without this level of commitment, the clients could lack engagement, limiting data availability and hindering the adoption of changes. This absence could make it difficult for the researcher to accurately diagnose issues, design effective solutions, and generate actionable findings (Saunders, Lewis and Thornhill, 2019).

These themes developed in the first Cycle of the Action Research project highlighted various challenges within the company's operations. They included inefficiencies in critical processes, a lack of robust planning and control systems, frequent project delays, and the need for client commitment to the research project.

The participant interviews revealed that these issues were interrelated and contributed to the persistent problem of project delays. The sentiments expressed by the participants were confirmed by the statistical analysis of the schedule variance %, suggesting that projects usually took much longer to complete than planned.

Moreover, the client's commitment to the Action Research project was particularly encouraging. It set the stage for an open and constructive process. The organisation demonstrated a proactive attitude towards addressing the identified issues, and its support for the research process was instrumental in diagnosing problems, designing solutions, and implementing changes aligned with institutional norms and expectations.

With this firm foundation, the next Action Research explored the challenges and limitations of AL DAR's current planning and control so that the proposed planning and control system could be tailored according to the challenges, considering the ETO characteristics and the current inefficiencies in AL DAR's processes, as mentioned in the previous themes. However, before moving on to the next Cycle, the remaining steps to close Action Research Cycle 1 were completed, as seen in Figure 3-2.

4.1.3 Planning Action

4.1.3.1 Planning for Developing the SIPOC Diagram and Articulating the Researcher-Client Agreement

Based on the above analysis and the insights derived from Institutional Theory through the identification of coercive, mimetic, and normative pressures, some organisational processes needed to be changed to enhance the effectiveness and efficiency of the operations. Accordingly, developing a high-level organisation Process Map (i.e. a SIPOC) was decided for further understanding. SIPOC stands for Supplier-Input-Process-Output-Customer, a Six Sigma tool used to document the organisation's processes from start to end and summarise the input and output of the processes (George, 2005). Additionally, the researcher-client agreement was articulated, and an Action Research project management plan was developed as the basis for the Action Research journey recommended by Davison, Martinsons, and Kock (2004).

4.1.3.2 Planning for Developing the Process Map

Based on the above analysis and observations, many inputs could potentially affect the on-time delivery of the ETO products at AL DAR for each process. Theme 2 represents the analysis of each process as a first step to enhance the effectiveness and efficiency of the operations. Accordingly, AL DAR's top management asked for a Process Map detailing the SIPOC framework for further understanding.

4.1.3.3 Planning for Developing the Cause-and-Effect Matrix

The schedule variance indicator presented in Theme 3 was affected by all processes and their inputs in the Process Map. Although the findings concluded in identifying, measuring, and analysing the problem step of this Action Research Cycle that having a proper planning and control system in place was the cornerstone of ensuring timely project delivery, top management decided to reinforce this qualitative finding with quantitative analysis using a Cause-and-Effect Matrix to helps identify the relationship between causes and their effects on a specific problem. This quantitative analysis covered a broader section of employees across various departments. Similarly, the researcher found that Baker and Jayaraman's (2012) Action Research also deployed a Process Map and a Cause-and-Effect Matrix.

4.1.4 Implementing the Planned Action

4.1.4.1 Developing the SIPOC Diagram and Articulating the Researcher-Client Agreement

Following the planning phase, the planned action was initiated. To devise a comprehensive outline of the operational processes within the organisation, the SIPOC tool, a well-regarded Six Sigma methodology, was employed. This high-level map was formulated through two focus group interviews conducted with key stakeholders: one was managerial, and the other was non-managerial. The rationale for interviewing at the managerial level was an overarching and strategic view of the process, while interviewing at the non-managerial level investigated the details of the process, capturing a comprehensive understanding from different perspectives. As per interview structure 2 (Appendix D), the focus group interviews lasted 40 minutes, allowing for in-depth discussions that provided crucial insights into the organisation’s functioning. Accordingly, the SIPOC diagram was formulated to summarise all processes, from receiving an order to delivering a finished product to the customer.

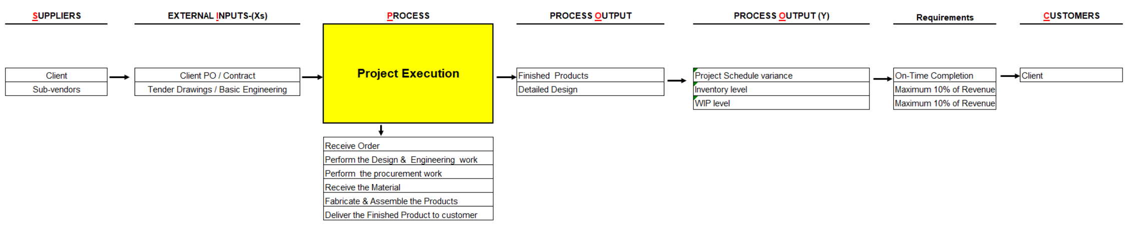

Figure 4-2: SIPOC Diagram

Figure 8 shows six main processes for executing any project: receiving the order, performing the design and engineering work, performing the procurement work, receiving the material, fabricating and assembling the products, and delivering the finished products to the customers. There are two process outputs: finished products to be delivered on time in ideal cases and the detailed design. Three main measures were established to gauge the efficiency and effectiveness of these outputs: the project schedule variance, the inventory level, and WIP. The project schedule variance was adopted to offer a quantitative basis for assessment, complementing the qualitative insights from the research interviews.

Based on the data analysed in the diagnosing phase, the researcher and the organisation CEO signed a researcher-client agreement/project charter recommended by Davison, Martinsons, and Kock (Davison, Martinsons and Kock, 2004). It highlighted that the current schedule variance measure would be compared to the schedule variance after implementing the proposed system. Moreover, the project charter highlighted the roles and responsibilities of the researcher and the organisation members.

4.1.4.2 Developing the Process Map

Following the planning phase, the development of the input map was initiated. The Process Map detailed the SIPOC framework presented above and summarised Theme 2, representing the analysis of each process as a first step to enhance the effectiveness and efficiency of the operations.

Process Inputs (Xs)	Process Step	Outputs (y's)
Client PO	**Receive Order**	Issuance of Project Memo within one week
Client Requirements	**Perform the Design & Engineering work**	Issuance of Basic Engineering within 2 weeks
software		Issuance of RFQ within 3 weeks
Designer		Approved Quotations within 5 weeks
Procurement Officer		Detailed Design & Fabrication Drawings 2 months
Work Instruction		Issuance of Material Request within 3 months
Quotations		
Procurement Officer	**Perform the procurement work**	Getting Quotations after 2 weeks from RFQ
Work Instruction		Issuance of Pos within 3 days from Material Request
RFQs		Receving NMR after 2 weeks from PO
Material Request		Material Receiving within the contractual lead time and before Needed by Date
Budget		
Schedule Plan		
Procurement Officer	**Receive the Material**	Minimum Inventroy level
Work Instruction		
Schedule Plan		
Detailed Design & Fabrication D	**Fabricate & Assemble the Products**	Fabricated Finished Products within as per the schedule
Schedule Plan		
Material		
Finished Products	**Deliver the Finished Product to customer**	Finished Products delivery within the contractual duration

Figure 4-3: Process Map in AL DAR Company

Figure 4-6 shows that the Process Map was summarised based on the focus group interview with department managers and several informal discussions. This Process Map represented AL DAR's current practice and the job task each department head was responsible for regarding the input for each department's primary process and output. These outputs were not limited to physical goods but also represented a performance metric for each process. Linked to the research aim, the output from the "deliver the finished product to customer" process, which was "finish product delivery within the contractual duration", was the primary performance metric this research sought to enhance.

4.1.4.3 Developing the Cause-and-Effect Matrix

The Cause-and-Effect Matrix was developed by communicating it as a survey to

20 participants across various departments to complement the qualitative data. The Cause-and-Effect Matrix is a quality management tool used for root cause analysis designed to identify and prioritise potential causes of a specific problem (effect) to address them effectively. It reveals the correlation between the process input variables (mentioned in the Process Map) and the main output variables, as mentioned in Figure 4-5. The main output variable of this research was “project schedule variance”. This metric calculated the deviation between the planned and actual project completion dates, indicating the delay concerning the contract, which was the output of the last process, as shown in Figure 4-3. However, the matrix needed to include at least three output variables, so the inventory and WIP levels were included with lesser weightage than the project schedule variance since those issues were highlighted in the top management interviews related to the planning and control system.

Twenty participants were asked to fill in the correlation score with values of 0, 1, 3, or 9 instead of a 1 to 10 rating to allow the participants to “ride the fence” and avoid compromising with the five scores for the input that caused debates (Clay, 2015). Additionally, they were advised that 0 would be assigned when there was no relationship between the input and output, 1 would be assigned to a slight relationship between input and output, 3 would be assigned to an average relationship, and 9 would be assigned to a direct relationship between the input and output.

This survey generated the Cause-and-Effect Matrix by mathematically calculating the relationship between the key process input variables mentioned in the input map (Xs) and the customer outputs (Ys). The key process input variables (KPIVs) were the variables the process input consisted of and were controlled during the operation of the process. These were given the most attention based on the priority of the key process output variables (KPOVs), representing the final output or the result of the process, as shown in Figure 4-4.

Rating of Importance to Customer (Rating Scale of 1-10) >>		10	6	8	
Process Step	**Inputs**	Project Schedule variance	Inventory level	WIP level	**Weighted Total**
Fabricate & Assemble the Products	Material	5.9	6.8	6.9	155
Fabricate & Assemble the Products	Schedule Plan	7.2	3.45	7.1	149.5
Perform the procurement work	Schedule Plan	5.6	3.9	6.6	132.2
Receive the Material	Schedule Plan	5.7	3	6.6	127.8
Perform the Design & Engineering work	Work Instruction	6.3	2.9	1.8	94.8
Receive the Material	Work Instruction	5.4	3.75	1.3	86.9
Perform the procurement work	Work Instruction	5.1	3	1.8	83.4
Deliver the Finished Product to customer	Finished Products	2.85	0.35	6.3	81
Perform the Design & Engineering work	Client Requirements	6	2.3	0.9	81
Receive the Material	Procurement Officer	3.3	3.2	2	68.2
Perform the Design & Engineering work	Designer	5.4	1	0.8	66.4
Perform the Design & Engineering work	Quotations	5.85	0.45	0.45	64.8
Perform the procurement work	Procurement Officer	2.9	4.2	0.65	59.4
Fabricate & Assemble the Products	Detailed Design & Fabrication Drawings	0.3	0.75	5.9	54.7
Perform the Design & Engineering work	Procurement Officer	3.6	2.5	0.3	53.4
Perform the Design & Engineering work	software	3	1.3	0.75	43.8
Perform the procurement work	RFQs	1.2	2	1.05	32.4
Perform the procurement work	Budget	1.05	1.85	0.75	27.6
Receive Order	Client PO	1	0.85	0.4	18.3
Perform the procurement work	Pbars	0.65	0.9	0.75	17.9

Figure 4-4: Cause-and-Effect Matix Result

Figure 4-4 represents the average scores from the 20 participants. Unsurprisingly, the top three highest scores that impacted the project’s time delivery were related to the planning and control system: the material delivery (subcomponent), the schedule plan, and the work instruction. These three inputs represented the KPIVs, representing factors or elements within a process that could be controlled or changed with the most impact on the KPOVs, mainly on-time delivery of the ETO projects. This quantitative result was aligned with the qualitative analysis presented in Theme 1: “Having a proper planning and control system in place is the key process that might improve the project delivery”.

4.1.5 Evaluating the Effectiveness of the Implemented Action

The SIPOC diagram was utilised to investigate the processes within the organisation. To evaluate the effectiveness of the developed SIPOC diagram, we carefully examined its strengths and weaknesses.

The strengths of the SIPOC diagram were numerous. It provided an overview of our processes at AL DAR, from receiving client orders to delivering the product. This clarity was crucial for identifying areas to enhance our operations. Additionally, by incorporating insights from Institutional Theory, we gained an understanding of internal and external pressures impacting these processes.

Some limitations were associated with using the SIPOC diagram. While it offered perspective, it might have overlooked complex details and restraints of operational processes. For example, the diagram might not have captured the complexities of each of the six processes.

However, these limitations did not undermine the usefulness of the SIPOC diagram. Instead, they highlighted areas requiring investigation. When combined with insights for focus groups guided by Institutional Theory, the SIPOC diagram became a tool for highlighting and evaluating organisational processes. Hence, acknowledging and synthesising its strengths and limitations provided a comprehensive and critical evaluation of the effectiveness of the implemented action, thus informing further Action Research Cycles.

The evaluation of the effectiveness of implementing the Cause-and-Effect Matrix was performed through the lens of Institutional Theory to provide a broader perspective, illuminating the deep-rooted institutional pressures that might have influenced the feedback and responses from the 20 participants.

Per the matrix results, the material delivery, the schedule plan, and the work instruction were the top three highest scores that impacted the project's delivery time. This quantitative result aligned with the qualitative analysis finding related to Theme 1: "Having a proper planning and control system in place is the key process that might improve the project delivery". This result also hinted at possible institutional pressures within AL DAR, especially in the context of coercive isomorphism. Regulations, industry norms, and powerful stakeholders could influence the company's emphasis on these aspects.

4.1.6 Specifying the Learning Stage and General Findings Through Reflection

The first Action Research yielded a considerable wealth of experience and knowledge. Reflecting on the preunderstanding of the organisational power structure and politics, it was evident how these aspects influenced the research process.

Given the researcher's dual role as an operations planning expert in the subject company and his role as a researcher, the preunderstanding risk could not be avoided totally while interpreting and analysing the data, which could introduce potential biases. However, as a mitigating strategy, the researcher used the unlearning technique for some of his knowledge and practice to manage his preconceptions and preunderstandings. This strategy helped the researcher explore new factors rather than those he was fully aware of. This strategy helped keep challenging the proposed solutions that emerged and existing assumptions, as recommended by Coghlan, Coughlan, and Shani (2019).

The initial concerns about the power asymmetries within the organisation were validated throughout the research. As an Operations Planning Manager directly reporting to the CEO, the researcher's position could have induced bias or caused hesitance among the interviewees, especially those in lower positions, when expressing criticism or sharing honest insights. However, the approach of minimising power differentials during the interviews, as suggested by Srivastava (2006), proved effective. As a result, the researcher gleaned valuable insights and data that might have otherwise been withheld by reassuring participants about a safe space to criticise and share opinions.

Moreover, this Action Research was a unique journey through the organisation's hierarchy, even interviewing the CEO and deputy CEO. In these scenarios, leaning into the power differentials and assertively asking challenging questions was necessary. Per Björkman and Sundgren (2005), practising political entrepreneurship was instrumental in maintaining focus and securing vital information during these interactions.

Balancing those power relationships and ensuring smooth data exchange required continued caution. Taking the advice of Brewis and Wray-Bliss (2008), considering who might gain and who might lose during this research process was a constant question that shaped the approach and conduct of this research Cycle.

In conclusion, the first Action Research Cycle emphasised that being an insider researcher was a balancing act requiring political acumen, assertiveness, diplomacy, and continual reflexivity. These learnings and insights enriched the subsequent research Cycles and contributed to a deeper understanding of the organisation's dynamics.

4.1.7 Action Research Cycle 1 Conclusion

The first Cycle of the Action Research project at AL DAR was instrumental in exploring the complexities and challenges within the company's processes operating in the ETO environment. This Cycle identified several critical areas of concern through comprehensive data collection and analysis utilising input from 37 participants and 118 projects, adopting five interviews, three focus groups, and statistical analysis for schedule variance variable that measures the missed order due dates. These data identified areas of concern related to inefficiencies in various processes, the need for an integrated planning and control system, frequent project delays, and the crucial role of client commitment in the research process.

One significant finding in this Action Research was the complexity of managing the ETO processes, marked by a high degree of customisation requiring careful coordination between the design, procurement, and manufacturing processes. The first research Cycle underscored the need for an integrated planning and control system that could adapt to the dynamic nature of ETO projects and improve coordination across departments, thus addressing the late deliveries of the ETO projects.

Using tools like the SIPOC diagram and the Cause-and-Effect Matrix provided valuable insights into exploring operational processes and their effectiveness. The client's commitment to the Action Research project emerged as a critical factor for success. It set a positive tone for the research and ensured access to necessary data and support for implementing changes.

In conclusion, Action Research Cycle 1 laid a strong foundation for understanding the challenges in AL DAR's ETO environment. It set the stage for the subsequent research Cycles to explore potential ingredients of the proposed planned and control system that can improve project delivery and operational efficiency.

Moreover, analysing processes and their effectiveness with tools a SIPOC diagram and a Cause-and-Effect Matrix proved extremely helpful. The client's commitment to the Action Research project also counted, creating a vibe for the research, and ensuring we received vital data and the support needed to drive changes.

To conclude, the initial Action Research Cycle laid the groundwork for comprehending the challenges in AL DAR's ETO environment to explore the potential ingredients of the proposed planned and control system to improve project delivery and operational efficiency in the upcoming Cycles.

4.2 Action Research Cycle 2

4.2.1 Identifying, Measuring, and Analysing the Problem

4.2.1.1 Application of Data Collection Methods

Following "Research Data Collection and Data Analysis Methods" described in 3.6 section, this cycle involved the data collection and analysis of the two focus groups. These data aimed to explore the challenges and Limitations of AL DAR's Current planning and control. additionally, data collection in this stage is aimed at critical success factors of a proposed planning and control system for effective implementation. The table below summarises data collection Methods and Sample Sizes for Action Research Cycle 2.

Table 4-3:Summary of Data Collection Methods and Sample Sizes for Action

SN	Data Type	Interview ID	Method	Interviewee/Data Source	Sample size
1	Qualitative	04-01	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager, Factory Manager & Logistics Manager	6 Participants
2	Qualitative	04-02	Semi-Structure Focus Group	5 Project Engineer	5 Participants

As shown in the above table, data were gathered through the two focus group interviews using distinct interview structures (4) detailed in Appendix K.

4.2.1.2 Application of Data Analysis Methods

Utilizing the Thematic Analysis procedure as described in 3.7 Research Data Collection and Data Analysis Methods section, the analysis generated a list of codes as shown in Appendix N. Those codes were grouped into the following themes: 1) Challenges and Limitations of AL DAR’s Current Planning and Control, 2 Critical Success Factors of a Proposed Planning and Control System for Effective

Implementation. The following section discusses these themes.

4.2.1.3 Findings and Discussion

4.2.1.3.1 Theme 1: Challenges and Limitations of AL DAR's Current Planning and Control

4.2.1.3.1.1 Introduction To Theme 1

This theme emerged from the two focus group discussions (interview structure 4), which revolved around the critical challenges, shortcomings, and limitations of the current planning and control system at AL DAR. Participants, including the Project Engineers and department heads, consistently highlighted various issues that affected the efficacy of the company's current planning and control system practices. Through the lens of this theme, the identified challenges and limitations were classified under various high-level codes, such as a lack of flexibility, integration, proactive planning, and real-time updates. These findings were linked with the research objective, specifically Research Objective 1, and revealed that understanding the current system's shortcomings was paramount. Identifying these challenges sets the stage for subsequent themes. Additionally, it laid the groundwork for potential interventions for the Action Research Cycles.

4.2.1.3.1.2 Subtheme 1-1: Lack of Flexibility in the Current Planning and Control System

A prominent issue was the lack of flexibility in the current planning and control system. The inflexibility was a technical challenge and a strategic impediment that hindered the company's ability to respond effectively and efficiently to the dynamic and complex nature of the ETO environment. Engineer 3 made an observation highlighting the limitations of the MRP system in accommodating the ETO system: *“Our MRP system . . . it isn’t flexible enough for our engineer-to-order system*”. This observation was not a comment but reflected the feelings of many people within the organisation. Engineer 2, for example, emphasised the pressing need for flexibility by *“system should let us change planning parameters on the fly”.* These remarks demonstrated a sense of frustration and the desire for an adaptable, flexible planning and control system.

The rigidity in AL DAR’s MRP system extended beyond its inability to handle the dynamic changes of the ETO environment. Engineer 4 provided insights into another dimension of this rigidity, stating that the *“MRP system is difficult to understand”.* This complexity in usability likely contributed to inefficiencies and delays, further worsening the system’s rigidity.

This lack of flexibility held implications beyond technical limitations: it had significant strategic implications. The Procurement Manager mentioned an attempt to utilise the MRP system, acknowledging that while it was theoretically meant *“to simplify our processes”,* in practice, the system *“wasn’t tailored to meet our engineer-to-order requirements”.* Such a mismatch between system capabilities and organisational needs can lead to operational disruptions. The Project Engineer further echoed this sentiment, asserting the need for a *“comprehensive system that can adapt quickly”.*

Another dimension of this rigidity mentioned above was the time consumed due to system limitations, as highlighted by Engineer 4’s statement about the MRP system failing to consider customisation needs. This oversight consumed a “*significant amount of time*” and caused delays. Such instances underscored the inefficiencies embedded within the current system. Additionally, the Engineering Manager's comment on the time-consuming data entry processes necessitating coordination across different departments further revealed the operational challenges of the system's inflexibility.

Another aspect of this inflexibility was the time wasted because of the system's limitations, as highlighted by Engineer 4 when discussing how the MRP system failed to consider customisation needs. This limitation led to a "*significant amount of time"* being consumed and causing delays. These instances highlighted the inefficiencies in the current planning and control system. Furthermore, the Engineering Manager commented on the current practices: "*They involve data entry, consume an amount of time, and require coordination across different departments".* This comment further emphasised the challenges arising from the inflexible nature of the system.

The literature strongly supports these findings. For example, Olhager (2013) highlighted the significance of having flexible systems in the make-to-order environment, similar to the ETO environment. Olhager suggested that flexibility in the planning and control systems could enhance the efficiency of the operations. Similarly, Bertrand and Muntslag (1993) argued for evidence that MRP tends to suit manufacturing strategies with lower variety levels, such as make-to-stock, rather than strategies with higher variety, such as ETO or assemble-to-order Additionally, they argued that MRP had been implemented in many ETO organisations without success due to its functionality.

When we compared the research objective with the information gathered from the interviews, it became clear that tackling the inflexibility in AL DAR's planning and control system was crucial. Scholars have also highlighted the significance of adaptability in today's business landscapes. As we delved deeper into this topic, we examined challenges that worsened AL DAR's operational efficiency concerning the on-time delivery of projects.

4.2.1.3.1.3 Subtheme 1-2: Lack of Integrity in the Current Planning and Control System

Another issue in the planning and control system at AL DAR was the fragmented nature of the current planning and control practices. In today's business world, where everything is interconnected and information flows rapidly, integrated systems have become more crucial. Without an approach, it can result in operations, communication gaps and inefficiencies. The interviews conducted at AL DAR provided insights demonstrating the impacts of a disjointed system and emphasised the urgent need for a more cohesive planning and control system integrating all aspects seamlessly.

Engineer 2's statement, *"Excel sheets being like islands on their own"*, summarised this integrity issue that the planning and control system lacked at AL DAR. The comparison of Excel sheets to islands visualised the existing disconnect. This idea was further emphasised by the observation that each department's Excel sheets operate independently, creating data pools and fragmented workflows. The consequences of such a system go beyond operational inefficiencies. As Engineer 5 explained, *"I am in a meeting with suppliers or clients, it's important for me to view the full project data",* showcasing the severe limitations of the current system.

The consequences of this disintegrated approach were multi-fold. As Engineer 3 pointedly remarked, *"Each department has visibility into the current state of each* *project"*. This segmented vision complicated interdepartmental collaboration and created an absence of a unified view, resulting in redundancy and potential misalignments and conflicts. The Factory Manager further echoed this sentiment, "*Currently, many of our schedules function autonomously with a focus on production activities".* Such a narrow perspective, concentrating solely on production, failed to consider the holistic needs of the organisation. As underscored by Engineer 3's observation of distinct departmental bottlenecks, this narrowness could lead to potential bottlenecks and misalignments between all departments.

However, integrating elements is not combining data or procedures but promoting a culture of teamwork and unity. As Engineer 2 asserted, agencies had to *"improvise their response rather than work together",* suggesting a reactive approach rather than only working together. Similarly, Engineer 3 commented, *"Marketing made a promise to clients about delivery without consulting with us first",* highlighting the outcomes of such fragmented practices and emphasising that having an integrated planning and control system could prevent such mismatch by describing a *"system that was able to synchronise data in real-time from all of the departments would have prevented such a mismatch".* Expanding on the discussion of the lack of integrity in the existing planning and control system and the advantages of having an integrated planning and control system, Engineer 3 envisioned a situation where resources could be allocated quickly with an integrated system, avoiding delays or inefficiencies by stating, *"With an integrated system, resources could be assigned immediately".*

These issues related to the lack of integrity in the planning and control system experienced by AL DAR aligned with the concerns shared by the industry's existing literature within the ETO environment. Moreover, these ongoing issues related to planning and control systems and, more specifically, the lack of integrated planning and control systems aligned with the research gap the researcher attempted to address. In an empirical study of 21 machinery-building ETO companies, Adrodegari et al. (2015, p.925) argued that the ETO firms suffered from the lack of comprehensive planning and control tools; hence, they called for a new framework for other ETO industries: "*Considering both the practitioners' and researchers' points of view, further investigations are required to tailor the framework to other real cases, even involving other ETO industries".*

Other authors have been more specific about the lack of integrity by highlighting the absence of planning and control approaches that adequately address engineering and procurement activities. Based on Little et al.'s (2000) research on 13 study cases, they argued that planning and control practices in ETO projects primarily focused on detailed production plans while neglecting an integrated approach encompassing engineering activities (Little et al., 2000, p.553):

> *In addition, the research identified a number of key generic issues for the ETO sector identified by the case study companies during the interviews . . . Lack of design planning and monitoring. Whilst production is typically planned in detail, design planning is largely ignored.*

The Logistics Manager highlighted this aspect of the lack of integrity by stating, *"The stand-alone schedules only focus on production".*

AL DAR's challenges were not isolated incidents but symptomatic of broader systemic issues hindering the ETO sector. The repeated call for tailored integrated planning and control systems in the literature has highlighted the pressing nature and significance of filling this gap in research. The input from engineers and managers at AL DAR also confirmed the necessity for such research. This finding emphasised the urgency of transitioning from traditional disintegrated frameworks to flexible integrated systems explicitly designed for the dynamic ETO environment.

4.2.1.3.1.4 Subtheme 1-3: Lack of Lookahead and Proactive Planning in the Current Planning and Control System

Another critical issue was revealed in the focus group with AL DAR engineers. AL DAR used a reactive approach instead of being the planning and control proactive or forward-looking. As Engineer 1 acknowledged, "*We're always putting out fires, as you may know*", revealing the organisation's reliance on crisis management. This sentiment was not an isolated feeling. Engineer 2 reinforced this perspective: "*Working with reactive planning can be tough*". Therefore, AL DAR's planning and control system revolved around reacting to crises rather than proactively addressing issues and being prepared.

This approach impacted the efficiency and effectiveness of AL DAR's operations. As Engineer 2 stated, "*Because our planning is not proactive, we frequently find ourselves rushing*". The effects of this approach were varied and far-reaching. It strained our resources, added unnecessary stress, compromised the quality of our work, and caused us to miss deadlines. The same engineer explained the challenges of this mindset: *"We frequently find ourselves rushing around to make adjustments at the last minute".* These last-minute scrambles could significantly harm the quality of our projects, eroding trust with our clients and stakeholders even further.

To better demonstrate the difficulties associated with this reactive planning approach, Engineer 4 offered a telling example: "*When the customer finally made* *their choice about the material, we were almost through the design phase*". This instance highlighted the drawbacks of lacking Lookahead and proactive planning in the current planning and control system. These situations resulted in wasting time and resources, misallocating resources, and even potential rework, causing more delays to project timelines.

Prior studies have noted the importance of foresight and the existing gap in its implementation. For example, Wesz, Formoso, and Tzortzopoulos (2018) investigated gaps in the implementation of Lookahead planning in the ETO environment and highlighted the need for a more forward-looking practice in the planning and control system. These findings aligned with the challenges faced by AL DAR, highlighting the difficulty that ETO firms encounter when attempting to implement proactive planning, as observed in this section. Furthermore, Telles et al. (2022) confirmed the gaps in implementing Lookahead planning in the ETO environment. However, they emphasised that this gap was due to time and Cycle time variations among ETO products.

Concerning the first research question related to exploring the shortcomings and limitations in the current planning and control system, the interviewees' experiences with a "lack of foresight and proactive planning" were an aspect of these limitations. Hence, recognising the recurring theme of reactive planning and the resultant "firefighting" approach in AL DAR and the ETO industry contributed significantly to the research's first objective. Additionally, recognising this recurring theme necessitated rectifying the gaps in AL DAR's operations by developing and implementing an integrated planning system to overcome such limitations and eventually address missed orders' due dates, which was the research aim.

In conclusion, as voiced by the interviewees, the lack of proactive planning and control hindered AL DAR's operational efficiency and the ETO industry. This limitation underscored the pressing need to shift towards a more proactive, anticipatory planning paradigm while proposing and implementing an integrated planning and control system to address the issue of missed orders' due dates, which was the main aim of this research.

4.2.1.3.1.5 Subtheme 1-4: Lack of Real-Time Updates in the Current Planning and Control System

The fourth predominant subtheme that emerged from the interviews as hindering effective decision-making while posing substantial risks to the project's timely execution was the absence of real-time updates.

The comment by Engineer 1*, "We don't know about provider issues until it's too late",* provided insight into the weaknesses in the system. When crucial information, such as concerns with the provider, is not promptly disclosed, it can result in a domino effect that influences the timeframe for the project. Engineer 1 stressed the importance of information being *"immediately communicated to all departments . . . in the event that there is a delay".* The same engineer raised concerns about using a static, outdated Excel schedule: "*They tend to become obsolete".* Engineer 5 reinforced this perspective and emphasised the implication of the lack of real-time updates in the planning and control system, noting that the "*absence of visibility into data in real-time affects customer interactions*". He referred to the implications of not having real-time data beyond internal operations directly impacting AL DAR customer relations, potentially undermining trust and satisfaction. These observations from AL DAR's engineers illustrate clearly that the existing planning and control system does not provide real-time updates.

Additionally, when the researcher asked for more insights about the challenges of the planning and control system, Engineer 2 concisely summarised the core of the situation by stating, *"Having insight in real-time is a must*". However, Engineers 3 and 5 were stimulated by the researcher when asked for more insights by dictating that *"it was only after several days that we realised there was a problem".* As Engineer 5 observed, this delay in communication meant that "*not all teams were immediately aware of these adjustments*". This poor communication seemed to be due to an inappropriate planning and control system that could not communicate real-time information. However, such lapses disrupt the workflow; as Engineer 2 stated, it "turns into a loop that never ends".

One unexpected finding was how the Factory Manager acknowledged his satisfaction with using Excel schedules instead of advanced planning and control software: "*We rely on Excel for our planning needs since it allows us to make updates and adjustments*". One possible reason for this claim could be the simplicity and flexibility offered by Excel. Unlike the planning software, Excel provides an interface that many users are comfortable with, allowing for easier adjustments without a steep learning curve.

In reviewing the literature, these experiences related to the lack of real-time update issues in the planning and control at AL DAR were not unique. This issue has been a recurrent theme in ETO environments, as reported by Jünge et al. (2019). Jünge et al. emphasised that many ETO companies do not have a well-defined planning and control process, so they often rely on stand-alone applications that do not provide real-time updates.

Concerning the first research question related to exploring the shortcomings and limitations in the current planning and control system, the interviewees' experiences with a "*lack of real-time updates"* in the current planning was one aspect of these limitations. Hence, recognising the recurring theme of the lack of real-time updates in AL DAR and the ETO industry contributed significantly to the research's first objective. Additionally, recognising this recurring theme necessitated rectifying the gaps in AL DAR's operations by developing and implementing an integrated planning system to overcome such limitations and eventually address missed orders' due dates, which was the research aim.

4.2.1.3.1.6 Subtheme 1-5: Lack of Proper Conversation, Communication and Coordination in the Current Planning and Control System

The technical aspects of the current planning and control system seemed to be symptomatic of a broader issue related to the lack of proper conversation, communication, and coordination among the project team, as drawn from the insights shared by the interviewees. Engineer 1's observation that *"we do not know about provider issues until it's too late*" suggested a communication gap in the real-time reporting of crucial information. This sentiment was further reinforced by the same engineer's remark about the company's reactive approach: *"We are always putting out fires, as you may know",* indicating that teams were not communicating proactively to prevent issues but reacted after problems arose. Moreover, Engineer 3's insights about the departmental bottlenecks and the pressing need for resources to be allocated immediately revealed a more profound lack of coordination and timely communication between departments.

Engineer 2 briefly captured the situation's essence by emphasising that *"having insight in real-time is a must".* This statement highlighted the critical importance of timely communication and its current absence. The Factory Manager's acknowledgement of the prevalent use of Excel schedules further illuminated the issue by stating, *"We rely on Excel for our planning needs since it allows us to make updates and adjustments".* The statement implied that the organisation depended on a tool like Excel, which was not inherently designed for collaborative real-time communication. This reliance suggested a more profound communication breakdown. Similarly, Engineer 3's statement, *"It was only after several days that we realised there was a problem",* underscored the profound absence of proactive conversation within the organisation.

These insights in this theme and the technical insights in previous subthemes related to lack of flexibility, integration, proactive planning, and real-time updates painted a clear picture of AL DAR's planning and control system challenges. Accordingly, in AL DAR seeking to address these challenges, recognising that the solution was not just about adopting a new system to overcome technical issues but overcoming the identified lack of conversation among the project team was imperative. It was equally crucial to foster a culture of open dialogue, facilitate regular conversations among teams, and establish mechanisms for seamless coordination. Only by addressing these foundational issues could AL DAR truly optimise its planning and control system to be poised to meet the dynamic demands of the ETO environment and ultimately achieve the overarching aim of this research: improving on-time project delivery.

4.2.1.3.2 Theme 2: Critical Success Factors of a Proposed Planning and Control System for Effective Implementation

By synthesising the insightful discussions in our focus group concerning the challenges and limitations of AL DAR's current planning and control and the gaps identified in the literature review, the researcher identified ten Critical Success Factors to be incorporated into a proposed planning and control system to ensure its effective implementation, as stated below:

4.2.1.3.2.1 The Flexibility of the Planning and Control System:

The inflexibility highlighted in Theme 1, such as the inability of the MRP system to adapt to the dynamic ETO environment, can be directly countered by ensuring that the new system is inherently flexible. This flexibility should allow for adjustments in planning parameters on the fly and accommodate customization needs.

4.2.1.3.2.2 Integration Across Departments

The issues of lack of integrity and the fragmented nature of current practices (like isolated Excel sheets) identified in Theme 1 suggest a need for a more cohesive system. Integration across departments will ensure a unified view of projects, preventing misalignments and inefficiencies.

4.2.1.3.2.3 A Proactive and Forward-Looking Approach

The current reactive approach, as discussed in Theme 1, leads to inefficiencies and crisis management. A proactive and forward-looking system anticipates potential issues, enabling better resource allocation and efficient management.

4.2.1.3.2.4 Real-Time Data and Updates

The absence of real-time updates in the current system, which leads to delays and communication gaps, can be rectified by ensuring the new system provides immediate data sharing and update capabilities.

4.2.1.3.2.5 Effective Communication and Coordination

The problems with communication and coordination, as identified in Theme 1, can be addressed by a system that promotes open dialogue, regular interactions among teams, and seamless coordination mechanisms.

4.2.1.3.2.6 A User-Friendly and Understandable System

The complexity in usability of the current MRP system, which contributes to inefficiencies, can be countered by developing a user-friendly and easily understandable system

4.2.1.3.2.7 Continuous Monitoring and Control

he lack of proper monitoring and control in the current system, leading to operational disruptions, can be overcome by a system that allows continuous tracking and adjustments

4.2.1.3.2.8 A Commitment to Continuous Improvement

The identified challenges in Theme 1 underline the need for an organizational culture that is committed to continuous improvement, ensuring that the system evolves to meet changing requirements.

4.2.1.3.2.9 Stakeholder Involvement and Commitment

The gaps highlighted in Theme 1, such as misalignments between departments and unmet project deadlines, require active stakeholder involvement for an effective planning and control system.

4.2.1.3.2.10 Training and Support

The complexity and inefficiencies in the current system, as well as the need for new skills to handle a more integrated system, call for comprehensive training and support for the users.

4.2.2 Planning Action

4.2.2.1 Planning for Proposing an Integrated Planning and Control System

Based on the findings related to the limitations of AL DAR's current planning and control system explored in the focus group interviews summarised in Theme 3, top management requested the researcher to propose a planning and control system to be reflected in the company's procedure and implemented in the further research Cycle.

4.2.3 Implementing the Planned Action

4.2.3.1 Proposing an Integrated Planning and Control System

Building upon the insights derived from the focus group discussions, the themes generated, and the gaps identified in the literature review, the pressing need for an improved planning and control system was evident. AL DAR's current challenges in its existing planning and control system, particularly those mentioned in Theme 1, necessitated formulating a new, integrated planning and control system. The proposed system was tailored to address the persistent issues of late deliveries in AL DAR's ETO projects. The proposed system aimed to address the deficiencies noted previously and the late deliveries by drawing on elements from LC and traditional project management.

This system was circulated to all departments and was part of AL DAR's policy and procedures for further implementation in the following research Cycle. Accordingly, Figure 4-10 shows the proposed planning and control system.

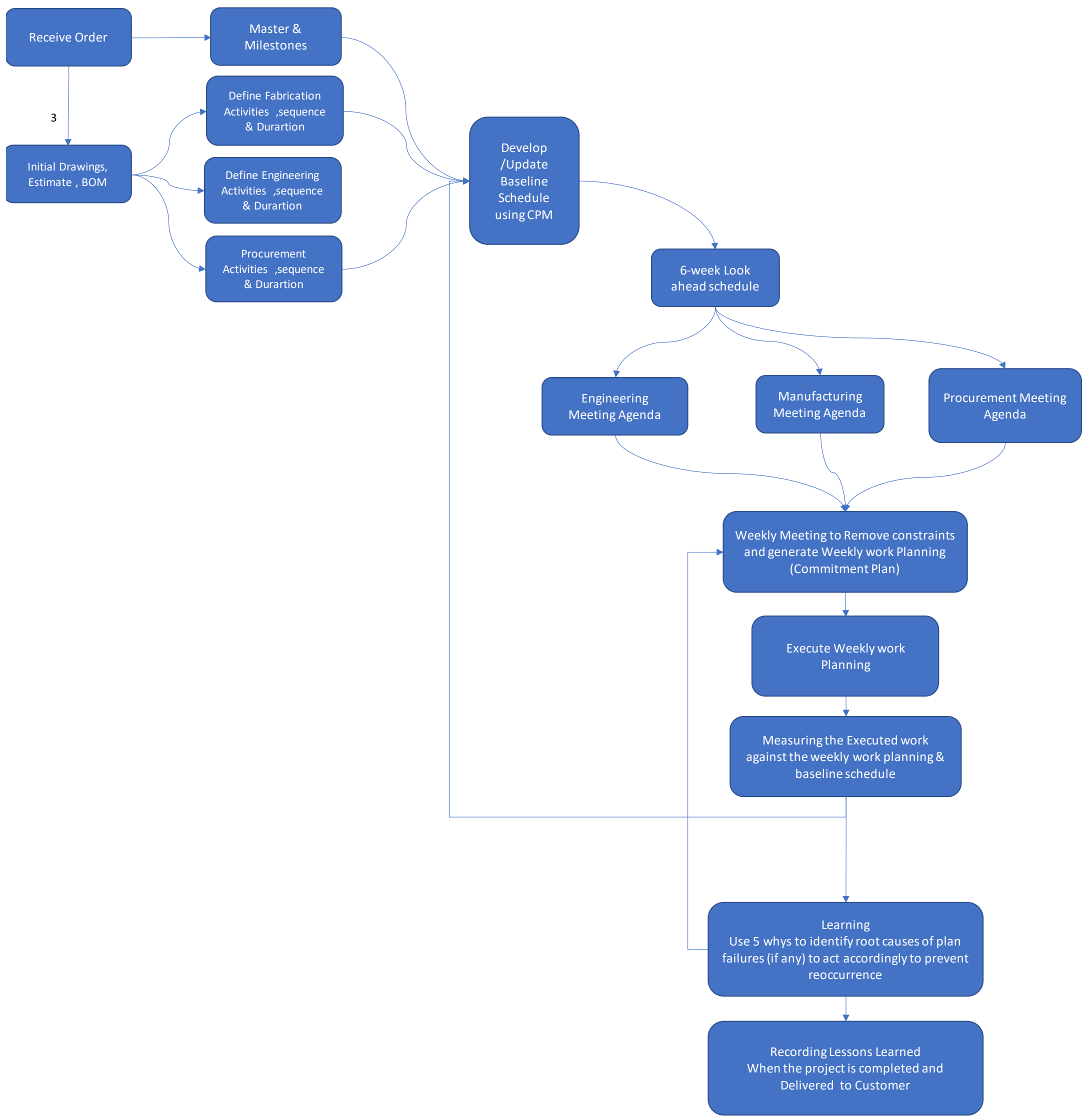

Figure 4-5: Modified Integrated Planning and Control Model

As shown in Figure 4-10, the system starts with receiving the order and ends with the project being completed and delivered to the customer. Once the order is received, the initial drawing, an estimate, and the BOM are generated. Then, the planning and control process starts based on the initial input per the procedure below.

4.2.3.1.1 Developing Master and Milestone Schedule – Pulling Planning Theory

The Master and milestone schedule is a high-level schedule that outlines the main deliverables alongside the sequence and timing of each of the deliverables and project milestones (Mubarak, 2015). It provides a roadmap for the project team to coordinate and execute the project efficiently. It also informs the development of Lookahead planning and weekly work plans (Sánchez et al., 2019), as elaborated on in subsequent sections.

Based on the Purchase Order (PO) that stipulates the customer's requirement, the Master schedule is developed by adopting the pull planning concept originating from Lean thinking theory. Unlike the traditional push planning methodology, pull planning emphasises collaboration. It employs a backward calculation from the contractual project completion date to determine the completion dates for primary tasks and milestones. Therefore, each task is "pulled" based on the contractual completion date and the sequence of works. Adopting pull planning ensures that each finished product is completed when required and when the customer is ready to receive it. In other words, pull planning aligns the sequence of the upstream activities to meet downstream needs.

The development of the Master schedule was borrowed from the LPS, which is one of the most popular Lean planning systems found in literature and claimed to be successful by some scholars (Ballard and Howell, 1998; Macomber and Howell, 2003; Emblemsvåg, 2014). The LPS also deploys pull planning as a collaborative approach that encourages conversation and communication within the project team. Adopting this approach will assist in addressing the lack of proper conversation highlighted in Theme 3-5, as derived from the focus group discussion.

4.2.3.1.2 Defining Engineering, Procurement, and Manufacturing Activities, Along with Their Duration and Sequence – WBS Principle

The subsequent step in the proposed planning and control system defines the tasks involved, such as fabrication, engineering, and procurement, with their durations and sequences. This comprehensive task definition ensures the project's flow and integrity. To facilitate this process, we employed the WBS principle recommended by the Project Management Institute (2017), which allows for a breakdown of the project into its components, ensuring comprehensive coverage of all project activities.

The reflections from our focus group discussion underscored the urgency of this step, as represented in Theme 1, which was related to the limitation of AL DAR's current planning and control system and, more particularly, the lack of integrity in the current system. This lack of integrity was encapsulated by Engineer 2's characterisation of *"Excel sheets being like islands on their own",* referring to a segmented and disjointed approach. The fragmented workflows stemming from this lack of integration hindered operational efficiency and interdepartmental collaboration, leading to potential misalignments, redundancies, conflicts, and late deliveries.

The literature and industry studies have further reinforced the importance of this step. As highlighted by Adrodegari et al. (2015) and Little et al. (2000), the ETO sector often struggles with disjointed, unintegrated planning, focused mainly on detailed production plans, neglecting other activities related to engineering and procurement. The call for a cohesive, integrated planning and control system is not just an academic pursuit but an industry necessity, reiterated by the professionals' experiences at AL DAR.

In conclusion, defining the engineering, procurement, and manufacturing activities, backed by the principles of WBS, addressed the current challenges of AL DAR while aligning with calls for a more integrated approach in the literature to ensure a harmonious, efficient, and successful project execution.

4.2.3.1.3 Developing and Updating the Baseline Schedule Using the Critical Path Method (CPM) And Rolling Wave Planning

A robust project baseline schedule is essential for success (Van de Vonder et al., 2005). In their seminal article, Kelley and Walker (1959) introduced the CPM to resolve issues related to coordinating many diverse activities required to complete the projects. They highlighted that large construction and ETO projects involve numerous stakeholders with varied expertise focused on specific tasks. Hence, managing the coordination of these interrelated activities is a fundamental aspect of management that can be addressed by adopting the CPM.

Similarly, Jaafari (1984) argued that project planning should use the CPM despite the numerous criticisms considering three main factors that affect its successful implementation. Firstly, the CPM should be fed with a realistic productivity rate for the crews considering the job management efficiency conditions. Secondly, the CPM should include sufficient safety buffers (float) between dissimilar trades. These factors were considered while implementing the CPM at AL DAR.

However, scholars have criticised the schedule resulting from the CPM as having little value for the site or shop floor management. Planning is put aside before the work begins (Koskela et al., 2014). Additionally, the CPM can identify productivity variances or schedule deviations and capacity waste very late, comparing the line-of-balance method, which even provides a better visualisation of such variances (Seppänen and Aalto, 2005). Moreover, Sacks and Harel (2006) argued that traditional project management practices based on the CPM have resulted in situations where all project stakeholders, including subcontractors, compete, creating adversarial relationships. Hence, project stakeholders make decisions based on their interests and goals rather than considering the planned dates generated from the CPM without aligning with the overall project's goal.

Since the literature review did not offer an alternative scheduling theory that comprehensively considers project activities and their interrelationships, the researcher deemed the adoption of the CPM. However, the researcher considered implementing mitigation measures for the CPM's aforementioned shortcomings. Firstly, addressing the criticism of having the schedule result from the CPM put aside before the work began, as Koskela et al. (2014) highlighted, the researcher adopted the concept of Rolling Wave Planning, highlighted by the PMI (2017), in his proposed system. Based on this concept, planning and action are not separated, and planning out all activities from the start is not meaningful. Instead, planning is an ongoing process that evolves gradually, allowing for adjustments as new information becomes available. Therefore, the proposed system develops a baseline and updates it weekly, reflecting new insights, progress, and team interactions to ensure that the planning remains relevant and responsive to real-time developments.

Additionally, having a weekly update of the schedule minimises the risk of late identifying of the productivity variances or schedule deviations, as highlighted by the CPM, can identify productivity variances or schedule deviations and capacity waste very late, comparing the line-of-balance method, which even provides better visualisation of such variances than Seppänen and Aalto (2005). This iterative approach allows flexibility and adaptability, ensuring planning remains relevant and aligned with real-world developments.

Overall, the sentiments echoed in our focus group discussions related to the shortcomings of the current planning and control system, particularly the lack of real-time updates and flexibility, were addressed by integrating the CPM and Rolling Wave Planning.

4.2.3.1.4 Developing a Six-Week Lookahead Schedule for Proactive Planning

The importance of proactive, Lookahead planning cannot be overstated. Developing a six-week Lookahead schedule based on LC principles is a forward-looking tool, ensuring that upcoming tasks are ready and feasible while promoting proactive over reactive planning (Ballard, 2000). Additionally, the six-week Lookahead schedule can reduce the uncertainty existing in the Master schedule, as claimed by Daniel et al. (2019)

This step also emerged from our focus group discussions, particularly Theme 3-3, which underscored the current planning and control system's lack of foresight and proactive planning. Engineer 1's comment, "*We're always putting out fires, as you may know*", painted a vivid picture of AL DAR's current state – constantly reacting to crises rather than anticipating them. As Engineer 2 mentioned, this reactive approach often resulted in the company "*rushing around to make adjustments at the last minute*", straining resources and compromising project quality, thereby leading to missed deadlines and eroding client trust.

In light of these findings from the feedback from AL DAR's team and the existing literature, developing a six-week Lookahead schedule was an operational necessity that aligned with the broader academic discourse and industry best practices. Such a tool can enable AL DAR to transition from its current reactive stance to a more anticipatory, forward-looking approach, thereby enhancing efficiency and ensuring timely project execution, the eventual aim of this research.

4.2.3.1.5 Conducting Weekly Meetings to Remove Constraints and Generating Weekly Work Planning (Commitment Plan): Drawing Inspiration from Linguistic Action Theory

The next pivotal step in the proposed planning and control system is conducting weekly meetings to identify and eliminate constraints, ensuring a smooth workflow. These meetings are a platform for coordination and facilitate the creation of the weekly work planning or the commitment plan.

The core idea behind these weekly meetings is borrowed from the LPS, a collaborative, commitment-based approach to project planning and control recognised for its effectiveness in promoting proactive management and enhancing project performance (Ballard, 2000). The LPS emphasises the importance of front-line workers (the "last planners") in planning, including the meetings, ensuring that those who execute the work have a voice in planning it. During planning meetings, the project team discusses the constraints that may prevent the completion of the tasks so that the team works collaboratively to remove those constraints. As a result, the project team makes commitments for the completion. The foundational theory that explains this approach's success is the Linguistic Action Theory. Based on this theory, Winograd and Flores (1986, cited in Koskela and Howell, 2002) argued that project activities are coordinated through the act of language by making and keeping commitments. Thus, actions are coordinated by people's commitments rather than central control acting through commands, as in traditional management. Therefore, planning from the Linguistic Action perspective is a conversation that continues over the project's timeframe to get tasks completed (Macomber and Howell, 2003).

Our focus group discussions revealed a clear need for such collaborative planning. The prevalent sentiment among AL DAR engineers echoed the current planning system's reactive nature and challenges. Engineer 2's lamentation, "*Working with reactive planning can be tough*", underscored the daily challenges they faced, stemming from a lack of coordinated, forward-looking planning.

The weekly meetings, as envisioned in the LPS, serve as a platform to bridge this gap. The planning process becomes more dynamic, realistic, and aligned with ground realities by bringing together all stakeholders to review the week's work, identify potential constraints, and collaboratively decide on the next steps. By design, these meetings foster a culture of collective responsibility, ensuring that all stakeholders are committed to the plan and aware of their respective roles.

The commitment plan, which emerges from these meetings, is more than just a schedule; it is a pact among all project stakeholders. It outlines what needs to be done, who is responsible, and when it will be completed, ensuring clarity and accountability.

Previous research and industry experiences have underscored the value of such an approach. The LPS, emphasising collaborative planning, constraint removal, and commitment-based scheduling has improved project predictability and performance (Ballard and Howell, 2003). As highlighted in our focus group discussions, AL DAR's current challenges align with the gaps the LPS aims to address.

In conclusion, the proposed step of conducting weekly meetings to remove constraints and generate the commitment plan is a response to AL DAR's identified challenges and an alignment with best practices from the broader construction industry. By integrating principles from the LPS, the proposed system ensures that planning remains relevant, collaborative, and commitment-driven.

4.2.3.1.6 Measuring the Executed Work Against the Weekly Work Planning & Baseline Schedule Using the Earned Value Methodology and Percent Plan Complete (PPC)

An integral part of an effective planning and control system is regularly monitoring and controlling progress (Mulcahy, 2010). This step can be achieved while measuring the executed work against the weekly work planning and the baseline schedule to ensure that a project remains on track (Project Management Institute, 2017). Additionally, the continuous monitoring and controlling of the progress facilitates the early detection of deviations and enables prompt interventions. By consistently comparing actual work to planned activities, Project Managers can ensure the project remains on its predetermined path, addressing potential issues before they escalate and eventually completing the project on time (Project Management Institute, 2017).

Earned Value Methodology (EVM), a powerful tool for measuring and monitoring project performance, was adopted in the planning and control system. The U.S. Department of Defense originated this methodology in the 1960s (Stone, 2023). EVM has been used to compare the actual progress versus the planned so that the project team can detect any deviation from the Master plan at any time during the project execution. Alongside EVM, the PPC metric, a pivotal element from the LPS, offers a simple, effective tool to calculate the percentage of planned tasks completed on time concerning the weekly plan. It provides a clear picture of how effectively plans are executed, promoting accountability and insight into areas of improvement.

Our focus group discussions with AL DAR engineers highlighted the need for a robust monitoring mechanism. As encapsulated by Engineer 1's comment on "*putting out fires*", the recurring theme of reactive planning can be mitigated with continuous checks on alignment between planned and executed work. Tools like EVM and PPC can provide the quantitative insights required for proactive decision-making.

4.2.3.1.7 Using "5 Whys" to Identify Root Causes of Plan Failures

An imperative component of any robust planning and control system is the commitment to continuous learning and improvement. As Kerzner (2014) argued, successful project management is not merely about adherence to plans but their constant evolution and improvement based on real-world experiences.

The "5 Whys" for root cause analysis was introduced in this step as an important element in the LPS (Ballard, 2000). Root cause analysis is an LC principle emphasising continuous improvement and learning from the project's failures

(Ballard, 2000). By repeatedly asking "why" until the core issue is identified, teams can move beyond treating symptoms to address underlying (root) causes of problems. Based on those root causes, Appropriate actions are taken to prevent recurrences. Additionally, lessons learned are recorded throughout the project so that the same failure is not repeated.

4.2.4 Evaluating the Effectiveness of the Implemented Action

The proposed planning and control system was based on the insights derived from the focus group discussions on the challenges and limitations of AL DAR's current planning and control and the gaps identified in the literature review. The proposed system drew on elements from LC and traditional (non-Lean) project management and was tailored to address the persistent issues of late deliveries in AL DAR's ETO projects. Considering the challenges and limitations of AL DAR's current planning and control and the gaps identified in the literature review, both were formulated in the critical success factor table below, which shows the alignment of Critical Success Factors with components of AL DAR's proposed integrated planning and control system.

Table 4-4: Alignment of Critical Success Factors with new System Components and Underpinning Theories

#	Critical Success Factor	System Component/Theory	Rationale
1	Flexibility of the planning and	Developing Master and milestone schedules using pull planning theory	Allows adjustments based on real-time changes and

#	Critical Success Factor	System Component/Theory	Rationale
	control system	(Lean)	customer requirements
2	Integration across departments	Defining engineering, procurement, and manufacturing activities using WBS principles (non-Lean)	Facilitates cross-departmental coordination and integration
3	Proactive and forward-looking approach	Developing a six-week Lookahead schedule (Lean)	Enables proactive planning by anticipating future tasks and preparing for them in advance
4	Real-time data and updates	Updating the baseline schedule using the CPM and Rolling Wave Planning (non-Lean)	Allows for real-time tracking of project progress and adjustments as needed
5	Effective communication and coordination	Conducting weekly meetings for constraint removal and weekly work planning using Linguistic Action Theory (Lean)	Facilitates communication among team members and coordination of tasks
6	User-friendly and understandabl e system	Use of user-friendly tools like Excel in conjunction with advanced project management software (Lean)	Encourages adoption and effective use by all team members
7	Continuous monitoring and control	Measuring executed work against plans using EVM and PPC (Lean and non-Lean)	Provides a structured approach to continuously monitor and control project progress

#	Critical Success Factor	System Component/Theory	Rationale
8	Commitment to continuous improvement	Employing the "5 whys" for continuous learning and improvement (Lean)	identifying root causes of issues and enabling continuous improvement
9	Stakeholder involvement and commitment	Inclusion of all relevant stakeholders in the planning process (Lean)	Ensures stakeholder commitment and aligns their expectations with project progress
10	Training and support	Providing training sessions on the new system and ongoing support (Lean)	Ensures effective utilisation of the new tools and methodologies by all team members

The above table demonstrates how each component of the proposed system aligns with and supports the identified Critical Success Factors, offering a comprehensive approach to address the challenges in AL DAR's project planning and control.

4.2.5 Specifying the Learning Stage and the General Findings Through Reflection

The significant challenges identified in this Cycle, such as the lack of flexibility, integrity, proactive planning, real-time updates, and proper communication, identified the gaps in AL DAR's planning and control system. This understanding gained from the focus group assisted in proposing a planning and control system tailored to such environments. This proposed integrated planning and control system, incorporating elements from LC and traditional project management principles, provided potential pathways to mitigate AL DAR's challenges. The theories embedded in the proposed system, like the CPM, Rolling Wave Planning, Lookahead scheduling, and the EVM, linked academia with practical situations.

Overall, the learnings from this Cycle paved the way for the third Cycle for real-world implementation and testing of the proposed system.

4.3 Action Research Cycle 3

4.3.1 Identifying, Measuring, and Analysing the Problem

4.3.1.1 Application of Data Collection Methods

Following the "Research Data Collection and Data Analysis Methods" section described in 3.6 section, this cycle involved the data collection and analysis of the four focus groups and 118 project documents. These data aimed to explore the impact of implementing the newly proposed system on the project execution processes and the rate of missed order due dates. The below table summarises the data collection attributes in this cycle.

Table 4-5: Summary of Data Collection Methods and Sample Sizes for Action

Research Cycle 3

SN	Data Type	Interview ID	Interview Structure ID	Method	Interviewee/Data Source	Sample size
1	Qualitative	Interview 05-01	05	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager, Factory Manager, and Logistics Manager	6 Participants
2	Qualitative	Interview 05-02	05	Semi-Structure Focus Group	5 Project Engineer	5 Participants
3	Qualitative	Interview 06-01	06	Semi-Structure Focus Group	Project Engineer, Engineering Manager; Procurement Manager, Warehouse Manager, Factory Manager, and Logistics Manager	6 Participants
4	Qualitative	Interview 06-02	06	Semi-Structure Focus Group	5 Project Engineer	5 Participants
5	Quantitative	N/A	N/A	Document analysis	Project Documents	29 Projects

As shown in the above table, Soft data were gathered through four focus group interviews using distinct interview structures (5 and 6) detailed in Appendix O and Appendix P

In contrast, hard, quantifiable, and objective data from 29 project documents were retrospectively collected to analyse and measure existing delays in the execution and delivery of projects at AL DAR after implementing the new system.

4.3.1.2 Application of Data Analysis Methods

Utilizing the Thematic Analysis procedure as described in 3.7 Research Data Collection and Data Analysis Methods section, the analysis generated a list of codes as shown in Appendix S and Appendix T. Those codes were grouped into the following themes: 1) The New System has Streamlined Project Execution Processes and Mitigated Missed Order Due Dates, 2) The New System has Overcome the Previous System's Limitations, 3: The Proposed System Has Some Limitations. The following section discusses these themes.

4.3.1.3 Findings and Discussion

4.3.1.3.1 Theme 1: The New System has Streamlined Project Execution Processes and Mitigated Missed Order Due Dates

4.3.1.3.1.1 Introduction To Theme 1

Theme 1 emerged from the two focus group discussions (interview structure 5), which revolved around exploring the effect of the proposed integrated project planning and control system implemented in the previous Cycle on the project lead time at AL DAR (Research Objective 3). Participants, including the Project Engineers and department heads, consistently highlighted various areas of improvement in the project execution processes starting from the initial stages, consequently enhancing the project lead time by 30%.

The subsequent section elaborates on how introducing the suggested integrated planning and control system at AL DAR significantly streamlined and improved project execution processes. Identified improvements are classified under various subthemes: 1) post-implementation outcomes on project delivery efficiency – statistical and qualitative synthesis, 2) efficient initial stage, 3) efficient design stage, 4) efficient procurement and material delivery, 5) efficient inventory management, 6) efficient manufacturing stage, and 7) efficient logistic process. These improvements marked a milestone in achieving the research aim of mitigating the missed order due dates in the ETO environment at AL DAR and the community of practice.

Identifying these improvements and the implication of the new system set the stage for subsequent themes related to previous system challenges that the new proposed system has overcome. It laid the groundwork for exploring rooms to refine the new system further.

4.3.1.3.1.2 Subtheme 1-1: Post-Implementation Outcomes on Project Delivery Efficiency -Statistical and Qualitative Synthesis

Implementing the integrated project planning and control system at AL DAR was transformational in achieving efficient overall project execution from initiation until the finished product shipment to the client. The focus group discussions, confirmed by empirical data, revealed a notable enhancement in operational efficiency and adherence to project timelines.

Qualitative data from the focus group participants confirmed the system's efficacy in reducing the lead time of the projects from 25% to 35%, as indicated by the participants collectively. One participant said, *"We have witnessed a 25% enhancement in on-time deliveries".* Others concurred, noting significant improvements in response times and a palpable reduction in lead times—observations supported by statistics indicating around a 35% reduction in such instances: "*We're now more aligned with project deadlines . . . Statistically speaking, they have observed a reduction in times of, around 35%*".

Additionally, other participants attributed the improvement brought by the new system to the proactive feature of the new system: *"This proactive planning helped us avoid the last-minute rush and kept the project on track"*. These quotes completely contrasted with the one quoted before the implementation of the new system when one engineer said, *"We consistently miss deadlines. It feels like we're always firefighting, never proactively managing projects*", and another said, *"Delays have become the norm, not the exception. It's affecting our reputation with clients".*

Complementing these personal perspectives, the researcher performed descriptive and inferential analysis for the missed order due dates variable (the dependent variable) and the efficiency of the proposed planning and control system (the independent variable). The missed order due date was measured using the schedule variance % indicator, a project management KPI indicating the degree to which the actual performance deviates from the planned schedule. A negative value typically meant a delay or missed order due date, while a positive value indicated work was ahead of schedule or met the order due date.

The schedule variance % was calculated for 29 of 41 projects (completed after implementing the new system) based on their similarity in scope and complexity. The schedule variance % for the 29 projects was compared with the 118 analysed before implementing the new system. The selection criteria were established to control for variability and ensure that the comparative analysis accurately reflected the efficiency gains of the new system.

The table below shows brief statistics about the schedule variance % extracted from SPSS V29 for the 29 projects.

Table 4-6: Post-Implementation Schedule Variance Statistics

Statistics

Schedule Variance %

N	Valid	29
	Missing	0
Mean		-15.5886%
Median		-7.6400%
Mode		10.00%
Std. Deviation		26.60788%
Range		91.90%
Minimum		-81.40%
Maximum		10.50%

The above table shows that the schedule variance % was calculated for 29 projects. Since this variable was an interval, the mean, median, and mode were central tendency measures (Bryman, 2012). A comparison of these central tendency measures for project schedule variance % KPI before and after system implementation was conducted considering Table 4-2: Pre-Implementation Schedule Variance Statistics and Table 4-6, as shown in Figure 4-14 below.

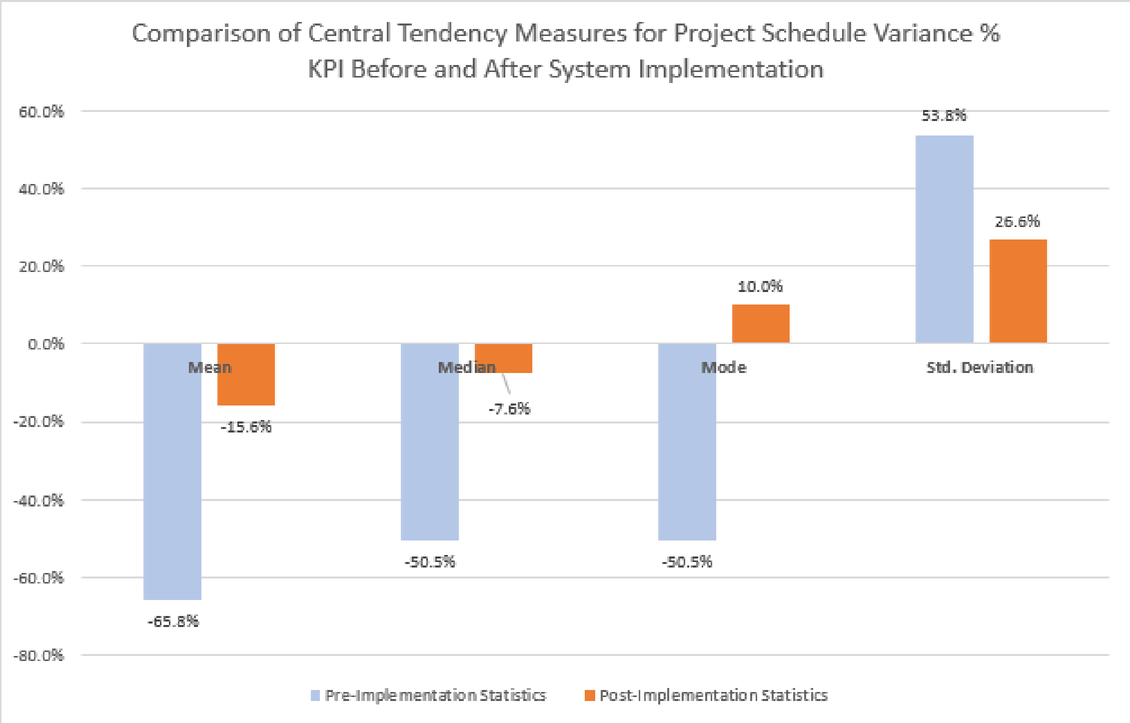

Figure 4-6: Comparison of Central Tendency Measures for Project Schedule Variance % KPI Before and After System Implementation

As depicted above, the mean value for the schedule variance of –15.6% was –65.8% before implementation, suggesting that a project with a contractual duration of 100 days was typically extended to 165.8 days before implementing the new system. However, the new system only extended it to 115 days, reducing the lead time by 30%, as aligned with the qualitative insights from the focus group.

The median schedule variance showed an 85% improvement, meaning that the midpoint of delay across all projects was reduced substantially from –50.5% to –7.6%, indicating better adherence to the schedule. The mode representing the most commonly occurring schedule variance in the data was –50.5%. However, it improved to 10%, indicating completion ahead of the contractual duration, hence mitigating the missed order due dates. These stark statistical data confirmed the sentiments expressed by the interviewees: "*We're now more aligned with project* *deadlines . . . Statistically speaking, they have observed a reduction in times of around 35%*".

Furthermore, the analysis found considerable improvement in the variability in the schedule performance, as indicated by the standard deviation of 53.8% pre- versus 26% post-implementation. The standard deviation of 26% indicated that the schedule variances deviated from the mean by approximately 26%. The table below shows the comparative analysis between these measures with the interpretation for each.

Table 4-7: Comparative Analysis of Project Schedule Variance: Pre- vs Post-System Implementation

Pre-Implementation Statistics		Post-Implementation Statistics		Delta %	Interpretation
Schedule Variance %		Schedule Variance %			
N Valid	118	N Valid	29		
N Missing	0	N Missing	0		
%Missed Order due date	94.1%	%Missed Order due date	65.5%	-30%	(30% Mitigating in % Missed Order due date):The % missed order due dates has been reduced significantly after implementing the new system
Mean	-65.8%	Mean	-15.6%	-76%	(76% improvement in Schedule variance % or 30 % in the lead time): Projects with 100 planned days, are on average completed on 115 day instead of 165 day before implementing the new system.
Median	-50.5%	Median	-7.6%	-85%	(85% improvement): The median schedule variance shows an 85% improvement, meaning that the midpoint of delay across all projects has been reduced substantially from -50.5% to -7.6% indicating better adherence to the schedule.
Mode	-50.5%	Mode	10.0%	-120%	(120% improvement) in mode schedule variance means that the most common value for schedule variance has not only been reduced to zero but has actually crossed over to indicate early completion. This is a complete reversal from the most common outcome being a significant delay to now being an early finish.
Std. Deviation	53.8%	Std. Deviation	26.6%	-51%	(51% reduction).The reduction in standard deviation by 51% shows that there is now less variability in project completion times. Projects are now more consistently meeting their scheduled times than before.

Overall, the post-implementation statistics reflected a substantial improvement in project schedule adherence, with projects more likely to be completed on time or early, less variability in project completion times, and fewer extreme cases of delay, with eventually 30% mitigating the percentage of missed order due dates since it was 94.1% and decreased to 65.5%.

However, two opposing hypotheses were formulated to guide the statistical analysis to confirm statistically if the implementation of the proposed system had a significant impact on reducing schedule variances and missed order due dates.

Null Hypothesis (H0): The implementation of the proposed integrated project planning and control system has no significant effect on the schedule variances of projects and, consequently, on the number of missed order due dates.

Alternative Hypothesis (H1): The implementation of the proposed integrated project planning and control system significantly reduces the schedule variances of projects, thereby decreasing the number of missed order due dates.

Given the non-normal distribution of data and the variance inequality between the two sets (schedule variance after implementation and before implementation), as indicated by the Shapiro-Wilk and Kolmogorov-Smirnov tests (Table 4-8), a Chi-Square test was employed.

Table 4-8: Test of Normality

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre_Implementation	.129	118	<.001	.918	118	<.001
Post_Implementation	.220	29	<.001	.864	29	.001

a. Lilliefors Significance Correction

As shown in Table 4-8, both the Shapiro-Wilk and Kolmogorov-Smirnov tests showed that the data in post-implementation and pre-implementation were not normally distributed, with both *p*-values at or below 0.001, indicating significant evidence against the hypothesis of normality. Accordingly, the Chi-Square test was employed. The collected data were categorised into time periods (with values before or after) and order statuses (with values missed or not missed).

To produce a contingency table using SSPS, Bryman (2012) recommended assigning the presumed independent variable as the column variable while the dependent as the row variable. Accordingly, the contingency table was produced, as shown in Table 4-12.

Table 4-9: Contingency Table for Order Status and Time Period (Pre- and Post-Implementation)

Time_Period * Order_Status Crosstabulation

			Order_Status		
			Missed	Not Missed	Total
Time_Period	After	Count	19	10	29
		Expected Count	25.6	3.4	29.0
		% within Time_Period	65.5%	34.5%	100.0%
	Before	Count	111	7	118
		Expected Count	104.4	13.6	118.0
		% within Time_Period	94.1%	5.9%	100.0%
Total		Count	130	17	147
		Expected Count	130.0	17.0	147.0
		% within Time_Period	88.4%	11.6%	100.0%

As shown above, the pre-implementation period consisted of 118 orders, with 111 (94.1%) missed, substantially higher than the expected count of 104.4 under the assumption of no change. Conversely, only 7 (5.9%) orders were not missed, less than the expected count of 13.6. This discrepancy suggested that the system in place before the implementation was associated with a higher rate of missed orders than expected if the time period had no effect.

In the post-implementation period of 29 orders, 19 orders were missed (65.5%) compared to an expected count of 25.6, indicating a reduction in missed orders following the new system's implementation. Furthermore, 10 (34.5%) orders were not missed, exceeding the expected count of 3.4. This improvement in order fulfilment demonstrated a notable decrease in the proportion of missed orders post-implementation.

However, the null hypothesis could not be rejected unless we tested it statistically using the Chi-Square to determine the statistical significance of our findings, as shown in Table 4-10.

Table 4-10: Chi-Square Tests

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	18.554[a]	1	<.001		
Continuity Correction[b]	15.867	1	<.001		
Likelihood Ratio	14.813	1	<.001		
Fisher's Exact Test				<.001	<.001
N of Valid Cases	147				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 3.35.

b. Computed only for a 2x2 table

Pearson's Chi-Square statistic was calculated to be 18.554 with 1 degree of freedom, and the associated two-sided *p*-value was less than 0.001. This significant result indicated an association between the time period and order fulfilment status, suggesting that implementing the new system significantly reduced missed orders.

Additionally, the continuity correction, a 2 x 2 table to adjust for the bias in the Pearson Chi-Square test when sample sizes are small or when data are sparse, yielded a value of 15.867 with a *p*-value of less than 0.001, further supporting the significant association.

The Likelihood Ratio another measure of association for categorical data which is most often used when the data set is too small to meet the sample size assumption of the Chi-Square test (McHugh, 2013), also indicated a significant result with a statistic of 14.813 and a *p*-value less than 0.001. This finding reinforced Pearson's Chi-Square test calculations, suggesting robust evidence against the null hypothesis of no association.

Fisher's exact test which is a bit more precise than the Chi-Square (McHugh, 2013), used to examine the significance of the association between two kinds of classifications, provided a two-sided exact *p*-value of less than 0.001 and a one-sided exact *p*-value of less than 0.001. This outcome confirmed the findings of the other tests, indicating a statistically significant difference in the proportion of missed orders before and after the system change.

Notably, while the Pearson Chi-Square test is robust, it is not assumption-free. One assumption is that the expected frequency in each cell should be at least 5 (Beacom, 2023). In this analysis, 25.0% of cells had expected counts less than 5, with the minimum expected count of 3.35. The Continuity Correction adjusted for this deviation from the ideal condition and was further examined by Fisher's Exact test and Likelihood Ratio test, which did not rely on such assumptions, so it was particularly suitable for the small sample size.

However, McHugh (2013) argued that the researcher's work is not quite done yet by obtaining the Chi-Square with significance statistics and emphasised that the Chi-Square should be followed with a strength statistic test like Cramer's V, the most common strength test, using the formula below.

$V = \sqrt{(x^2 / (n * \min(r - 1, c - 1)))}$

where:

• x^2 is the Chi-Square statistic from the test (18.554 in this case),

• n is the total sample size (147),

• r is the number of rows (2),

• c is the number of columns (2).

The calculation of Cramer's V yielded a value of approximately 0.355 out of possible maximum value of 1, indicating a moderate correlation as suggested by Field (2017) and a statistically significant association between the implementation time period (pre- and post-implementation of the new system) and order status (missed or not missed). This Cramer's V result quantitatively supported the qualitative evidence of the system's efficacy in improving project delivery efficiency and adherence to project timelines.

Consequently, all tests support the rejection of the null hypothesis, indicating a moderate and statistically significant association between the implementation of the new system and the improvement in order fulfilment accuracy. This analysis substantiated the efficacy of the system changes made.

In Conclusion, the evidence gathered through rigorous focus group interviews and statistical analysis illustrated that the new integrated project planning and control system substantially streamlined AL DAR's project execution processes, reducing schedule variance while enhancing project lead times. These improvements were critical milestones in achieving the research aim of mitigating missed order due dates in the ETO environment, thereby contributing to the field of OM in practice and academia.

4.3.1.3.1.3 Subtheme 1-2: Efficient Initial Stage

One of the most pronounced improvements observed was the reduction of lead times during the initial stages of projects. As one interviewee noted, *"The new system has made an improvement in reducing lead times during the initial stages of projects"*. This enhancement was vital in establishing the direction for the entire project life cycle. It laid a foundation for efficiency and timely delivery, directly contributing to the third research objective of exploring the effects of the proposed system on project lead times. Another interviewee echoed this view: *"We have observed noticeable improvements during the initiation phase"*.

4.3.1.3.1.4 Subtheme 1-3: Efficient Design Stage

The design stage was also positively impacted after introducing the proposed planning and control system, as evidenced by the qualitative data gathered. This impact, represented by streamlining the design process, enhancing the efficiency of handling design changes, and reducing the time spent on revisions, aligned with contemporary project management methodologies, and reflected advancements in managing ETO environments.

One of the reported streamlining of the design phase was minimising the need for revisions or the time needed to redo the design. This claim was stated by the Engineering Manager, who said: "*From an engineering perspective, the system has streamlined the design phase, minimising the need for revisions".* The Project Engineer agreed, "*During the design and engineering stages, we have noticed a decrease in time spent on redoing* work". Hence, the streamlining in the design phase reflected the introduction of Lean engineering that aligns with the principles of integrated project delivery (IPD; (Boudouh and Gomes, 2017). IPD emphasises implementing project management collaboratively and in an integrated approach with people, systems, business structures, and practices (Khanna et al., 2021). As echoed by interviewees, the proposed planning and control system's role in reducing the design effort indicated a more integrated and collaborative approach in the design stage, aligning with IPD principles of enhancing efficiency through collaboration and the early involvement of key stakeholders.

4.3.1.3.1.5 Subtheme 1-4: Efficient Procurement and Material Delivery

The procurement phase was also streamlined by aligning the material delivery schedule with project timelines as shared by key stakeholders, including Project Engineers and the Procurement Manager. The Procurement Manager stated, "*From a procurement perspective, we've noticed an improvement in meeting our material delivery deadlines".* Similarly, the Project Engineer commented, "*From a procurement standpoint, a 40% improvement in meeting material delivery deadlines"*. These enhancements in the procurement process underscored the system's effectiveness in reducing lead times and mitigating missed orders, which was the eventual aim of this research.

However, some participants highlighted challenges. A Project Engineer highlighted an instance where "*a client made a last-minute request for features that required us to revise the plan. The system helped us quickly reassess the project timeline and allocate resources accordingly but still resulted in a one-week delay*". While this instance highlighted the system's agility in adapting to changes, it also revealed the inherent challenges in managing client expectations and external dependencies, an area of improvement to be considered in the refinement process of the proposed system in pursuit of Research Objective 4.

4.3.1.3.1.6 Subtheme 1-6: Efficient Manufacturing Stage

The manufacturing stage under the newly implemented integrated planning and control system at AL DAR demonstrated remarkable improvements, particularly in reducing production delays and enhancing workflow consistency due mainly to newly incorporated features in the new system related to the Lookahead and constraint removal in the meetings. This efficiency was crucial to achieving the research objectives, notably enhancing operational efficiency and mitigating missed order due dates at AL DAR and the ETO environment.

A key feature of this efficiency was the significant reduction in manufacturing delays. One participant noted, "*Regarding manufacturing, we have observed a 40% to 30% decrease in delays due to upfront planning and coordination and mainly due to Lookahead and constraints removal process*". This improvement was attributed to effective planning and coordination facilitated by the system, which enabled the completion of a manufacturing phase two days earlier than planned in one instance, as indicated by the Factory Manager.

Moreover, the new system led to a more consistent flow of work in the manufacturing phase, as one of the interviewees observed, "*In manufacturing, we* *have seen a more consistent flow of work*". This consistency is pivotal in the ETO environment, where each project has unique demands and timelines, so a steady workflow is crucial for meeting varying demands efficiently.

The integration of milestone schedules and real-time updates provided by the system has played a significant role in these improvements. As stated by a participant, "*The system's integration of milestone schedules and real-time updates has significantly reduced the challenges caused by last-minute design changes and material delays*". Consequently, this integration ensured that the manufacturing process was adaptable and responsive to changes, reducing delays and inefficiencies.

Records from the manufacturing department corroborated these improvements, showing a "*35% reduction in production delays*". Such data are vital in demonstrating the tangible impact of the system on the manufacturing process.

Moreover, the potential for further optimisation of the supply chain by expanding system integration to include partners like suppliers was highlighted, indicating room for continuous improvement as stated by the Project Engineer: "*From a manufacturing perspective, incorporating our systems has been highly beneficial. Moving forward, expanding this integration to include partners, like suppliers, could optimise our supply chain further*".

In summary, the efficiency in the manufacturing stage under the new system at AL DAR was marked by a significant decrease in production delays, a more consistent workflow, and improved adaptability to project demands. These advancements aligned with the goals of enhancing operational efficiency and reducing missed order due dates, which were the main issues at AL DAR and crucial for the ETO environment in general. The improvements observed were a testament to the new system's effectiveness and paved the way for future enhancements.

4.3.1.3.1.7 Subtheme 1-7: Efficient Logistic Stage

The efficient logistic stage, a subtheme under the new integrated planning and control system at AL DAR, significantly improved delivery scheduling, transportation organisation, and overall logistics management. These improvements aligned with the primary research objectives in mitigating missed due dates at AL DAR in the ETO environment.

A notable improvement observed in the logistics stage was the advanced planning capabilities provided by the new system. One participant reflected, *"In a project, we had planned the delivery schedules in advance, allowing us to efficiently organise transportation*". This proactive approach contrasted with previous reactive methods, where last-minute requests often dictated logistics. The participant continued, *"They used to react to last-minute requests, but with advanced planning, they can schedule deliveries more effectively"*. This shift from a reactive to a proactive approach in logistics planning was a significant step towards enhancing the efficiency of the logistics process that consequently reflected on the overall project timeline.

The new system's impact on transportation and logistics from a delivery standpoint was notably efficient. As stated by another interviewee, *"The improved planning has resulted in the handling of transportation and logistics from a delivery standpoint efficiently*". This efficiency is critical in the ETO context, where timely deliveries are essential for project success.

The system's advanced planning capability greatly improved delivery schedule, as highlighted by a participant: *"When it comes to logistics, the system's advanced planning capability has greatly improved our delivery scheduling*". Such improvements are pivotal in ensuring that the logistics phase aligns with the overall project timeline, thereby contributing to the on-time completion of projects.

The system's flexibility in logistics was particularly advantageous. As stated, *"Finally, from a logistics perspective, the flexibility of the system has played a role in improving our delivery schedules"*. Flexibility is essential in logistics in the dynamic ETO environment where requirements can rapidly change.

4.3.1.3.2 Theme 2: The New System has Overcome the Previous System's Limitations

4.3.1.3.2.1 Subtheme 2-1: The New System Was More Flexible Than the Previous System

The introduction of the new proposed planning and control system at AL DAR significantly enhanced the flexibility of project management, a transformative shift from the rigidity of the previous planning and control system that depended on stand-alone Excel sheets, schedules, and MRP. This improvement was clearly highlighted in the experiences project participants and department heads shared, as reflected in their interviews.

A recurring theme in the feedback was the system's ability to adapt to changing project needs and requirements. One participant noted, *"The new system has made improvements in terms of project customisation. The planning and control system is more adaptable to meet each project's needs. Project schedules and* *planning processes are adaptable, which was a concern with the previous system".* The new system's flexibility was crucial in handling project customisation and coordinating between different departments. One interviewee summarised, *"Thanks to the system, we were able to coordinate with both engineering and procurement teams to clarify the requirements during those weekly planning meetings. This helped us avoid prolonged back-and-forth communications and saved time*".

The enhanced flexibility also extended to the design phase, as mentioned in Theme 1. Participants identified that the new system provided the flexibility absent in the previous system, enabling the integration of design alterations more smoothly into project schedules and planning documents. This adaptability was crucial, as one participant explained,

From a design standpoint, the new system provides the flexibility that was absent in the previous system. It enables us to integrate design alterations into the project schedule. Previously, as we discussed, implementing design changes often necessitated starting over from the beginning, as the planning documents were static.

The new system's capability to quickly adapt to design changes and material availability significantly impacted the manufacturing process, addressing a key concern with the previous system, as stated by one participant: *"The customisation capabilities of the system have had a positive impact on the manufacturing process*".

From a logistics perspective, the new system's flexibility was crucial in improving delivery schedules mentioned in 4.3.1.3.1.7 section. This adaptability was particularly notable in handling ETO projects, as one participant highlighted, "*The system's flexibility in handling engineer-to-order projects has been a game changer*".

The shift to the new system significantly increased project management capabilities. It provided real-time updates and offered a degree of previously unattainable flexibility. As one participant clearly put it, *"Overall, I must say that the new system has brought improvements, in terms of project management. It has greatly enhanced coordination efforts and offered flexibility*".

This increased flexibility aligned well with the literature, where flexibility in project management systems is emphasised as crucial, especially in dynamic and complex project environments like ETO. The ability to adapt to changing requirements and conditions is a critical factor in successful project delivery and customer satisfaction (Jalali Sohi, Bosch-Rekveldt and Hertogh, 2020). By introducing this new system, AL DAR addressed a significant limitation of its previous system while aligning its operations with best practices and theoretical frameworks in modern project management, as justified in Section 4.2.3.1.

4.3.1.3.2.2 Subtheme 2-2: The New System Offers an Integrated Approach and Improved Integrity

Implementing the new planning and control system at AL DAR integrated departmental activities coherently, from design and procurement to manufacturing and logistics. This integrated approach streamlined processes and improved the overall integrity of operations, consequently mitigating the missed order due dates.

Participants across different departments consistently noted the system's effectiveness in integrating project aspects, significantly enhancing planning and execution processes. One representative statement was, "*The integrated approach of the new system you know has significantly enhanced our planning and execution process*", illustrating the system's comprehensive nature.

The system's capability to integrate crucial elements of project management was further emphasised in situations where external factors, such as supplier delays, posed challenges. For instance, one participant noted. *"We encountered a situation where a crucial supplier failed to deliver essential components on time. The system helped us mitigate some of the impacts by adjusting our schedule but couldn't prevent the delay totally*", highlighting the system's adaptability in the face of external unpredictability.

From a manufacturing perspective, the system brought predictability and reduced reactivity in workflows, as one interviewee stated: *"On the manufacturing front, the system has brought predictability and reduced reactivity in our workflow by using Lookahead planning and constraints removals in weekly planning meetings with all department"*. This enhancement was significant in handling client orders, making the process more streamlined and efficient as the Project Engineer stated, *"The system has made handling client orders more streamlined".*

An innovative integration included the "5 Whys" into the system, helping to identify the root causes of delays. The Factory Manager noted that this proactive problem-solving approach reduced instances where last-minute changes impacted schedules: "*We have found that integrating the '5 Whys' technique into our system has been helpful in identifying the root causes of delays. This proactive problem-solving approach has reduced instances where last-minute changes impact our* *schedule".*

Clients also noticed and appreciated these changes, particularly the increased transparency and predictability the new system offers. As stated by the Project Engineer, *"Clients have expressed feedback regarding these changes. They appreciate the increased transparency and predictability offered by the system*". This feedback underscored the system's effectiveness in enhancing client satisfaction and trust.

The integrity approach of this system also facilitated better coordination among different teams. As described by a participant, *"Thanks to the system, we were able to coordinate with both engineering and procurement teams to clarify the requirements during weekly planning meetings"*. This improved communication and coordination saved time and reduced unnecessary back-and-forth communications.

Furthermore, the system's integration facilitated a more streamlined approach to handling material availability, significantly enhancing the production process. As one participant mentioned, timely information on material availability *"has significantly streamlined our production process".*

4.3.1.3.2.3 Subtheme 2-3: The New System Enables Proactive and Lookahead Planning

Implementing the new planning and control system at AL DAR notably shifted the company's planning approach from reactive to proactive. This shift was crucial in improving project execution and management, thus mitigating the missed orders' due dates as aligned with the research aim.

The new system's impact on on-time deliveries was significant, as highlighted by the Logistic Manager: *"We have witnessed a 25% enhancement in on-time deliveries. The system's advanced planning capabilities have allowed them to adopt a proactive approach compared to their previous reactive practices*". This change was not just a procedural shift but reflected a deeper transformation in how the company anticipates and manages project timelines and resources.

Moreover, the effectiveness of the Lookahead schedule and weekly planning features of the new system were explicitly mentioned as fundamental tools in foreseeing potential delays and preparing accordingly. For instance, the Project Engineer stated, *"In a project, the Lookahead schedule alerted us to a delay in material delivery".* This level of foresight was likely impossible with the previous system, marking a significant advancement in planning and execution and proving effective, as also emphasised by another participant: *"The Lookahead schedule and weekly planning features have proven effective*".

The move towards proactive planning and the effectiveness of Lookahead schedules resonated with the principles highlighted in project management literature, particularly in LC and agile methodologies. These methodologies emphasise the importance of adaptive planning, which involves foresight and flexibility to accommodate changes and unforeseen challenges (Kapogiannis, Fernando and Alkhard, 2021). As revealed through these insights, the case of AL DAR mirrored these concepts, showcasing an evolution in its project management practices aligned with contemporary best practices in the field.

4.3.1.3.2.4 Subtheme 2-4: The New System Provides Real-Time Data and Updates

Implementing the new planning and control system at AL DAR provided real-time updates and information. This progress significantly enhanced project execution processes, timelines, and client communication.

The efficient handling of real-time data positively impacted the overall project timelines and execution processes, specifically procurement processes, as summarised by Engineer 4: *"The improved handling of real-time data has made an impact on procurement processes and overall project timelines".* With access to up-to-date information, the procurement team at AL DAR could make more informed and timely decisions, streamlining the entire project life cycle. The procurement process is essential to completing the design process (some design-related information input is needed from the supplier) and the manufacturing process. This enhancement facilitated the accuracy and relevance of the accessed data, playing a critical role in project management and execution.

Similarly, one participant stated that "*receiving accurate information from design and procurement teams has led to decreased delays by 40%"*. This statement underscored the effectiveness of real-time data in enhancing project efficiency. This improvement directly resulted from the enhanced coordination and communication between different teams and, more specifically, the weekly planning meeting facilitated by the new system's ability to provide current and accurate data.

The new system's real-time updates also improved communication with clients.

Engineer 2 noted, "*The level of transparency offered by our system, with real-time updates, has improved our communication with clients*". This transparency, represented by sharing the updated schedules with clients, builds trust and enables more effective and collaborative client interactions, thus resulting in further streamlining the project process.

This advancement in the new planning and control system's capability aligns with the research aim and contemporary project management practices emphasising the importance of timely and accurate information that results in having a realistic schedule, which is among the top four Critical Success Factors of project success as per the seminal empirical study of White and Fortune (2002).

4.3.1.3.2.5 Subtheme 2-5: The New System Improves Communication, Coordination, and Collaboration

Implementing the planning and control system at Al DAR positively impacted communication, coordination, and collaboration among different departments, significantly improving project management processes.

While the system has its strengths, client responsiveness and engagement challenges still need to be addressed. According to the Project Engineer, *"While the system aids our processes, it doesn't entirely resolve issues related to client engagement".* This statement indicated a continuing need to enhance the system's communication capabilities in situations where "*delays when awaiting client approvals or feedback*", as indicated by Engineer 2, are still being encountered.

Clients appreciated the new system's ability to increase transparency and predictability, as indicated by the Project Engineer: *"Clients have expressed* *feedback regarding these changes. They appreciate the increased transparency and predictability offered by the system*". This enhanced efficiency directly impacts project deadlines and client satisfaction.

From a design standpoint, the Engineering Manager pointed out, "*The centralised communication platform of the system has greatly improved our interactions*". This observation represented an advancement in communication and project management, bridging gaps between departments, as indicated by the Procurement Manager: "*The system has bridged gaps between their department and others in procurement*", thus facilitating a more cohesive approach to the planning and control of the project execution.

Moreover, in the manufacturing phase, the system's effectiveness was notable, as the Factory Manager summarised, "*From a manufacturing perspective, improved coordination has resulted in an efficient workflow".* This quote highlights how the system positively reduced downtime and increased productivity by enhancing coordination and communication.

4.3.1.3.3 Theme 3: The Proposed System Has Some Limitations

Despite the aforementioned improvements and enhancements, the new integrated planning and control system brought to AL DAR, the system also exhibited limitations, as expected. Accordingly, the researcher conducted two focus group interviews to explore them. Based on those interviews, shortcomings crucial for refining the proposed planning and control system were identified (Research Objective 4).

Accordingly, the forthcoming sections explore these limitations in detail in three main categories: 1) the proposed system lacks visual management, 2) the proposed system lacks buffer consideration and Critical Chain Project Management (CCPM), and 3) the proposed system lacks links between the Master and Lookahead plan. Examining these areas assisted in a comprehensive understanding of the current state of the new system (Research Objective 3) and offered insights into potential avenues for future enhancements (Research Objective 4).

4.3.1.3.3.1 Subtheme 3-1: The Proposed System Lacks Visual Management Capabilities

First, the new system lacked visual management capabilities. Hence, department heads and Project Engineers emphasised integrating more intuitive visual tools.

Engineering personnel represented by the Engineering Manager highlighted the need for visual tools or cues such as colour-coded progress bars or risk levels to assess the project status easily. For instance, the Engineering Manager suggested, *"It could benefit from some cues that help engineers quickly assess project statuses. For instance, using colours to indicate risk levels or progress bars would make it easier to understand the health of a project at a glance"*. In the same vein, Engineer 3 stated, "*It would be beneficial to have an indicator that displays the current status of the data".* When the Engineering Manager asked for specific visual cues or tools he expected, he suggested "*having a dashboard that gives us an overview of project timelines and resource allocations would greatly enhance our planning and decision-making process".*

Additionally, the engineering team highlighted the absence of a visual planning tool that could show the task relationships in a simple format crucial for identifying paths and potential bottlenecks in ETO projects. "*The engineering team could really use a planning tool that shows the relationships between tasks in a visual way. This tool would be helpful in identifying paths and potential bottlenecks for our complex and customized projects*", the Engineering Manager explained. Moreover, he emphasised having a dynamic response feature to reflect the real-time effects of changes: *"It would be beneficial if we had a dynamic response feature that includes visualisation tools showing real-time effects of changes".*

Furthermore, the Procurement Manager highlighted that the new proposed system lacked a visualisation of the supplier performance to streamline the operations and manage potential delays. "*Considering procurement involves suppliers and timelines, having an interactive supplier performance map within the system would be immensely valuable in managing our orders and anticipating potential delays*", the Procurement Manager explained. When asked about the benefits of such a visualisation, he noted the need of *"having a representation showing the progress of each supplier's deliveries would greatly streamline our operations".*

Overall, while the new proposed system brought significant improvements, integrating robust visual management tools would add value to the proposed planning and control system to enhance the planning process, as indicated in the focus groups. Brady et al. (2018) emphasised that visualisation facilitates information flow and improves transparency between the interfaces of planning, execution and control. Thus, it leads to a more timely reaction to problems. Similarly, Biazzo, Fabris and Panizzolo (2020) argued that vitalisation facilitates the communication and efficient execution of projects.

4.3.1.3.3.2 Subtheme 3-2: The Proposed System Lacks Buffer Consideration/Critical Chain Project Management (CCPM)

The proposed system fell short of its consideration of buffer management, a key component of Critical Chain Project Management (CCPM). The department manager and Project Engineers consistently highlighted this gap.

This concept of buffer allocation was frequently mentioned by participants as an area of improvement. One engineer noted, *"If the system could provide us with some flexibility to allocate 'extra time' for stages, it would help us better manage these delays without impacting the project deadline*". Hence, the engineer sought breathing space to reduce team pressure, especially during unexpected issues.

Moreover, the feedback highlighted a need for an integrated approach to adjust procurement plans and manufacturing schedules, considering project buffers: *"Specifically, enhancing its ability to adjust manufacturing schedules in real-time while considering the project buffer would be a significant step forward",* a manufacturing supervisor mentioned. This adjustment would be necessary for more resilient and robust supply chain management.

A notable issue was the manual calculation and tracking of buffer times, which was found to be burdensome: "*Our system doesn't provide support for buffer management within our project timelines. During the manufacturing phase, we had to calculate and keep track of buffer times manually, which proved to be quite burdensome*", a Factory Manager commented. Automating buffer management would significantly streamline project timelines and risk management.

An automated buffer management feature with indicators was suggested as an improvement: "*Having an automated buffer management feature with indicators would be an improvement as it provides us with a clear understanding of where we have flexibility in our schedules*", noted a project coordinator. This feature would allow clearer visualisation of buffer utilisation and availability, aiding in more effective project management.

The consistent argument by the department manager and Project Engineers that incorporating a buffer management system into the planning and control system would assist in managing delays and minimising the impact on the project deadline was supported by Zohrehvandi (2022). He argued that using buffer management in project planning and control is derived from the CCPM method, aiming to reduce the project execution time while making it more realistic. Similarly, Jo, Lee, and Pyo (2018) argued that implementing buffer management improved material and procurement management, thus avoiding material shortages and minimising delays.

In summary, while the new system at AL DAR improved many aspects of project management, incorporating buffer consideration and CCPM elements would significantly enhance its effectiveness, as supported by the literature (Jo, Lee and Pyo, 2018; Zohrehvandi, 2022) and recommended by AL DAR staff. By integrating buffer management, AL DAR could better reduce the project execution time and minimise delays, thus mitigating the missed orders' due dates.

4.3.1.3.3.3 Subtheme 3-3: The Proposed System Lacks Links Between the Master and Lookahead Plans

The third notable limitation of AL DAR's current integrated project planning and control system is that it lacks the link between the Master and Lookahead plans.

Participants frequently cited this disconnect as a source of scheduling conflict and an area for refining the current planning and control system.

Department heads and engineers experienced challenges in aligning the Master and Lookahead plans, noting instances where changes made were not immediately reflected: *"We sometimes face challenges with aligning the Master plan and Lookahead plan. There are instances where changes made in one plan aren't immediately reflected in the other, causing scheduling conflicts*", a Factory Manager noted. This lack of synchrony led to discrepancies in scheduling and project execution.

The need for tighter integration of these plans was emphasised, particularly in manufacturing, where the ability to anticipate and quickly adapt to changes is crucial: "*Being able to anticipate and quickly adapt to changes is crucial in manufacturing, and tighter integration of these plans would facilitate that*", remarked the Factory Manager. The current system's inability to dynamically link these plans impedes the smooth flow of project activities.

Similarly, the Engineering Manager desired a more connected system where changes in the Master plan are immediately reflected in Lookahead schedules: "*It would be ideal if this tool is connected to the project's Master plan so that any changes made there are immediately reflected in our Lookahead schedules*". Such real-time updates are crucial for maintaining a consistent and accurate project timeline.

Synchronising the scheduling component from high to low level with the system was not as smooth as anticipated. During one project, a lack of easy alignment between the system and another planning tool led to scheduling issues, highlighting the need for improved integration: “To resolve this, it would be beneficial to establish a direct connection or integration between the Master planning system and the scheduling tools we use, such as the Lookahead”, a Project Engineer recommended.

This lack of an integrated system in planning and control systems such as the LPS has been argued by Dave et al.; Aslam, Gao, and Smith; and Dave et al. (2015; 2020). They argued that implementing the LPS overlooked many areas, emphasising missing links between the high-level and detailed plans in the LPS. Hence, they suggested identifying the information flow between all plan levels. In contrast, Mohamed et al. (2021) argued that integrating Lookahead planning and Master scheduling is critical for successful project delivery, supporting the research participant.

In conclusion, the aforementioned feedback from the department heads and Project Engineers noted the limitation of AL DAR’s current integrated project planning and control system’s lack of linking between the Master and Lookahead plans. Similarly, scholars have highlighted this shortcoming in other planning and control systems and called for bridging this gap. Addressing this gap is essential for AL DAR to manage its projects efficiently, especially during rapid change, thus mitigating the missed orders’ due dates.

4.3.2 Planning Action

In Action Research Cycle 3, the focus shifted to implementation strategies and the steps taken to address the challenges and limitations identified in the newly integrated project planning and control system. This phase was crucial in the Action Research process because it involved applying solutions and adjustments based on the insights gathered from the previous stages.

The main objective in this phase was to enhance the new system's effectiveness, particularly by addressing its three identified shortcomings. The planning action involved a multifaceted approach, considering the feedback from various departments and stakeholders within the company. Key areas of focus included the following.

4.3.2.1 The Proposed Planning and Control System Should Consider Linking the Master and Lookahead Plans to Enhance its Integrity

A primary goal was to improve the integration between the Master and Lookahead plans. Hence, the Lookahead plan should include fields that relate it to the Master schedule so that staff can indicate the planned date per the Master schedule.

4.3.2.2 The Proposed Planning and Control System Should Consider Using Visual Management Tools

Given the feedback on the lack of visual management in the system, the company planned to introduce more intuitive and interactive visual tools, including dashboards for project timelines, visualisation, and progress layouts, enhancing the overall user experience and decision-making process.

4.3.2.3 The Proposed Planning and Control System Should Consider Using Buffer Management and CCPM Implementation

The company recognised the need to incorporate buffer management and Critical Chain Project Management (CCPM) principles into the system, allowing extra time allocations in project stages while developing detailed and Master schedules.

4.3.3 Implementing the Planned Action

The abovementioned planned actions were reflected in the proposed system and communicated with AL DAR staff for further implementation of the refinement version. Below is the refined system.

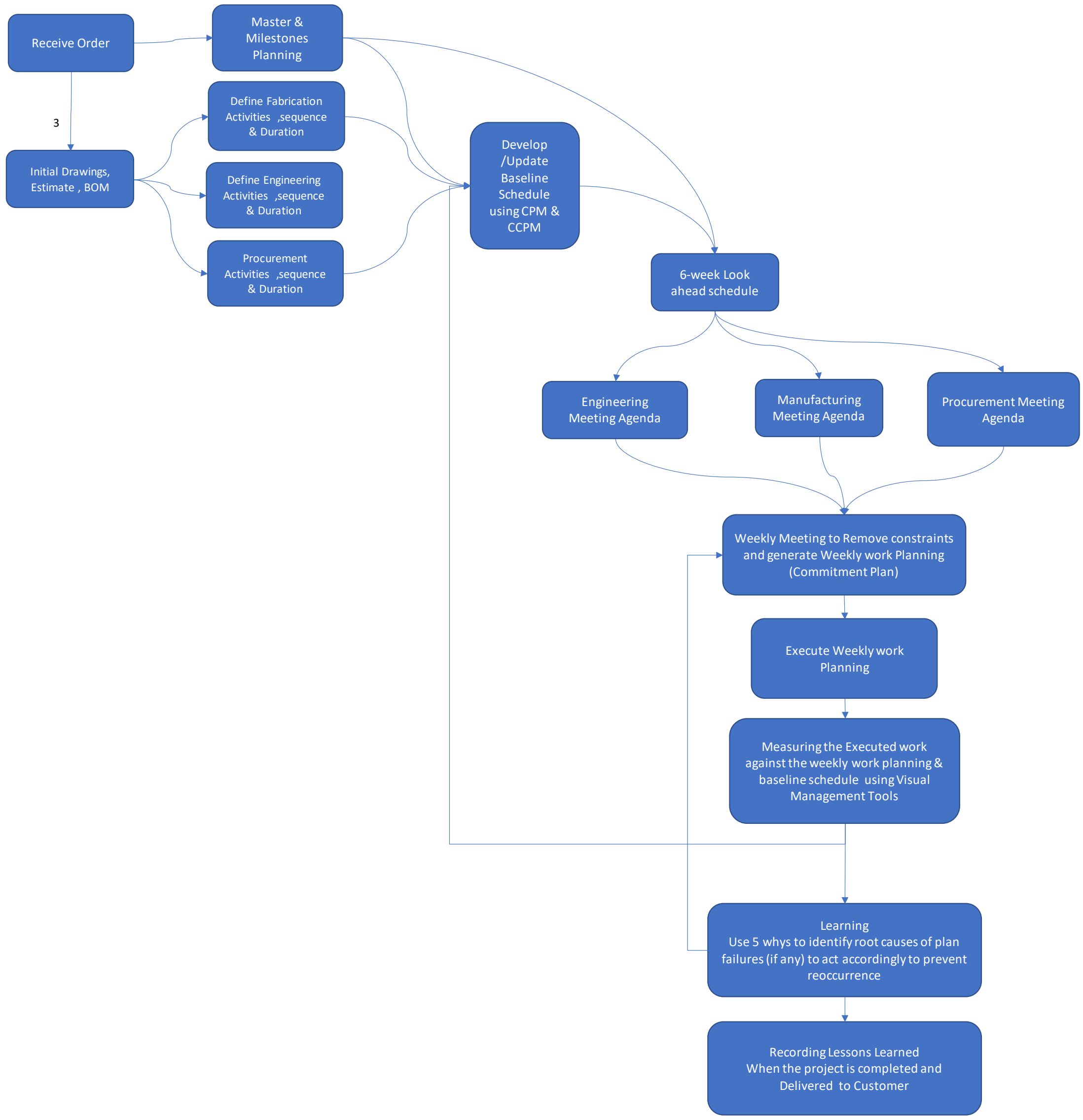

Figure 4-7: Final Integrated Planning and Control Model

As shown in Figure 4-7, the link between the Lookahead and Master plans was implemented. Buffer management (i.e. CCPM) was introduced while developing the schedule and visual management tools to be utilised while reporting the progress.

4.3.4 Evaluating the Effectiveness of the Implemented Action

In the "Evaluating the Effectiveness of the Implemented Action" stage of AL DAR's Action Research Cycle 3, the effectiveness of the updated project planning and control system was assessed against theoretical frameworks and relevant literature. This evaluation sought to understand how well the system's enhancements addressed the previously identified limitations and contributed to project management efficiency.

A key focus was incorporating buffer management into the planning and control system. This approach was supported by consistent feedback from department managers and Project Engineers, who noted its effectiveness in managing delays and minimising impacts on project deadlines. This perspective aligned with Zohrehvandi (2022), who emphasised the critical role of buffer management, derived from the CCPM method, in reducing project execution time and enhancing realism. Jo, Lee, and Pyo (2018) also supported this viewpoint, highlighting material and procurement management improvements through buffer management, helping to avoid shortages and minimise delays.

Another aspect evaluated was the integration of the system. The feedback indicated a need for better alignment between the Master and Lookahead plans, a gap identified in the literature. Dave et al. and Aslam, Gao, and Smith (2015; 2020) critiqued the LPS for overlooking critical areas, specifically the missing links between high-level and detailed plans. In contrast, Mohamed et al. (2021) underscored the importance of integrating Lookahead planning and Master scheduling as essential for successful project delivery, echoing the sentiments of research participants.

The third area of evaluation focused on visual management tools. The research participants suggested that robust visual management tools would significantly enhance the planning process. This perspective was supported by Brady et al. (2018), who argued that visualisation facilitates information flow and improves transparency across planning, execution, and control interfaces, leading to timelier problem resolution. Biazzo, Fabris, and Panizzolo (2020) further contended that visualisation aids communication and efficient project execution.

4.3.5 Specifying the Learning Stage and the General Findings Through Reflection

The learnings from this Cycle addressed specific challenges at AL DAR. They contributed to a broader understanding of planning and control, particularly in ETO environments. The Cycle underscored the dynamic nature of ETO systems, where continuous learning and adaptation are crucial for addressing evolving challenges and enhancing overall efficiency.

In this final Action Research Cycle, these insights laid the foundation for further testing, exploration, and refinement in other research, aligning practical needs and theoretical advancements in operation management.

4.4 Evaluation of This Action Research's Quality

Although Action Research has been recognised for its relevance in the real world (Baskerville and Wood-Harper, 1996; Bradbury, 2015), concerns have been expressed regarding its level of rigour (Cohen, Manion and Morrison, 2018). In response, scholars have articulated principles and guidelines for conducting rigorous scientific Action Research (Melrose, 2001; Davison, Martinsons and Kock, 2004). Therefore, this Action Research adhered to the five principles articulated in the seminal study of Davison, Martinsons, and Kock (2004) to maximise the rigour and relevance. Additionally, they proposed a set of criteria for each principle to ensure its effective application. The application of these principles and criteria was evaluated in the table below, providing evidence for their effective implementation. These principles and criteria are illustrated in Section 3.5.

Table 4-11: Evaluation of this Action Research's Quality

Principle	Criteria	Response & Evidence from the Research
Research-Client Agreement (RCA)	Did the researcher and the client agree that Action Research was appropriate for the organisational situation?	Yes, it was confirmed by the researcher-client agreement/project charter signed by the researcher and the organisation's CEO (Section 4.1.4.1). The continuation into the second and third Cycles and addressing issues based on previous findings supported this agreement (Sections 4.2 & 4.3)
	Was the focus of the research project specified clearly and explicitly?	The focus defined in the project charter was confirmed by exploring the challenges and limitations of the current planning and control system to improve project delivery (Section 4.2.1.1).
	Did the client make an explicit commitment to the project?	Yes. The allocations of resources like Primavera P6 and personnel for collaboration were evidence, as stated by the CEO and deputy CEO (Section 4.1.5). The commitment was also inferred from the request for the researcher to propose a new system to be reflected in the company's procedure (Section 4.2.2.1).
	Were the roles and responsibilities of the researcher and client organisation members specified explicitly?	Yes. They were outlined in the researcher-client agreement/project charter (Section 4.1.4.1).
	Were project objectives and evaluation measures specified explicitly?	Project objectives and evaluation measures were specified. Objectives and measures such as project schedule variance are explicitly mentioned (Sections 4.1.4.1 & 4.1.2.3.3). Additionally, identifying Critical Success Factors and aligning with system components implied clear objectives ().

Principle	Criteria	Response & Evidence from the Research
	Were the data collection and analysis methods specified explicitly?	Yes, they were confirmed by the researcher-client agreement/project charter signed by the researcher and the organisation's CEO (Section 4.1.4.1).
Cyclical Process Model (CPM)	Did the project follow the CPM or justify any deviation from it?	The research followed the CPM as illustrated in the Action Research Framework (Section 3.5) outlined in Figure 3-2. Three Action Research Cycles were conducted (Sections 4.1, 4.2, & 4.3).
	Did the researcher conduct an independent diagnosis of the organisational situation?	Yes, it was conducted through multiple focus groups and interviews across different organisational levels in Cycle 1 (Section 4.1.2.1). Then, the diagnosis continued in more depth in Cycles 2 and 3 via focus groups (Sections 4.2.1.1 & **Error! Reference source not found.**).
	Were the planned actions explicitly based on the results of the diagnosis?	Yes, this process was shown in developing SIPOC diagrams and Process Maps based on the initial findings (Section 4.1.3). Actions such as proposing an integrated planning and control system were based on diagnosis (Section 4.2.2.1). Then, in Cycle 3, planning actions were aimed at system refinement, including visual management and buffer considerations (Section 4.3.2).
	Were the planned actions implemented and evaluated?	The SIPOC diagrams and the Cause-and-Effect Matrix were implemented with subsequent evaluation (Sections 4.1.4 & 4.1.5). Then, in Cycle 2, planning actions such as proposing an integrated planning and control system were based on diagnosis (Section 4.2.2.1). In Cycle 2, the proposed planning and control system was implemented based on the findings (Sections 4.2.3.1 & 4.2.4).
	Did the researcher reflect on the outcomes of the intervention?	The research reflected on the strengths and weaknesses of the SIPOC diagram and its alignment with institutional pressures (Section 4.1.6).
	Was this reflection followed by an explicit decision on whether to proceed through an additional process Cycle?	Moving forward was determined by evaluating actions and reflections, which then informed the subsequent Cycle (Sections 4.1.6, 4.2.5, & 4.3.5).
	Were the researcher's exit and the project's conclusion based on the project objectives being met or some other clearly	Yes, the exit was based on the project objectives being met, as justified in the conclusion chapter (Section 5.2.1).

Principle	Criteria	Response & Evidence from the Research
	articulated justification?	
Principle of Theory	Were the project activities guided by a theory or set of theories?	Institutional Theory guided understanding the organisational dynamics and pressures (Sections 4.1.2.3.1 & 4.1.2.3.4). Then, in Cycle 2, the proposed system was informed by LC and traditional project management theories (&). The implementation and refinement were guided by project management theories, including visual management and CCPM (Section 4.3.4).
	Were the domain of investigation and the specific problem setting relevant and significant to the interests of the researcher's community of peers and the client?	Yes. They were justified in the (Section 1.5)
	Was a theoretically based model used to derive the causes of the observed problem?	Yes, it was justified in Planning for Developing the Cause-and-Effect Matrix (Section 4.1.3.3). Moreover, Institutional Theory explained the observed inefficiencies and the need for system improvements (Sections 4.1.2.3.1 & 4.1.2.3.4).
	Did the planned intervention follow from this theoretically based model?	The new system integrated theoretical insights and addressed identified problems (Section 4.2.3.1). Then, the implementation and refinement were guided by project management theories, including visual management and CCPM (Section 4.3.4).
	Was the guiding theory, or any other theory, used to evaluate the outcomes of the intervention?	The evaluation of SIPOC effectiveness incorporated Institutional Theory to assess the influence of external and internal pressures (Section 4.1.5). Additionally, in Cycle 2, theory informed the evaluation of the proposed system's effectiveness ().
Change through Action	Were both the researcher and client motivated to improve the situation?	Yes. Both were demonstrated by the client's commitment to providing resources and personnel (Section 4.1.5). Then, in Cycle 2, The company's request for a new system indicates motivation for change (Section 4.2.2.1). Then, in Cycle 3, the focus on system improvement indicated a drive for change (Section 4.3).
	Were the problem and its hypothesised cause(s) specified due to the diagnosis?	A detailed analysis of ETO process inefficiencies, current project delays, and the need for planning and control improvements provided the evidence (Sections 4.1.2.3.2, 4.1.2.3.3, & 4.1.2.3.4). Moreover, the new system's limitations suggested a clear understanding of problems and causes (Section 4.3.1.3.3).

Principle	Criteria	Response & Evidence from the Research
	Were the planned actions designed to address the hypothesised cause(s)?	The proposed system was designed to tackle the specific issues identified (Section 4.2.3.1). Then, the planning action phase was directed at overcoming the identified limitations of the proposed system (Section 4.3.2).
	Did the client approve the planned actions before they were implemented?	The system was circulated to all departments, implying approval (Section 4.2.3.1). In Cycle 3, it was also implied through participation in the evaluation and refinement process (Section 4.3.4)
	Was the organisation's situation assessed comprehensively both before and after the intervention?	The assessment used qualitative and quantitative analysis for schedule variance KPI to measure the missed order due dates pre-implementation (Section 4.1.2.3.3). Then, in Cycle 3, the system was assessed after implementation (Sections 4.3.1.3.1 & 4.3.1.3.2)
	Were the timing and nature of the actions clearly applied and completely documented?	Detailed recordings of the interviews, focus groups, and the development of tools like SIPOC and Process Maps showed the application and documentation (Sections 4.1.4.1 & 4.1.4.2). In Cycle 2, The process and components of the proposed system were thoroughly documented. In general, the actions taken were well-documented and aligned with the feedback from staff, as narrated in the thesis.
Learning through Reflection	Did the researcher provide progress reports to the client and organisational members?	Yes. Weekly and monthly reports were sent to the client as a part of the researcher's role in the organisation. Generally, the research process was clearly outlined and communicated with AL DAR.
	Did the researcher and the client reflect upon the project's outcomes?	Yes. This reflection was demonstrated in the evaluation and learning stages of each and through the collaborative approach in evaluating and refining the system (Sections 4.3.4, 4.1.6, 4.2.5, & 4.3.5)
	Were the research activities and outcomes reported clearly and completely?	The activities and outcomes were provided through extensive narrative and analysis of each stage (Sections 4.1, 4.2, & 4.3)
	Were the results considered in terms of implications for further action in this situation?	The reflections and findings informed the next steps and future Cycles (Sections 4.1.6, 4.2.5, & 4.3.5)
	Were the results considered in terms of implications for action to be taken in related research domains?	The potential applicability of findings to broader ETO contexts was suggested (Sections 4.1.2.3.4 & 4.2.3.1).

Principle	Criteria	Response & Evidence from the Research
	Were the results considered in terms of implications for the research community (general knowledge, informing/re-informing theory)?	The research addressed the pressing issue of missed order due dates in the ETO environment at AL DAR, leading to improved project performance, customer satisfaction, and profitability. In addition, the integrated planning and control system proposed through this research can serve as a practical framework for other ETO companies facing similar challenges (Section 5.3.2).
	Were the results considered in terms of the general applicability of CAR?	The research addressed the pressing issue of missed order due dates in the ETO environment at AL DAR company, leading to improved project performance, customer satisfaction, and profitability. In addition, the integrated planning and control system proposed through this research can serve as a practical framework for other ETO companies facing similar challenges (Section 5.3.2).

4.5 Evolution of Planning and Control Models

This section documents the iterative development and refinement of the planning and control models introduced in this research. Each model underwent several revisions based on feedback, empirical data, and theoretical insights, enhancing their alignment with the operational realities of AL DAR Company.

4.5.1 Journey of Figure 2-3: Initial Proposed Integrated Planning and Control Model

The Initial Proposed Integrated Planning and Control Model shown in Figure 2-3 was designed to systematically address the dynamic nature of Engineer-to-Order (ETO) projects considering the theoretical insights. This model, as depicted in the Figure 2-3 flowchart, strategically depicts the planning and control process from order receipt to product delivery, ensuring each phase aligns with rigorous project management protocols.

Upon receiving an order, the process begins by generating the basic design drawings, estimates, and a bill of materials (BOM), which contribute as the main inputs for defining the project activities and developing the master and milestone schedules. Master and milestone schedules are developed by adopting the pull planning concept originating from Lean thinking theory. Unlike the traditional push planning methodology, pull planning emphasises collaboration. It employs a backward calculation from the contractual project completion date to determine the completion dates for primary tasks and milestones.

Master schedule development was borrowed from the Last Planner System (LPS), which is one of the most popular Lean planning systems found in literature and claimed to be successful by some scholars (Ballard and Howell, 1998; Macomber and Howell, 2003; Emblemsvåg, 2014)

The subsequent step in the proposed planning and control system defines the tasks involved, such as fabrication, engineering, and procurement, with their durations and sequences. This comprehensive task definition ensures the project's flow and integrity. To facilitate this process, we employed the WBS principle recommended by the Project Management Institute (2017), which allows for a breakdown of the project into its components to ensure a comprehensive coverage of all project activities. The importance of this attribute was highlighted by Adrodegari et al. (2015) and Little et al. (2000) who argued that the ETO sector often struggles with disjointed, unintegrated planning, focused mainly on detailed production plans, neglecting other activities related to engineering and procurement.

Developing and updating the baseline schedule using the Critical Path Method (CPM) and Rolling Wave Planning as traditional project management elements is essential for success (Van de Vonder et al., 2005). The Critical Path Method (CPM) as a scheduling technique is instrumental in mapping out the sequence and duration of all project activities. Additionally, having a weekly update of the schedule emphasizes the agility aspect of the system.

A pivotal feature of this model is the 6-week look-ahead schedule. This 6-week lookahead acts as a short-term planning tool that helps the project team anticipate upcoming tasks and prepare accordingly so that the responsiveness and agility of the project management approach can be enhanced (Ballard, 2000).

Execution, monitoring, and control of the planned work processes are introduced to enable the project team to maintain tight control over the project's progress. By continuously measuring the executed work against the baseline schedule, the model allows for real-time adjustments and interventions to ensure that the project remains on track and aligned with the contractual obligations.

4.5.2 Journey of Figure 4-5: Modified Integrated Planning and Control Model

Building on the Initial Proposed Integrated Planning and Control Model shown in Figure 2-3 discussed in the previous section, the Modified Integrated Planning and Control Model presented in Figure 4-5 introduces key enhancements that further optimize the management of Engineer-to-Order (ETO) projects at AL DAR Company. These enhancements were primarily driven by insights from focus group discussions and identified gaps in the existing planning and control systems.

The first enhancement introduced in the modified version is related to conducting weekly meetings to identify and eliminate constraints, ensuring a smooth workflow for the 6-week look ahead plan. This was a response to the practical insights explored during the focus groups related to the lack of conversation among the project team. The core idea behind these weekly meetings is borrowed from the LPS, a collaborative, commitment-based approach to project planning and control recognised for its effectiveness in promoting proactive management and enhancing project performance (Ballard, 2000). The foundational theory that explains this approach's success in those meetings is the Linguistic Action Theory. Based on this theory, Winograd and Flores (1986, cited in Koskela and Howell, 2002) argued that project activities are coordinated through the act of language by making and keeping commitments. Thus, actions are coordinated by people's commitments rather than by central control acting through commands, as in traditional management. Therefore, planning from the Linguistic Action perspective is a conversation that continues over the project's timeframe to get tasks completed (Macomber and Howell, 2003).

The second enhancement introduced in the modified version is related to the PPC (Percent Plan Complete) metric, a pivotal LPS element, which offers a simple, effective tool to calculate the percentage of planned tasks completed on time concerning the weekly plan. It provides a clear picture of how effectively plans are executed, promoting accountability and insight into areas of improvement. the calculation of the PPC metric will be followed by using "5 Whys" to identify the root causes of plan failures. This process promotes constant evolution and improvement based on real-world experiences as argued by Kerzner (2014). Additionally, it will promote continuous learning and improvement by recording the lessons learned as the last enhancement added to the modified model.

4.5.3 Journey of Figure 4-7: Final Integrated Planning and Control Model

Building on the previous iterations, the final integrated planning and control model integrates visual management tools to enhance the measurement of executed work, facilitating clearer and more effective project tracking. It adopts a hybrid approach using both CPM and Critical Chain Project Management (CCPM) for developing schedules, linking the master with lookahead schedules to provide a more comprehensive view of project timelines and resource allocation. This final version embodies the culmination of iterative refinements, showcasing a robust system that supports proactive management and continuous learning.

Overall, this section discussed the iterative development and refinement of the planning and control models introduced in this research from the initial model to the final one. A summary of the alignment of Critical Success Factors with new System Components and the respective underpinning theories have been captured in Table 4-4.

CHAPTER 5: CONCLUSION

5.1 Introduction

This research aimed to mitigate the pressing issue of missed order due dates in the ETO environment at AL DAR, a Saudi Arabian ETO manufacturer. Despite the common adoption of ETO approaches in several industries, a significant research gap existed regarding consensus on integrated planning and control systems designed for ETO manufacturing firms. Therefore, this research aimed to address this gap by evaluating the planning and control practices and investigating the impact of implementing a proposed integrated planning and control system on reducing missed order dates in an ETO environment at AL DAR and within the community of practice.

Additionally, this research sought to bridge the gap in the existing literature by offering an integrated planning and control approach tailored to ETO environments. This approach was expected to improve operational efficiency and customer satisfaction at AL DAR and contribute to the broader body of knowledge in OM, particularly in addressing the unique challenges of ETO manufacturing.

5.2 Summarisation of Key Findings Relation to the Objectives

5.2.1 Objective-Wise Summary of Findings

5.2.1.1 Objective 1: To Examine Theoretical Underpinnings and Shortcomings of the Existing Lean and Non-Lean Planning and Control System Used to Deliver ETO Projects in the ETO Environment at AL DAR Company

Objective 1 of this research aimed to critically examine the theoretical underpinnings and shortcomings of Lean and non-Lean planning and control systems, particularly in the context of ETO projects at AL DAR. This objective was achieved successfully by integrating the theoretical insights from the literature review with the practical findings gained through thematic analysis of individual interviews and focus group discussions in Action Research Cycles 1 and 2. This methodology provided a comprehensive understanding of both theoretical frameworks and practical applications.

The findings from AL DAR’s current system gave real-world evidence of the theoretical limitations of Lean and non-Lean planning and control systems previously identified in the literature. Key issues such as inflexibility, poor integration, and a tendency towards reactive planning were observed, as detailed in Theme 1 of Action Research Cycle 1.

The successful achievement of this objective underscored the need for a more adaptable and integrated planning and control approach in ETO environments, thus paving the way for mitigating the missed order due dates in the subsequent Action Research Cycles, which was the eventual aim of this research.

Achieving this objective contributed significantly to theory and practice. Theoretically, it challenged and expanded the existing understanding of planning and control systems in ETO contexts, advocating for a hybrid approach combining Lean and non-Lean elements. Practically, the insights from AL DAR's experiences provided a real-world verification of these theoretical gaps, offering a grounded perspective on the need for more flexible and integrated planning and control systems. This perspective informed future Action Research Cycles at AL DAR and offered a blueprint for other ETO firms grappling with similar challenges.

5.2.1.2 Objective 2: To Explore the Critical Success Factors to be Incorporated into a Proposed Planning and Control System to Ensure its Effective Implementation

Objective 2 of this research focused on identifying the Critical Success Factors necessary for effectively implementing a planning and control system in the ETO environment at AL DAR. This vital objective and the findings from Research Objective 1 provided a roadmap for developing an integrated planning and control system. This system was designed to effectively mitigate missed order due dates, aligning with the ultimate aim of this research.

This objective was successfully achieved by synthesising theoretical perspectives from extensive literature reviews and practical insights derived from AL DAR's current practices as explored via thematic analysis of focus group discussions in Action Research Cycle 2. The research identified ten CSFs to be incorporated into the planning and control system 10: 1) flexibility, 2) integration across departments, 3) proactive and forward-looking approaches, 4) real-time data and updates, and 5) robust communication and coordination mechanisms. Additional factors such as a 6) user-friendly interface, 7) continuous monitoring and control, 8) a commitment to continuous improvement, 9) stakeholder involvement and commitment, and 10) comprehensive training and support were also identified as crucial.

The proposed integrated planning and control system for AL DAR, initially outlined in Action Research Cycle 2 (as shown in Figure 4-5) and later fine-tuned (as shown in Figure 4-7), was designed to address these factors. The system begins with the order receipt and concludes with project delivery, encompassing various stages like developing Master and milestone schedules using pull planning theory (Lean), defining engineering, procurement, and manufacturing activities with their durations and sequences using WBS principles (non-Lean), and updating the baseline schedule using the CPM (non-Lean) and Rolling Wave Planning (non-Lean). The system also includes a six-week Lookahead schedule (Lean), conducting weekly meetings for constraint removal and weekly work planning (Lean), measuring executed work against plans using EVM and PPC (Lean), and employing the “5 Whys” for continuous learning and improvement (Lean). These components were summarised in Table 4-6.

Achieving this objective had significant implications. Theoretically, it contributed to knowledge by providing the CSF for a planning and control system to serve as a checklist. Moreover, it challenged and extended the existing understanding of planning and control systems by introducing a hybrid approach tailored to the ETO context. Practically, it provided AL DAR with a robust framework to mitigate missed order due dates and enhanced planning and control practices. More broadly, it offered other ETO firms a blueprint for addressing similar challenges, thus extending its practical utility beyond a single case study.

5.2.1.3 Objective 3: To Explore the Effect of the Proposed Integrated Project Planning and Control System on the On-Time Delivery of Projects

Research Objective 3 focused on exploring the effect of the proposed integrated project planning and control system that incorporated the CSFs (from Research Objective 2) on the on-time delivery of the projects in the ETO environment, particularly at AL DAR. This objective was vital to validate the theories, CSFs, and frameworks to develop the new system.

This objective was successfully achieved by adopting semi-structured focus group interviews and statistical analysis. Interviews were conducted with relevant stakeholders at AL DAR, including Project Managers, engineers, and other team members involved in implementing the proposed integrated project planning and control system. These interviews aimed to gather qualitative data on workflows and operational performance after implementing the system. The collected data were then analysed to determine the factors influencing the project lead time and assess the system's efficacy. Challenges faced during the implementation process were also identified, providing insights for improving Critical Success Factors.

Additionally, statistical analysis of project performance was conducted for 29 projects completed after implementing the new system to measure project schedule variances and compare them to the measurement before the new system implementation. Both qualitative observations and statistical analyses led to a positive outcome, demonstrating significant progress in implementing the new system. " In Action Research Cycle 3 marked a pivotal shift in AL DAR's project management approach. Implementing the integrated project planning and control system at AL DAR significantly enhanced project delivery efficiency, as evidenced by the qualitative and quantitative data. Focus group discussions revealed operational improvements, including a 25% to 35% reduction in project lead times. Descriptive and inferential analyses were conducted on key performance indicators like the schedule variance %, confirming the system's effectiveness in reducing missed order due dates from 94.1% to 65.5%, showing a 30% improvement. The inferential analyses included hypothesis testing, the Chi-Square test of independence, continuity correction, Likelihood Ratio and Fisher's Exact tests followed by Cramer's V strength statistic test. These tests supported the rejection of the null hypothesis, indicating a moderate and statistically significant association between the implementation of the new system and the improvement in order fulfilment accuracy. Thus, the analysis substantiated the efficacy of the system changes in mitigating the missed order due dates, marking a significant contribution to operational management in the ETO environment.

The achievement of Research Objective 3 contributed significantly to theory and practice. Theoretically, it provided a practical example of how integrated planning and control systems, combining Lean and non-Lean elements, could effectively address the unique challenges of ETO environments. Practically, the new integrated project planning and control system at AL DAR successfully demonstrated its impact on mitigating the missed order due dates, fulfilling the research aim and setting a precedent for further system fine-tuning and future enhancements in ETO planning and control practices.

5.2.1.4 Objective 4: Refine the Proposed Planning and Control System Based on the Outcomes of the Implementation

Research Objective 4 focused on refining the proposed planning and control system based on the outcomes of its implementation for further alignment with the dynamic requirements of ETO projects. This objective was pivotal to ensuring that the system was theoretically sound, practically robust, and adaptable to the evolving demands of ETO projects. By incorporating user feedback and practical insights into the refinement process, the research ensured that the system's evolution was grounded in real-world needs and experiences, thereby enhancing its relevance and effectiveness in the ETO context.

The practical findings of the focus group discussion, as mentioned in Action Research Cycle 3, highlighted specific limitations of the newly implemented system. These included the lack of visual management capabilities, insufficient buffer consideration, and a disconnect between the Master and Lookahead plans. These insights were crucial in identifying the precise areas where the system could be refined.

Based on these identified shortcomings, Action Research Cycle 3's planning involved a multifaceted approach to translating practical insights with a theoretical basis into actionable improvements in the system. The first actionable improvement was the integration of the Master and Lookahead plans. The second improvement was the incorporation of visual management tools. The last was the implementation of the buffer management. These enhancements incorporated into the proposed system were responsive to the identified needs and challenges and aligned with the latest theoretical insights.

The achievement of Research Objective 4 contributed significantly to theory and practice. Theoretically, it highlighted the importance of flexibility and adaptability in planning and control systems, especially in dynamic ETO environments. The research's approach to system refinement also demonstrated a valuable methodology for others in the field, showing how theory and practice can inform each other in a cyclical improvement process. By effectively addressing the identified limitations, AL DAR could expect to see more mitigation in the missed order due dates, which was the eventual aim of this research.

5.2.2 Interlinking the Findings and the Overall Research Aim

This research aimed to **evaluate the current planning and control practices and explore the effect of proposing an integrated planning and control system on mitigating missed order due dates in the ETO environment at AL DAR Company and the community of practice.**

The main research question was as follows:

What is the evaluation of the current planning and control practices, and what is the effect of proposing an integrated planning and control system on mitigating missed order due dates in the ETO environment at AL DAR Company?

Collectively, the research objectives mentioned in the previous section and their corresponding findings directly addressed the main research question. Evaluating current practices (Research Objective 1) identified critical gaps in the planning and control system applied in the ETO context at AL DAR. Developing and implementing an integrated system (Research Objectives 2 and 3) demonstrated a tangible improvement in mitigating missed order due dates, a key issue in ETO environments. The continuous refinement of the system (Research Objective 4) further enhanced its effectiveness, indicating a progressive approach towards optimising planning and control practices in ETO settings.

5.2.3 Action Research Cycles Summary

Figure 5-1 below summarises the three Cycles of the Action Research including the five stages for each Cycle.

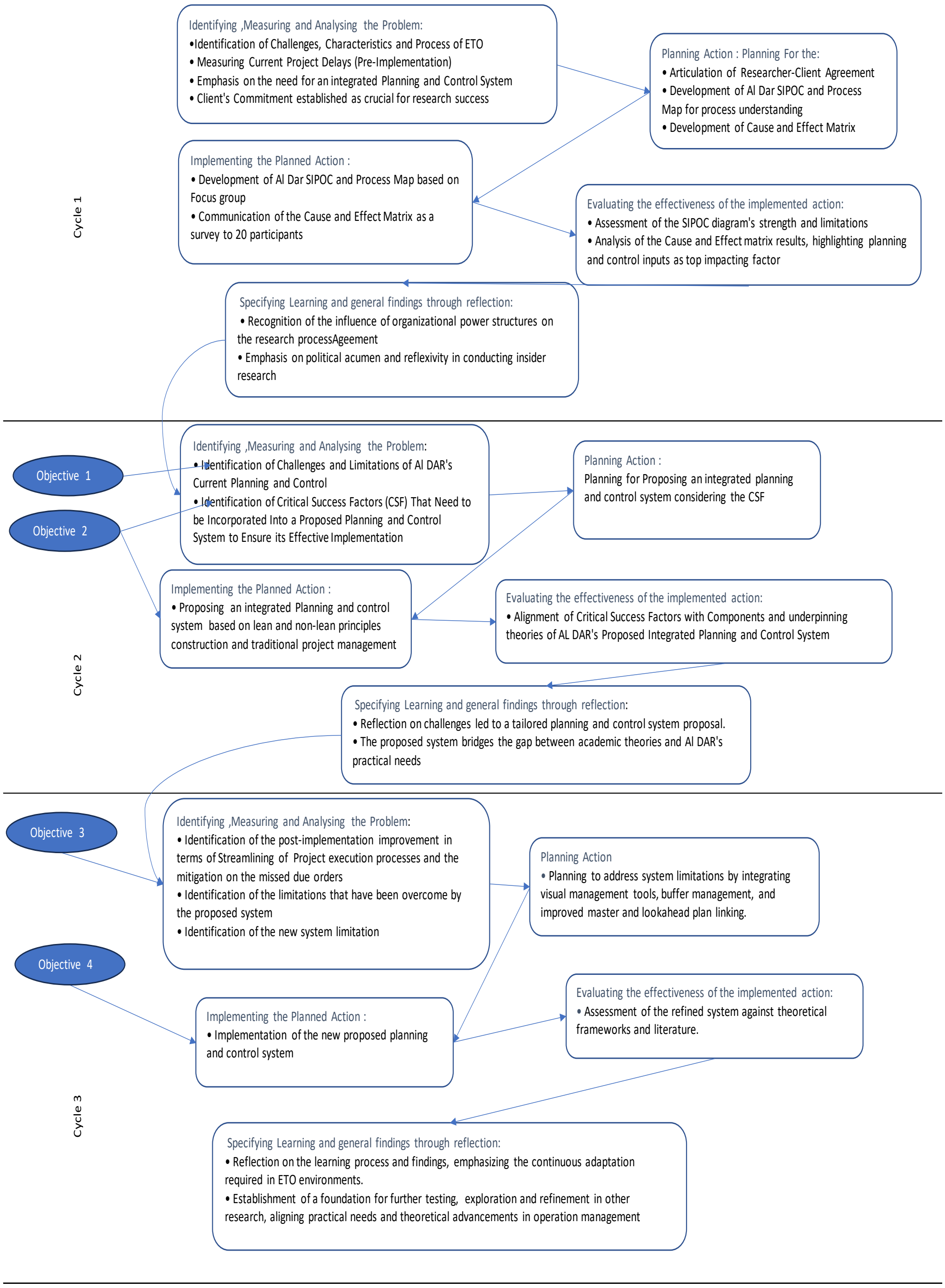

Figure 5-1: Action Research Summary

5.3 Discussion of Theoretical and Practical Implications

5.3.1 Theoretical Implications

5.3.1.1 Re-Evaluation of Current Theories

This research critically examined existing theories underpinning the planning and control systems adopted in the ETO environment. As a result, Lean and non-Lean (traditional) theories were examined. The finding suggested the need for a hybrid approach combining elements from Lean and non-Lean theories, as shown in Figure 4-7, which reflects the refined planning and control system and Table 4-4, which shows the alignment of the Critical Success Factors with the new system's component and underpinning theories. This re-evaluation challenged the conventional dichotomy between Lean and non-Lean systems by proposing an integrated framework suitable for the dynamic nature of ETO projects, as shown in Figure 4-15.

5.3.1.2 Contribution to ETO Operation Management Theory

This research bridged the gap in the existing body of knowledge by proposing an integrated planning and control system designed explicitly for ETO operations to mitigate the missed order due dates by integrating Lean and non-Lean elements.

5.3.2 Practical Implications

5.3.2.1 Improvements in Planning and Control Practices

The research addressed the pressing issue of missed order due dates in the ETO environment at AL DAR by reducing them from 94.1% to 65.5%, demonstrating a remarkable improvement of 30%, as evidenced by quantitative and qualitative analysis, leading to improved project performance, customer satisfaction, and profitability. In addition, the integrated planning and control system proposed through this research can serve as a practical framework for other ETO companies facing similar challenges.

5.3.3 Contribution to Society

The proposing, implementation and fine-tuning of the integrated planning and control system at AL DAR has demonstrated significant societal contributions alongside its theoretical and practical implications mentioned above. This research extends beyond academic and corporate realms by impacting the broader community in several meaningful ways:

5.3.3.1 Enhanced efficiency:

The reduced missed order due dates translate to smoother project delivery and consequently can lead to cost savings for ETO companies. These cost savings can then be passed on to consumers or can be reinvested in further research.

5.3.3.2 Increased customer satisfaction:

This research provides a framework for ETO companies to improve their on-time delivery rates which consequently lead to happier customers.

5.3.3.3 Inspiration for Similar Implementations:

The success achievement of this Action research project can serve as an inspirational model for other ETO companies that face similar challenges. Blending lean and non-lean methodologies in project planning and control successfully motivates others to conduct similar transformative projects.

5.4 Reflection on Methodology and Action Research Process

5.4.1 Methodology Overview

5.4.1.1 Adoption of Action Research

Following the pragmatic philosophy suggested by Johansson and Lindhult (2008), this research employed Action Research to address immediate organisational issues at AL DAR. This approach was aligned with the need for concerted action and continuous learning within the company's dynamic ETO environment.

5.4.1.2 Collaborative Engagement

The research strategy, rooted in the principles of Action Research, emphasised participative collaboration (Argyris, cited in Prybutok and Ramasesh, 2005). This collaborative nature was vital in studying organisational issues thoroughly, as it involved academia and managers in a joint effort to improve practice and develop relevant theories.

5.4.1.3 Data Collection Methods

This research adopted the data collection methods detailed below and listed in 0:

1. Five semi-structured individual interviews
2. Nine focus groups totalling 45 participant instances
3. Survey responses from 20 respondents
4. Statistical analyses of 147 project documents

Using various data collection methods ensured the reliability and validity of the collected data.

5.4.2 Reflections on the Action Research Process

5.4.2.1 A Cyclical and Evolving Process

This research employed an Action Research Framework (Figure 3-1) built by the researcher. Based on previous perspectives of the Cyclical Process Model proposed by Lewin, Susman, Evered, Moroni, Cohen, Manion, and Morrison (1946; 1978; 2011; 2018) and five principles articulated in the seminal study of Davison, Martinsons, and Kock (2004) to maximise the rigour and the relevance of Action Research, this framework, depicted in Figure 3-1, provided a systematic and structured approach to guide the implementation of the Action Research process.

5.4.2.2 Challenges and Adaptability

Implementing the new system highlighted challenges in balancing the need for practical solutions with academic rigour. Adhering to the five principles for conducting rigorous Action Research (Davison, Martinsons and Kock, 2004) helped maintain this balance, as detailed in Table 4-11: Evaluation of this Action Research's Quality.

5.4.2.3 Real-Time Learning and Improvement

The Action Research methodology facilitated real-time learning and problem-solving. The cyclical process enabled the researcher, an Operations Planning Manager at AL DAR, to reflect on each stage, leading to iterative improvements in the company's planning and control system.

5.4.2.4 Integrating Theory and Practice

Consistent with Coghlan and Shani's (2018) definition of Action Research, this study integrated applied behavioural science knowledge with organisational knowledge to address real organisational issues. This blend ensured that theoretical insights were grounded in practical realities.

5.5 Limitations of the Study

Although this research achieved significant theoretical and practical insights, as clarified above in an ETO environment at AL DAR, it is important to acknowledge several limitations.

5.5.1 Scope and Generalizability

The research was conducted at a single organisation, AL DAR, in a specific industrial context. Hence, the findings of this research may not be generalisable to other ETO organisations.

5.5.2 Dual Role of the Researcher

The dual role of the researcher as an employee of AL DAR and a doctoral student could introduce inherent biases, particularly in interpreting findings and interactions with other employees. Efforts were made to mitigate these biases, but they could not be entirely ruled out.

Additionally, given the researcher's dual role as an operations planning expert in the subject company and his role as a researcher, the preunderstanding risk could not be avoided totally while interpreting and analysing the data, which could introduce potential biases. However, as a mitigating strategy, the researcher used the unlearning technique for some of his knowledge and practice to manage his preconceptions and preunderstandings. This strategy helped the researcher explore new factors rather than those he was fully aware of. This strategy helped keep challenging the proposed solutions that emerged and existing assumptions, as recommended by Coghlan, Coughlan, and Shani (2019).

5.5.3 Methodological Constraints

While beneficial for practical, real-time problem-solving, reliance on Action Research could limit the ability to draw broader theoretical generalisations. The iterative nature of Action Research and the evolving context of the company could also affect the consistency and replicability of the study.

5.5.4 Data Collection and Analysis

Depending heavily on qualitative methods such as interviews, focus groups, and surveys provides depth to understanding the planning and control system in the ETO environment. However, these methods were subject to the subjective interpretation of responses, so they may not capture all perspectives within the company. Additionally, the statistical analysis, while robust, depended on the accuracy and completeness of the project documentation reviewed.

5.5.5 Temporal Limitations

The study was conducted over a specific period, which may not have allowed for observing the long-term effects of the implemented changes. Considering the dynamic nature of the ETO environment, this may evolve in the long run with operational challenges and requirements beyond this study’s scope.

5.5.6 External Factors

Although this research considered internal operational aspects of AL DAR, external factors such as market changes, supply chain dynamics, and customer behaviour might significantly impact order due dates and were not considered.

5.6 Recommendations for Future Research

The research conducted at AL DAR offers valuable insights into implementing and refining integrated planning and control systems in an ETO environment. These findings provided the following insights for future research to further enhance understanding and development in this field.

5.6.1 Extending Research Scope and Duration

Longitudinal Studies: Longitudinal studies can assist in observing the long-term effects and sustainability of the implemented changes with a deeper understanding of the new system.

Wider Industry Applications: Expanding the study to include multiple ETO companies from different industries would allow for comparing challenges and solutions, thus enhancing the generalizability of the findings.

5.6.2 Testing and Refining Critical Success Factors

While this study identified and implemented CSFs for ETO planning and control, ongoing research should continuously test and refine these factors. This iterative process would ensure that the CSFs remain relevant and effective in the face of changing organisational and market dynamics.

5.6.3 Incorporating Diverse Stakeholder Perspectives

Client and Supplier Involvement: Future studies should involve clients and suppliers to understand their implications for planning and control systems.

5.6.4 Methodological Innovations

Conducting comparative Action Research studies across different ETO projects and companies would allow for a deeper understanding of contextual influences on planning and control system efficacy.

5.7 Concluding Remarks

This research journey at AL DAR was challenging and enlightening. It stood as a testament to the power of collaborative research in bringing about meaningful change and improving practices in complex organisational settings. The learnings from this study extend beyond AL DAR, offering valuable lessons for the community of practice within the world of ETO environments.

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APPENDIXES

Appendix A Consent Form

University of Central Lancashire
UCLan

Participant Consent Form

Version number & date: REV-00 15-Jan-2022
Research ethics approval number: BAHSS2 0430
Title of the research project: A Proposed Integrated Planning and Control System to Mitigate Missed Order Due Dates in an Engineer-to-Order Environment
Name of researcher(s): Mohammad Omar Hajeer

Please initial box

1. I confirm that I have read and have understood the information sheet dated 15-Jan-2023 for the above study, or it has been read to me. I have had the opportunity to understand why the research is being done and what it will involve, to ask if I would like more information or if there is anything that I do not understand and I have had the opportunity to discuss this with my friends, relatives, line manager or Trade Union Reps.
2. I understand that taking part in the study involves audio recorded interview.
3. I understand that my participation is voluntary and that I am free to stop taking part and can withdraw from the study at any time without giving any reason and without my rights being affected. In addition, I understand that I am free to decline to answer any particular question or questions.
4. I understand that I can ask for access to the information I provide and I can request the destruction of that information if I wish at any time within one month. I understand that after one month I will no longer be able to request access to or withdrawal of the information I provide.
5. I understand that the information I provide will be held securely and in line with data protection requirements at the University of Central Lancashire.
6. I understand that signed consent forms and original audio will be retained in the researcher personal computer to be accessed by the researcher until completion of the transcript. Transcript will be retained for 7 years or till graduation.
7. I agree to take part in the above study.

Mohammad Hajeer	________	__________________
Name of person taking consent	Date	Signature

Principal Investigator
Prof. Yahaya Yusuf

YYusuf@uclan.ac.uk

Student Investigator
Mohammad Hajeer

moyhajeer@uclan.ac.uk

Appendix B 15-Point Checklist of Criteria For Good Thematic Analysis (Braun and Clarke, 2006)

Process	No.	Criteria
Transcription	1	The data have been transcribed to an appropriate level of detail, and the transcripts have been checked against the tapes for 'accuracy'.
Coding	2	Each data item has been given equal attention in the coding process.
	3	Themes have not been generated from a few vivid examples (an anecdotal approach), but instead the coding process has been thorough, inclusive and comprehensive.
	4	All relevant extracts for all each theme have been collated.
	5	Themes have been checked against each other and back to the original data set.
	6	Themes are internally coherent, consistent, and distinctive.
Analysis	7	Data have been analysed – interpreted, made sense of – rather than just paraphrased or described.
	8	Analysis and data match each other – the extracts illustrate the analytic claims.
	9	Analysis tells a convincing and well-organized story about the data and topic.
	10	A good balance between analytic narrative and illustrative extracts is provided.
Overall	11	Enough time has been allocated to complete all phases of the analysis adequately, without rushing a phase or giving it a once-over-lightly.
Written report	12	The assumptions about, and specific approach to, thematic analysis are clearly explicated.
	13	There is a good fit between what you claim you do, and what you show you have done – ie, described method and reported analysis are consistent.
	14	The language and concepts used in the report are consistent with the epistemological position of the analysis.
	15	The researcher is positioned as *active* in the research process; themes do not just 'emerge'.

Appendix C Interview Structure # 1

Question
Q1: How would you define the Engineer-to-order or Project Manufacturing environments?
Q2: How many projects do you usually manage at the same time?
Q3: How does the term Project Manufacturing differ from pure project and pure Manufacturing?
Q4: During the early stage of the project, after the awarding immediately, what is the level of details available in terms of scope and requirements?
a. Probe: So, the design starts evolving after awarding and continues to evolve? (closed question followed by) At which stage of the project can we reach the design freeze stage?
b. After we reach the design freeze stage, what is the possibility of client design change requests? Why?
Q5: What is the level of customisation of the projects you are dealing with?
a. Probe: What about the component of each product in terms of quantity and the required customisation?
b. Probe: What is the average lead time for the project component?
Q6: What other challenges do you usually face in managing your projects?
Q7: Can you explain the level of coordination needed During the project stages from design, procurement, fabrication, and assembly?
Q8: What are the implications of the Project Manufacturing environment characteristics on any planning and control system?

a. Probe: What about the uncertainty implications on planning and control systems?
b. Probe: What about the implication of the level of customisation on planning and control the projects?
c. Probe: What about the implication of the level of the complexity and coordination needed during the project execution on planning and control the projects?
d. Probe: in terms of the resources, what challenges do you face in managing your multiple projects simultaneously?

Appendix D Interview Structure # 2

Question
Q1: How do we handle receiving the purchase order from the client?
Q2: What challenges do we face when receiving the purchase order?
Q3: How do we perform the design and detailed engineering process, and what are its input and output?
Q4: How do we handle the challenges of design and detailed engineering process?
Q5: How do we perform the procurement process?
Q6: How do we handle the challenges of the procurement process?
Q7: How do we perform the fabrication and assembly process?
Q8: How do we handle the fabrication and assembly process challenges?
Q9: How do we handle shipping the finished product process, and what are the challenges if any?

Appendix E Interview Structure # 3

Question
Q1: I would like to hear from you about four major planning and controls-related issues you have been experiencing for a long time and impacting the company's annual goals a. **Probe: What do you think about delivery timelines?** b. **Probe: What do you think about the inventory level?** c. **Probe: What do you think about the WIP level?** **Q2: what improvements would you like to see made to the current planning & control system**
Q3: As per your understanding from the Research Information Sheet, can you describe your understanding of the Action Research Strategy? **Q4: Can you explain how you believe that Action Research will be effective in mitigating the missed order due dates?** **Q5: Have you had any previous experience with Action Research?**
Q6: Based on Research Objectives, can you articulate the problem that

research will address? **Q7: Are there any planning related issues we need to focus on?**
Q8: What specific resources will be dedicating as a project implementation team? **Are there any potential challenges you anticipate in terms of committing to research project?**
Q9: Can you describe the roles and responsibilities of researcher and AL DAR members?
Q10: How will the success of the project be measured or evaluated? **Q11: Are there any specific metrics or measures the project should address?**
Q12: Can you describe the data collection method and analysis? **Q13: Is there any limitation to data collection and analysis method that need to be addressed?**

Appendix F Word Frequency (Top 30) Using Nvivo- Action

Research Cycle 1:

SN	Word	Count	Weighted Percentage (%)	Similar Words
1	design	24	2.67	design, designing
2	customer	19	2.11	customer, customers
3	time	19	2.11	time, timely, times, timing
4	planning	18	2.00	planning, plans
5	process	17	1.89	process, process', processes, processing
6	products	17	1.89	product, production, products
7	levels	12	1.33	level, levels
8	delivery	11	1.22	deliveries, delivery
9	need	11	1.22	need, needed
10	inventory	10	1.11	inventory
11	problem	10	1.11	problem, problems
12	delays	9	1.00	delay, delayed, delays
13	work	9	1.00	work, worked, working
14	activity	8	0.89	active, activities, activity
15	procurement	8	0.89	procurement
16	effective	7	0.78	effective, effectively, effectiveness
17	efficiency	7	0.78	efficiencies, efficiency, efficiently
18	leading	7	0.78	lead, leading, leads
19	operational	7	0.78	operational, operations
20	order	7	0.78	order, orders
21	target	7	0.78	target, targets
22	additionally	6	0.67	additional, additionally
23	control	6	0.67	control, controls
24	cost	6	0.67	cost
25	engineering	6	0.67	engineering, engineers
26	impacting	6	0.67	impacting
27	materials	6	0.67	material, materials
28	phase	6	0.67	phase
29	revenue	6	0.67	revenue
30	satisfaction	6	0.67	satisfaction

Appendix G Word Frequency Visualisation Using Nvivo - Action Research Cycle 1:

Appendix H Coding Schemes Used in Interview Structure #1

Name	Files	References
Interview Structure 01	3	69
Engineer-To-Order environment definition and characteristics	3	69
Complexity	2	12
Control	3	5
Customization	3	14
Engineering	2	5
ETO	1	1
Multiple Projects	1	1
Planning	3	5
Procurement	2	6
Project Management	2	2
Resources	2	5
Scope & Requirement	3	5
Time Frame	2	8

Appendix I Coding Schemes Used in Interview Structure #2

Name	Files	References
Interview Structure 02	1	17
Inefficiencies and Deep Dive into the ETO Process and Challenges	1	17
Process Map	0	0
Deliver the Finished Product to customer	1	1
Fabricate & Assemble the Products	1	1
Perform the procurement work	1	1
Perform the Design & Engineering work	1	1
Receive Order	1	1
Receive the Material	1	1
SIPOC	1	17
Customers	1	1
Client	1	1
External Inputs	1	4
Client PO and Contract	1	1
Tender Drawings and Basic Engineering	1	3
Process Output	1	4
Detailed Design	1	2
Finished Products	1	2
Process Output variables	1	3
Inventory level	1	1
Project Schedule variance	1	1
WIP level	1	1
Requirements	1	2
Maximum 10% of Revenue	1	1
On-Time Completion	1	1
Suppliers	1	3
Client	1	2
Sub-vendor	1	1

Appendix J Coding Schemes Used in Interview Structure #3

Name	Files	References
Interview Structure 03	3	92
Client's commitment to Action Research Project	3	13
Action Research	1	4
Change	3	4
Data Collection Methods	1	1
Resources	1	2
Roles and Responsibilities	1	2
Current Project Delays	3	19
Delivery Dates	2	6
Evaluation	3	6
Timely Manner	3	7
Inefficiencies and Deep Dive into the ETO Process and Challenges- Process Map	3	25
Communication	2	3
Design	3	9
Inventory levels	3	3
Procurement	3	8
Work-In-Progress (WIP) levels	2	2
Need for Planning and Control System Improvements	3	35
Client Satisfaction	3	6
Cost Effective	2	3
Integration	2	3
Planning and Control System	3	10
Revenue	2	7
Visibility and Coordination	2	6

Appendix K Interview Structure # 4

Q1: What are the current planning and control practices?
Q2: How does the current planning system impact the processes?
Q3: What features would be ideal for a planning and control system?
Q4: What limitations have been observed with current planning methods?
Q5: In your opinion, what are the essential features needed for an integrated planning and control system

Appendix L Word Frequency (Top 30) Using Nvivo- Action Research Cycle 2:

SN	Word	Length	Count	Weighted Percentage (%)	Similar Words
1	engineer	8	70	2.61	engineer, engineering, engineers
2	system	6	63	2.34	system, systemic, systems
3	planning	8	54	2.01	plan, planned, planning, plans
4	time	4	50	1.86	time, times
5	project	7	48	1.79	project, projects
6	delay	5	28	1.04	delay, delayed, delays
7	order	5	26	0.97	order, ordering
8	works	5	26	0.97	work, worked, working, works
9	mrp	3	23	0.86	mrp
10	real	4	23	0.86	real
11	changes	7	21	0.78	change, changed, changes
12	customisations	14	20	0.74	custom, customer, customers, customisation, customisations
13	schedules	9	20	0.74	schedule, schedules
14	need	4	19	0.71	need, needed, needs
15	excel	5	18	0.67	excel, excellent
16	things	6	18	0.67	thing, things
17	client	6	17	0.63	client, clients
18	data	4	17	0.63	data
19	example	7	16	0.60	example, examples
20	problem	7	16	0.60	problem, problems
21	use	3	16	0.60	use, used, useful, using
22	material	8	14	0.52	material, materials
23	team	4	14	0.52	team, teams
24	departments	11	13	0.48	department, departments
25	flexible	8	13	0.48	flexibility, flexible
26	provide	7	13	0.48	provide, provided, provider, providers, provides, providing
27	requirements	12	13	0.48	require, required, requirements
28	get	3	12	0.45	get, gets
29	helpful	7	12	0.45	help, helpful, helps

Appendix M Word Frequency Visualisation Using Nvivo - Action Research Cycle 2:

Appendix N Coding Schemes Used in Interview Structure #4

Name	Files	References
Interview Structure 04	2	67
Challenges and Limitations of Al DAR's Current Planning and Control	2	67
Lack of Flexibility in the Current Planning and Control System	2	13
Adaptation Issues with MRP	1	1
Agile Adjustments	1	1
Complexity in Usability	1	1
Lack of Customization Provision	1	1
Manual Update Requirements	1	1
MRP System & ETO Mismatch	1	1
MRP System Implementation	1	1
MRP's Lack of Flexibility	1	1
Necessity for Quick Adjustments	1	1
Need for Adaptable System	1	1
System's Inflexibility	1	1
Technology Lag	1	1
Time Consumption & Coordination Needs	1	1
Lack of integrity in the Current Planning and Control System	2	17
Autonomous Scheduling	1	1
Departmental Bottlenecks	1	1
Departmental Transparency	1	1
Disjointed Schedules	1	1
Dynamic Resource Allocation	0	0
Dynamic Resource Reassignment	1	1
ETO Challenges with MRP	1	1
Excel Limitations	1	1
Immediate Data Access in Meetings	1	1
Individual vs. Integrated Schedules	1	1
Inter-departmental Transparency	1	1
Isolation of Data	1	1
Lack of Integrated Delivery Schedules	1	1
Mobile Notifications	1	1
MRP Mismatch with Circumstances	1	1
Need for Real-time Synchronization	1	1
Resource Reallocation	1	1
Standalone Production Focus	1	1
Lack of Look-ahead and Proactive Planning in the Current Planning anc	1	11
Automated Task Rescheduling	1	1
Challenges of Reactive Planning	1	1
Consequences of Non-Proactive Planning	1	1
Constant Crisis Management	1	1
Customer Induced Changes	1	1
Impact Analysis through Data	1	1
Importance of Analytical Alerts	1	1
Last-minute Adjustments	1	1
Predictive Analysis on Bottlenecks	1	1
Predictive Bottleneck Identification	1	1
System-led Risk Analysis	1	1
Lack of proper conversation, communication and coordination in the C	2	12
Cascading Delays	1	1
Communication Issues with Traditional Planning	1	1
Data Consistency Issues with MRP	1	1
Delay in Issue Awareness	1	1
Delayed Team Updates	1	1
Departments Working in Silos	1	1
Immediate Information Flow	1	1
Lack of Interdepartmental Sync	1	1
Misaligned Promises	1	3
Vicious Cycle of Delays	1	1
Lack of Real-time Updates in the Current Planning and Control System	2	14
Client Trust Erosion	1	1
Data Aging	1	1
Delay in Problem Identification	1	1
Importance of Real-time Data	1	1
Instant Data Communication	1	1
Integrative System Features	1	1
Lead Time Mismatch	1	1
MRP System Reliability Issues	1	1
Predictive Analysis Need	1	1
Reliance on Excel for Planning	1	1
Traditional Planning Limitations	1	1
Visualization of Real-time Data	1	3

Appendix O Interview Structure # 5

Q1: How have project lead times comparing to the contractual lead time changed since the implementation of the new system? Can you describe any increases, decreases, or consistencies observed?

Q2: Are there specific project phases where you've noticed significant changes in timelines compared to the planned or contractual timeline?

Q3: Can you share any statistical data or trends observed in project timelines since the system's introduction?

Q4: Starting from the Master/milestone schedule, using CPM, Lookahead schedule, weekly planning to remove constraints, using KPI and 5 whys to identify the root cause for the plan failures, Which features of the system have been most effective in managing project lead times?"

Q5: What has been the client response or feedback regarding project completion times since using the new system?

Q6: Are clients noticing changes in project delivery schedules?

Q7: Could you share your observations on how the new system influences flexibility and coordination across different departments? How does this approach compare with the traditional planning methods previously employed?

Q8: Could you describe how the new system has handled the customisation and flexibility issues that were problematic with the MRP system?

Q9: How has the integration of the new system influenced the efficiency and timelines of the design phase in your Engineer-to-order projects? Can you provide examples of how it has affected design planning, revisions, and coordination with other departments?

Q10: How has the integrated system impacted inventory management in terms of accuracy and timeliness of information on material requirements?

Appendix P Interview Structure # 6

Q1: How user-friendly is the system interface for different stakeholders (engineers, managers, procurement staff)? Q2: Are there any suggestions for enhancing the interface or user interaction to improve efficiency or ease of use? Q3: Have there been any challenges in integrating the system with existing workflows or other software tools? Q4: Can you provide specific examples where integration was not seamless, and how might these be addressed? Q5: Have there been instances where the real-time data provided was inaccurate or delayed? Q6: What improvements are needed to ensure data accuracy and reliability? Q7: How well does the system adapt to different types of projects, especially those with high variability or customisation needs? Q8: Are there specific project types where the system's adaptability could be enhanced? Q1: How effective are the system's feedback and reporting mechanisms in providing actionable insights? Q9: What additional features or data would enhance the utility of these reports?

Q10: How has the system performed under situations of rapid change or crisis (e.g., urgent design changes, supply chain disruptions)?

Q11: What modifications could help in better handling such scenarios?

Q12: How effective have training and support been for new users of the system?

Q13: Are there areas where additional training materials or resources could be beneficial?

Q14: How scalable is the system with growing project complexity and size?

Q15: What features could be added to ensure the system remains relevant and efficient as the company grows?

Q16: Are there specific customisations or features that different stakeholder groups (e.g., logistics, manufacturing, procurement) find missing or desire?

Q17: How can the system be tailored to better meet the distinct needs of these groups?

Q18: How effectively does the system utilise predictive analytics and AI for project planning and risk assessment?

Q19: What advanced features could be integrated to enhance predictive capabilities?

Appendix Q Word Frequency (Top 30) Using Nvivo- Action Research Cycle 3:

SN	Word	Length	Count	Weighted Percentage (%)	Similar Words
1	project	7	349	3.83	project, projected, projects
2	system	6	346	3.80	system, systems
3	engineers	9	212	2.33	engineer, engineering, engine
4	improvements	12	154	1.69	improve, improved, improvement, improvement: improves, improving
5	managing	8	113	1.24	manage, manageable, manag management, managers, managing
6	changes	7	102	1.12	change, changed, changes
7	delays	6	99	1.09	delay, delayed, delays
8	plans	5	95	1.04	planned, planning, plans
9	client	6	91	1.00	client, clients
10	design	6	86	0.94	design, designed, designs
11	procurement	11	79	0.87	procure, procurement
12	schedule	8	76	0.83	schedule, schedule', schedule schedules, scheduling
13	provide	7	69	0.76	provide, provided, provides, providing
14	integration	11	68	0.75	integrate, integrated, integrat integrating, integration, integrative
15	requirements	12	68	0.75	require, required, requiremen requires, requiring

Appendix R Word Frequency Visualisation Using Nvivo - Action Research Cycle 3:

Appendix S Coding Schemes Used in Interview Structure #5

Name	Files	References
Interview Structure 05	2	97
Theme 01- The New system has Streamlined Project execution processes and mitigated the missed d	2	52
01-Efficient Overall Project Execution	2	14
02-Efficient Initial Stage	1	2
03-Efficient Design Stage	2	8
04-Efficient procurement and Material Delivery	2	11
05-Efficient Inventory Managment	2	5
06-Efficient Manufacturing stage	2	6
07-Efficient Logistic Process	1	6
Theme 02- The New system has overcome the previous system limitation	2	45
01-The new system is more flexible than the previous system	2	12
Client Demand Complexity	1	1
Decreased Time on Redoing Work	1	3
Delays from Client Requirements in Design Phase	1	1
Disruptions from Project Scope Changes	0	0
Evolving Client Needs Challenge	1	1
Last Minute Client Requests	2	3
Past Delays from Design Changes	1	1
Past Setbacks due to Design Changes	1	2
Project Scope Changes Impacting Inventory	1	1
Quick Adjustments Capability	1	1
Streamlining Design Phase	1	4
02-The New System Offers an Integrated Approach and Improved Integrity	2	12
Example of Material Delivery Delay	1	1
Predictability in Manufacturing Workflow	1	3
Process Streamlining	2	5
Supplier Delay Challenges	1	1
Supplier Failure Impact	1	1
Supplier Reliability Challenges	1	1
03-The New System Enables Proactive and Look-Ahead Planning	1	3
Effective Transportation and Logistics Planning	1	2
Forecasting Capabilities	1	1
Inventory Forecasting Revolution	2	5
Predictive Capabilities in Inventory Management	1	2
Shift to Proactive Strategies in Logistics	1	1
04-The New System Provides Real-Time Data and Updates	1	3
Revolutionizing Approach with Real-Time Updates	2	2
05-The New System Improves Communication, Coordination, and Collaboration	2	15
Client Responsiveness Challenge	0	0
delays in client approvals	1	1
Handling Client Orders and Interdepartmental Challenges	1	3
Impact of Client Feedback Speed	1	1
Partial Resolution of Client Engagement	1	1

Appendix T Coding Schemes Used in Interview Structure #6

Interview Structure 06	2	47
Theme 03- The proposed system has some limitations	2	47
01-The proposed system lacks Visual Management Capabilities	2	22
Change Impact Visualization Need	1	1
Dashboard Inadequacy	2	5
Dynamic Response Visualization Tool	2	3
Forecasting_Visualization_Tool	1	1
Inventory Management Visual Tool	1	1
Realtime Inventory Visualization	1	1
Realtime_Scheduling_Visual_Interface	2	2
Supplier Progress Visibility	1	1
Supplier_Management_Visual_Tool	1	1
Supply Chain Visualization Need	1	1
Supply_Chain_Disruption_Visualization	1	1
Task Relationship Visualization Tool	1	1
Visual Cue Deficiency	2	3
02-The proposed system lacks Buffer consideration or Critical Chain Project Management (CCPM) ir	2	14
Anticipatory Buffering Need	2	2
Inventory Adjustment Buffer	1	1
Manufacturing Schedule Adjustment Buffer	1	1
Operational Buffer Necessity	1	1
Predictive Buffering Need	2	3
Procurement Plan Adaptability Buffer	1	1
Reactive_Versus_Proactive_Buffering	1	1
Schedule Flexibility Buffer	2	2
Supply Chain Disruption Strategy Buffer	1	1
Visual Buffer Tracking	1	1
03-The proposed system lacks the links between the master plan and the lookahead plan	2	11
Anticipatory Adaptation Need	1	1
Inventory Planning Integration Issue	1	1
Linking Master plan with lookahed	2	5
Master Lookahead Alignment Issue	2	4