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Cost Estimation and Risk Integration at PMO Level for Ship Electrical Projects (Early Phase)

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ABSTRACT

This paper explores cost estimation and risk integration at PMO level in ship electrical projects in early phase. Every ship electrical project is challengeable because every project is unique and scope is not fully finalized at the tender stage. So poor estimation during early phase can be reason for the entire project profit or partially lost. As per the literature cost estimation and risk management are studied separately. But there are only limited findings on the combination of these two in the Project Management Office (PMO) Level in ship electrical projects. The main objective of this study is how cost estimation and risk integration at PMO level can be used to improve better ideas and cost predictability within the early phase of ship electrical project. Cost estimation, risk integration, contingency determination engineer-to-order (ETO) project characteristics and PMO governance are the key concept of this thesis. This research is mainly based on the qualitative analysis of two completed ship electrical projects within the one organization. Tender stage estimations, commercial offers, cost overrun reports and project closure meeting records are the documents used in here. Five dimensions of analysis used in both projects. There is estimation methodology, risk identification, risk to cost integration, contingency determination and PMO governance. The company also confirmed that there are not any risk registers during the tender stage, and this directly help for the main empirical finding of the research. From both projects, analysis has shown that cost estimation and risk management were taken as separate factors. In tender stage existing documents could not found any formal risk register. There is not any separate contingency existed. So, the profit markup considered as commercial margin and risk buffer. PMO approval checklist also not completed. And performance indicators like KPIs only checked the pipeline values not the accuracy of the estimation. After reviewing all documents, eight systematic gaps were found. These are organizational failure rather than individual failures. One project faced a financial loss due to three foreseeable risks without cost provision. Some of these same risks found in previous project closure meeting were not adopted to inputs for future estimations. As a solution for that, five-phase PMO level framework has been introduced. This framework designed compulsory risk identification, contingency calculation based on probability and cost impact, estimation restructure with base cost, contingency and margin separately, PMO reviews and lesson learned feedback. Finally, to support this framework, simple excel tool has been created. By using this framework retrospectively, the document financial loss may have been drop down and risk involvement may have been identified before the tender submitted to client. As per those findings, it is showed risk integration in PMO level is practical and as well as commercial. Proposed framework is simple and addictive. It does not need special training or software. And this can be used automatically with each completed project.

KEYWORDS: cost estimation, risk integration, Project Management Office (PMO), ship electrical projects, early-phase estimation, PMO governance, engineer-to-order, contingency, framework

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1 Introduction

1.1 Background of study

The shipbuilding industry has faced increasing technological challenges because of rising difficulties with ship electrical systems. They look after the range of 8-15% of the total vessel cost (Alblas & Pruijn 2024). Modern vessels depend on electrical systems which generate power and distribute it and operate automation and control systems for all their essential functions. The ship building industry now requires electrical work as a fundamental, yet costly, element of its shipbuilding activities.

Ship electrical projects encounter their highest financial burden during their initial stages, which include tendering and concept design. The project team makes critical system configuration decisions during these initial phases when they have limited technical information about equipment selection and system integration. The combination of high-cost impact and low information availability creates major challenges for making accurate cost estimates in the early project phases.

The success of bid decision and budgeting activities and strategic planning efforts depends on accurate cost estimates which early project phases generate. The execution of ship electrical projects depends on engineering-to-order (ETO) environments because each project needs specific engineering work to meet its ship design and customer requirements (Hicks et al.,2000). The high level of customization prevents organizations from using past project data which causes their traditional estimation methods to produce less accurate results. Ship electrical projects face two major issues which are cost uncertainty and multiple risk factors.

The cost estimation process and risk management process function as two activities which become especially apparent during the initial stages of project development. The separation of these two processes results in two outcomes which include the underestimations of uncertainty and the inadequate assessment of risk when making cost-related decisions.

The Project Management Office (PMO) serves as a project management tool which helps manage multiple projects through its planning work and estimation work and governance work. The PMO function serves two important purposes which include supporting organizational cost estimation work and enabling risk assessment work to become an essential part of organizational operations (Hobbs & Aubry, 2007). The research field lacks studies which explain how organizations at the PMO level implement cost estimation and risk assessment work during early project development for their ship electrical projects.

The study aims to explain how organizations develop risk assessment methods and cost estimation methods during engineering-intensive project work in their early project stages. The research work on ship electrical projects and PMO-level processes will produce two outcomes which benefit academic research and practical applications by enhancing early project cost and risk management activities.

1.2 Problem Statement

The process of estimating costs during the initial stages of ship electrical projects needs to be accurate because it determines essential business and technical choices which must be made while design details remain incomplete and high levels of uncertainty exist (Williams & Samset, 2010). Early-phase cost estimation in ship electrical projects remains difficult because projects require custom solutions and complex system integration and project requirements keep changing.

Organizations implement cost estimation and risk management as a separate activity during the tender stage. Organizations follow a practice in which they create tender-stage cost estimates as single-points figures which assume fixed project scope and budget while treating early-phase cost estimates requires organizations to display precise estimates which do not show all possible cost outcomes (Weld & Klakegg, 2022).

The estimation process for ship electrical projects becomes more difficult because of their engineering-to-order (ETO) project structure. Each project requires a different electrical system design which prevents the use of common estimation models and limits the accuracy of previous cost estimation results. Experts must evaluate projects because their different requirements create diverse estimation methods which result in different estimation results.

PMOs have the duty to establish governance structures while they standardized project management methods for the entire organization yet their function to connect early-phase cost estimation with risk management in ship electrical projects remains undefined. Existing research has mainly studied the three domains of cost estimation and risk management and PMO governance as independent areas yet research on their simultaneous usage in organizations has been limited.

The absence of structured integration between theoretical recommendations and actual implementation creates a gap. Organizations rely on structured PMO-level methodologies which need proper cost estimation methods that include risk assessment to manage project uncertainty in early stages. The organization structure becomes vulnerable to budget overruns and incorrect tender assessments and projects which increase organizational risk throughout the entire project portfolio. (Flyvbjerg et.al., 2002; Welde & Klakegg, 2022)

1.3 Research Aim and Objectives

The research aims to create a system that enables Project Management Offices (PMOs) to assess early project costs and risk through structured methods which they will use to execute their work on ship electrical projects. The research investigates how cost and risk management practices should be implemented during the initial stages of projects because those periods contain high uncertainty while crucial decisions take place.

The research has established the following objectives to achieve its primary goal.

- The study aims to find the main expenses which lead to cost uncertainty for initial ship electrical project stages.
- The study evaluates existing research about early-phase cost estimation and risk integration and PMO governance and engineering-to-order project environments.

- The researchers will create a PMO-level framework which combines early-phase cost estimation and risk assessment requirements.
- The researchers will test and assess their framework through two ship electrical projects which they will conduct at one organization.

1.4 Research Question

The main research question guides all the research activities.

How can cost estimation and risk integration at the PMO level be improved to support better decision-making and cost predictability during the early phase of ship electrical projects?

The study examines sub-questions which support the main research question.

- What are the key cost drivers and sources of uncertainty in early-phase ship electrical projects?
- What methods do the Project Management Office (PMO) use to estimate costs and manage risks during early project phases?
- The PMO framework for early-phase cost estimation and risk integration development needs to combine specific literature findings with practical knowledge.

1.5 Scope and Limitations

The study examines the initial two stages of ship electrical projects which include tendering and concept design because this stage reveals maximum cost estimation inaccuracies while essential project decisions get established. The research scope focuses exclusively on how early-stage cost assessment interacts with risk assessment at Project Management Office (PMO) functions instead of applying to specific project implementation and technical design procedures.

The research study executes its empirical investigation at one ship electrical contracting company which uses two ship electrical projects to examine their embedded analytical units. The research scope enables through assessment of organizational processes which operate under stable governance standards. The research results do not support statistical generalization for the entire shipbuilding sector.

The research focuses exclusively on ship electrical projects that function within an engineering-to-order (ETO) framework. This study does not include any ship systems which involve essential components like hull structure or piping or mechanical systems. The analysis includes only the initial stages of a project up to the point of testing and commissioning.

The research boundaries establish scope and limitation parameters which enable the study to proceed while keeping dedicated research activities within their designated objectives. The findings from the study apply directly to projects that share similar characteristics although their use in different industries or project types requires careful assessment.

1.6 Structure of the Thesis

The thesis consists of six chapters which present its content.

The first chapter presents the study's background information and problem description and research objectives and research questions and study boundaries and study organization.

Chapter 2 presents the literature review which evaluates ship electrical systems and early-phase cost estimation and risk integration and Project Management Office (PMO) governance and engineering-to-order (ETO) design process. The chapter identifies a research gap that establishes the need for this study.

The research methodology section of Chapter 3 presents the research approach and case study design and data collection methods and data analysis procedures and research quality considerations and ethical aspects of the study.

Chapter 4 shows how two ship electrical projects from the case organization used the proposed PMO-level framework through an empirical case study which demonstrates its application.

The study findings in Chapter 5 demonstrate the proposed PMO-Level framework, discusses the findings and conclusions with recommendations, contribution, limitations and implications for future research.

2 Literature Review

2.1 Definition of Key Concepts

The current section establishes how central terms will be used throughout the thesis to maintain consistency and clear understanding of all concepts. The research presents particular definitions for three concepts which include cost estimation and risk integration and PMO governance because these terms have different meanings in various academic and professional settings.

A **ship electrical project** includes all stages which begin with engineering and procurement before moving to installation and testing and ending with commissioning of electrical systems on a ship. The systems comprise power generation and distribution systems and main and emergency switchboards and cabling network and automation and control systems and energy storage and electrical power systems which connect to propulsion and auxiliary systems. Ship electrical projects require execution within two restrictive environmental conditions which exist on vessels during construction because ships encounter both technical and unpredictable expenses.

The study uses **early phase cost estimation** to describe cost assessments made during the project's concept design and pre-contract and tendering periods. Estimators need to make their estimates based on different design progress levels which involve estimation based on existing information about the project which they must create from their assumptions and analogies and expert judgment. The estimates serve as essential foundations which support bid decisions and initial budgeting and strategic resource planning; any error made during this period will create problems that extend throughout the project.

The Project Management Office (PMO) operates as an organizational unit which establishes project management standards and governs practices while implementing decision making processes for all projects in the portfolio. The research needs to view the PMO as an operational unit because it operates through cross project functions which provide better cost estimation and risk management integration than single project teams.

Risk integration refers to the deliberate and systematic incorporation of uncertainty and identified risk factors into the cost estimation process itself rather than treating risk analysis as a parallel or post estimation activity. The integrated approach incorporates probabilistic thinking and contingency determination and uncertainty quantification into the estimate creation process which results in production of actual cost outcomes that show all possible cost variations instead of showing a single fixed value.

Engineering-to-order (ETO): Custom engineering projects require clients to create customized solutions which needs the design of original products because their projects involve multiple unique design phases. Ship electrical projects sit firmly within this category, as every vessel installation demands bespoke electrical designs, unique integration solutions, and project specific engineering effort. The early project phases of this research face cost uncertainty because this characteristic requires particular management methods.

2.2 Ship Electrical Power Systems and Cost Drivers

2.2.1 Electrical Load Profiles and Operational Modes

The electrical demand placed on a ship's power systems is not constant because it varies according to the vessel's mission phase and operational mode. The electrical infrastructure experiences different load profiles during transit and manoeuvring and dynamic positioning and port operations and hoteling which creates a basic problem for early phase estimation. The client requires the estimating team to make assumptions about simultaneity factors and diversity and peak demand before they establish their operational patterns which lead to major generator sizing and distribution architecture and project cost problems (Nakhai, 2023).

The assumptions which they make produce substantial consequences. The peak electrical demand has been overestimated, which results in equipment sizing that requires larger generators and heavier switchboards and more extensive cabling which increases capital costs. The current system will fail to support operational needs because it has been underestimated which will lead to expensive redesign work and change orders which extend project timeline during the project's later stages (Nakhai, 2023). The two failure modes occur frequently in ETO project environments because the client negotiations about load profiles remain unresolved during the tender estimate preparation.

Deterministic load estimate methods which assign a single expected load value to each consumer fail to capture the actual variability of consumer load characteristics. The literature increasingly points towards structured, uncertainty aware estimation processes as necessary response, particularly when the decisions being supported are made at an organizational or PMO level where consequences of systematic underestimation accumulate across projects (Berg et al., 2025).

2.2.2 Electrification, MVDC, and Energy Storage

The increasing use of electrical systems in shipbuilding projects results in higher technical difficulties which make it harder to create cost estimates for the electrical components of ships. The implementation of more stringent environmental regulations together with fuel efficiency requirements has forced various ship types to adopt all-electric or hybrid power systems which enable electrical systems to takeover loads that used to be managed by mechanical or thermal methods. The new architectural changes bring new cost elements which did not exist in the previous estimation bases (Albas & Pruijn, 2024).

The development of medium voltage direct current (MVDC) distribution system represents a new advancement in this field. MVDC systems enable more efficient distributed energy resource integration while delivering superior performance when compared to traditional alternating current systems. However, these systems need power electronic converters and protection systems development and control system development which create expenses and technical development challenges the tendering stage of projects not only lacks final decision making but also requires engineers to create cost estimates before key decisions which will determine expenses are made (Nakhai, 2023).

The energy storage systems of battery technology (BESS) present an equivalent obstacle. Battery systems provide operational and environmental advantages, but their costs depend highly on design choices about capacity and redundancy and safety and fire protection and cooling and power system integration. The necessary uncertainty range for energy storage vessels requires wide uncertainty limits because risk integration needs to reflect those ranges accurately (Alblas & Pruijn, 2024).

The use of MVDC systems and hybrid power systems and battery storage systems for ship electrification has created a more complicated and consequential connection between initial design assumption and the ultimate project expenditures. Estimation methods which fail to specifically account for this uncertainty will result in cost estimates which do not reflect actual cost differences. For PMO practice, the estimation standards which apply to standard vessel types need major adjustment when they come to projects that involve electrified systems (Nakhai, 2023 & Pruijn, 2024).

2.2.3 Cost-Critical Electrical Components

The research studies theta address ship electrical systems identify particular system components which create the highest construction cost uncertainty during the initial stages of building work. The PMOs need to know about estimation risk because it enables them to target their risk analysis resource allocation to the areas which need it the most instead of applying standard uncertainty estimates to all budget items.

The most expensive equipment category is including power generation and main distribution equipment which consist with generators and main switchboards and emergency switchboards. The equipment size determination requires peak electrical demand estimation because the required peak electrical demand remains uncertain during the initial project phase. Equipment based on conservative load assumptions requires larger equipment which results in higher equipment costs. The redesign process incurs costs because any change to generator capacity or switchboard specification after the tender stage requires organizations to redesign the whole system (Nakhai, 2023).

Cabling systems create major expenses because their installation difficulty affects system performance and costs. The document establishes that cable installation on ships requires heavy labour because the installation process needs to transport cables through extensive distances while facing limited access points and requires workers to synchronize their activities with other manual work tasks (Carstensen, 1978). The basic labour requirements for cable installation on ships have remained unchanged since Carstensen conducted his study in 1978 while the study shows that cable routing assumptions have a major impact on cost evaluations during initial project phases (Nakhai, 2023).

Power electronic components have become essential for cost management because they include converters and inverters together with their necessary protection equipment and control systems. The components exhibit three specific characteristics which include their overprices unit prices, their lengthy time between supplier order placement and delivery and their response to product design decisions about redundancy and cooling system design (Bertram et al., 2005). The expense for power electronics becomes impossible to predict because system architecture remains undecided at that time.

The preceding section addresses battery energy storage systems as technical systems that function as cost elements. The total installed cost of a BESS, including energy capacity, safety systems, fire protection, thermal management, and grid integration is highly variable and strongly influenced by operational assumptions that are frequently revised as the project develops. The early estimates which treat battery cost as a fixed line item without uncertainty allowance will result in a large budget overrun (Alblas & Pruijn, 2024).

The cost-critical components display a common structural characteristic which states that their total expenses depend more on design choices made during the initial project phase than on the decisions made during equipment procurement and installation processes. The PMO needs structured risk integrated estimation methods because organizations make their essential cost decisions when uncertainty reaches its peak (Bertram et al., 2005; Nakhai, 2023).

2.3 Cost Estimation in Shipbuilding and Ship Electrical Systems.

The project lifecycle needs shipbuilding cost estimation because it functions as a process that converts technical complexity into financial obligations. The early stages of ship electrical projects present translation difficulties because design data remains incomplete and the electrical system design has not yet reached its complete development. The research on shipbuilding cost estimation methods shows that existing methods have advanced to a high level of complexity but still encounter major difficulties in dealing with projects that involve extensive customizations and unpredictable elements.

2.3.1 Early Phase Cost Estimation in Shipbuilding

The capital project literature establishes that early phase decision making processes determine total project cost outcomes. Design commitments lead to system architecture decisions and major equipment choices and redundancy level selections which create a barrier to controlling lifecycle costs after detailed engineering starts (Smith, 2008). The quality of an early phase estimate goes beyond financial evaluation because it represents an important strategic matter; organizations face permanent cost pathways which become later challenging to reverse after they make poor initial estimates.

In shipbuilding the particular problem becomes more difficult because each project requires clients to drive their own custom design choices. Pre-contract stages start with design work which has not yet developed beyond its initial state while client demands continue to change and project scope requires major assumptions to determine final boundaries (Alblas & Pruijn, 2024). Electrical systems face this problem especially because the load assumptions and system architecture together with integration requirements undergo major changes from tender stage to detailed design stage. The early estimates must create multiple possible outcomes which vary from the expected results.

The strategic implications of this uncertainty extend beyond individual projects. The combination of organization wide ship electrical project estimation errors at the early phase generates increasing financial risk for the entire organization. The PMO requires estimation governance control because it represents the strongest evidence base in support of this argument. The cross-project view shows the full error pattern which enables error correction opportunities to become visible.

2.3.2 Cost Estimation Methods Used in Shipbuilding

The shipbuilding industry has developed various estimation techniques which enable project teams to deal with uncertainties that arise during initial project phases. Permitted estimation uses previous cost data from projects with similar characteristics to create initial cost estimates for upcoming work; parametric estimation uses statistical techniques to connect design measurements with their corresponding costs; feature based costing defines cost associations between engineering characteristics which are derived from preliminary design specifications.

Shipbuilding researchers have focused their attention on feature-based estimation as a method for creating reliable initial project cost predictions which can be drawn up before complete design plans are finished. Feature based methods enable estimators to create detailed cost estimations by linking design components to cost drivers which exist within the ship work breakdown structure (Lin & Shaw, 2017). The development of a method that enables quick design iterations during the early design stage through its application of short duration feature based costing to execute multiple cost assessments which take place during the initial design comparison process (Caprace & Rigo, 2012).

The performance of all these methods becomes limited when they are used in environments that require extensive custom project development. The historical data which supports analogous and feature based methodologies becomes untrustworthy when projects exhibit major differences in their specific areas of work and their operational systems and their chosen technical methods (Deul et al., 2024). Ship electrical projects create this problem through their custom configurations since the database needed for parametric or analogous estimation to function correctly does not exist in a way that can be used for estimating new vessel types. Experts continue to make decisions which lead to different project outcomes because organizations lack proper PMO governance throughout their projects.

2.3.3 Electrical Systems Within Ship Structures

The total expenses of a ship operating system include electrical systems which take up an important sizable portion of the total expenses. The work breakdown structure for ship costs separates electrical discipline into power generation and distribution and cabling and automation and control systems which need different estimation methods and contain distinct uncertainty patterns (Bertram et al., 2005). The challenge arises because these categories lack independence since decisions about one category impact the expenses of other categories which creates difficulties for simple unit rate estimation models to capture their interdependence.

The connection between design choices and their financial impact establishes a direct path between design choices and ship electrical system costs. The choice of system redundancy and voltage level and equipment topology lead to equipment procurement costs which results in additional engineering hours and more difficult installation processes and specific cable routing needs and testing requirements (Ross et al., 2003). The initial phase estimates which treat the cost elements as separate items instead of interconnected design outputs lead to systematic underestimation of cost impacts resulting from design uncertainty.

The estimations at early phases become problematic because they fail to address labour cost as an additional aspect. The installation of electrical systems in ships requires extensive labour which results in high expenses that depend on the distance of cable routing and the limitations of accessing areas and the efficiency of installation work which fluctuates with different types of work environments (Carstensen, 1978; Nakhai, 2023). The process of estimating tender stage factors depends on general rules instead of conducting specific project analyses which results in most cost overruns during the project.

The existing literature shows that estimation methods with structured frameworks deliver valuable outcomes while there remains substantial uncertainty for ship electrical systems, especially during the early project stages. The uncertainty that stays with ETO projects emerges as a fundamental characteristic of their operation which takes place under time and information limits. The proper response requires organizations to adopt methods that demonstrate uncertainty instead of pursuing more accurate results from their current single point assessments which need both methodological transformation and PMO governance structure to achieve success.

2.4 Project Management Office (PMO) and Cost Governance

The strategic value of cost management knowledge and practice establishes its significance for organizations which manage multiple complex projects portfolios. The PMO has emerged in both academic literature and professional practice as the appropriate organizational unit for this function, not because it replaces project level estimation but because it provides the cross-project perspective standardized processes and governance mechanisms which individual projects cannot supply for themselves.

2.4.1 Role of the PMO in Cost Management

The PMO centre handles cost management through budget tracking but it establishes standard operating procedures that enable organizations to compare their cost estimations and control methods with other projects. The established project management professional standards determine that organizations need to maintain process repetition throughout all project stages while implementing cost management systems that control expenses across project lifecycle (PMI, 2021). Organizations experience estimation problems because project teams use different methods to create their budget predictions which prevents them from assessing whether cost overruns result from improper estimation or scope changes or execution problems or the standard ETO project uncertainty.

The empirical literature on PMO structures reveals that PMOs vary considerably in their influence over project management practice. Research by Hobbs and Aubry (2007) found that mature PMOs which direct projects through their established authority resulted in better project outcomes because their leadership role enabled them to create unified project methods. The need for a PMO with complete power to establish estimation rules becomes essential in ship electrical contracting because the business operates on narrow profit margins and estimation mistakes lead to immediate financial losses.

PMO engagement in cost estimation includes strategic functions that extend beyond their duty to establish standardized procedures. The early project phase estimates serve multiple purpose because they function as project documents while also serving as necessary inputs for bidding decisions and portfolio resource distribution and organizational risk assessments. Inconsistent estimation practices across projects create fundamental obstacles for the organization which must manage its total financial risks. The PMO established estimation governance activities for organizations through its role in risk management and quality control functions.

2.4.2 Standardization and Estimation Governance at PMO Level

The PMO can provide its greatest assistance to cost estimation work by implementing a classification system which defines exact standards for estimating accuracy required at each phase of project development. The principle behind such framework 'that early phase estimates carry fundamentally different levels of reliability than later stage estimates and should be communicated and used accordingly' is well established in both academic literature and institutional practice (LBNL, 2024). Organizations that lack this classification system tend to treat early phase figures as more accurate than they actually are which creates false expectations that lead to apparent project failures when actual costs increase.

Standardized estimation governance also addresses a subtler but equally important problem; the inconsistency of assumptions applied across projects. The organization loses leaning potential when project managers or estimators select different contingency rates and labour productivity assumptions and scope uncertainty methods because it becomes impossible to determine whether one project achieved better results through superior execution or through choosing more cautious initial assumptions. Organizations need governance structure which mandate documentation of estimation assumptions because such structures enable them to achieve significant learning outcomes (Goh, 2005).

The literature identifies estimation practice transparency which requires clear description of included elements excluded elements and made assumptions and estimation confidence level as a major governance element. The transparency serves multiple stakeholders because technical teams must understand how estimates are created, and management requires uncertainty knowledge to decide on bid acceptance and PMOs need documented assumptions for their project assessments process (Goh, 2005). The transparency function assumes special importance in ship electrical projects because client-facing tender estimates impact both technical and commercial aspects.

2.4.3 PMO Decision Making in Early Project Phases

The project decision-making process becomes complicated because early projects face two opposing decision-making problems which create maximum decision impact with minimal decision support resources. The PMO's role in this context is to provide governance mechanisms that help organizations make defensible decisions under uncertainty not by eliminating uncertainty, but by ensuring it is explicitly acknowledged and measured where possible and factored into the decision (Monteiro et al., 2025) most effective decision making process which includes establishing governance mechanism and operational procedures for their staff and development decision frameworks.

PMOs face their main challenge during project execution because they must balance two opposing needs which require them to maintain control over project operations while allowing project teams to work flexibly. The creative problem-solving process which defines effective early phase engineering work gets obstructed by governance framework which impose excessive control over project activities while governance framework which impose insufficient control raise barriers to estimating project needs through improper governance. The literature states that effective PMO frameworks deal with this tension through established procedures which direct teams to create and store their project assumptions while maintaining the choice to establish project specific assumptions which serve their particular needs.

The PMO needs to concentrate on two specific aspects which involve discovering and measuring uncertainty during early phase estimation work for ship electrical projects because these areas require assessment throughout the project. The organization needs to develop governance activities, which need estimation, transparency, and organizational discipline because technical experts from ship electrical systems cannot complete these requirements.

2.5 Risk Integration and Early Face Cost Uncertainty

Early project phases established a fundamental link between risk and cost which functions as a permanent structural element. Early project estimates carry their original degree of uncertainty because they depend on initial project assumptions which will undergo changes throughout the project's progression. The present situation requires assessment to determine whether people recognize uncertainty or handle it through structured measurement and truthful communication of its existence. The research on risk integration within cost estimation demonstrates this specific issue because its main finding shows that separating cost estimation from risk assessment results in persistent estimation errors which directly impact PMO work in ship electrical contracting.

2.5.1 Sources of Early Face, Cause Uncertainty

The cost uncertainty that affects early project stages begins from several combined factors which can be classified into technical elements and organization elements. Technical estimation inputs for early project stages need known values because design information remains incomplete, and the system architecture remains unverified together with evolving client requirements (Odeh et al., 2019). In ship electrical projects, electrical load assumptions, equipment specification and integration requirements are particularly susceptible to revision. Each change to these inputs propagates through the estimate, sometimes with amplified effects.

Early face uncertainty involves organizational factors which maintain equal significance to the technical aspects, yet research studies show they receive less investigation in estimation studies. The combination of limited engineering discipline coordination together with unclear contractor-client scope responsibility distribution and the time pressure during tendering processes creates an environment where optimistic assumptions go unchallenged, which leads to cost risk underestimation (Torp et al., 2020). The errors which occur in this situation do not happen randomly, instead they form systematic biases, which stay fixed throughout the process of making individual estimates more accurate. Governance level authorities need to handle these matters.

Technical uncertainty and organizational uncertainty together produce actual cost estimation uncertainty throughout the project phase which decision makers receive only when they receive specific information. An estimate presented as one value shows confidence together with precision which the analysis behind it cannot prove. The research gap which this thesis addresses relates directly to one of the most common ways cost managers in early project phases misrepresent their confidence level.

2.5.2 Risk Integration in Cost Estimation

The case for integrating risk analysis directly into cost estimation rather than treating it as a separate downstream activity, rest on a straightforward observation: if the cost of a project depends on assumptions that carry uncertainty, then the cost estimate itself should reflect that uncertainty. A deterministic point estimate answers the question 'what do we expect this to cost?' but fails to answer the more important questions: 'what might it cost if things go worse than expected?' and 'how confident are we in this figure?' Risk Integrated estimation approaches are designed to answer these questions directly (Schieg, 2006; Odeh et al., 2019).

Decision makers receive risk adjusted cost ranges and confidence levels, which they obtain through probabilistic cost analysis that uses distributional cost elements and multiple uncertainty modelling through Monte Carlo simulation (Tayefeh Hashemi et al., 2020). The full probabilistic modelling process needs many resources for routine tendering work, but range-based methods that show optimistic, expected, and pessimistic cost scenarios improve decision-making results compared to deterministic methods.

The literature demonstrates that cost risk and schedule risk share a relationship which experts use to connect their analysis. The time-dependent nature of ship electrical installation labour-based costs creates a direct link between schedule risk and cost risk because delays cause extended labour hours and increased overheads. The risk adjusted cost estimates of the project improve their accuracy when project teams recognize these dependencies which connect cost risk and schedule risk (Hulett, 2004).

2.5.3 Contingency and Confidence Levels

The early face cost estimation process suffers from its most common mishandling when it comes to handling contingency which represents the cost estimate's uncertain elements and the known risk factors. The literature documents a widespread tendency to apply contingency as a fixed percentage of the base estimate which derives from rules of thumb rather than from any analysis of the specific risk and uncertainties associated with the particular project (Fouzi, 2010). The method results in contingency figures which lack both proper size and consistency across different projects and which cannot be justified based on the genuine risk assessment of the estimate.

The more defensible approach for determining contingency requires decision makers to assess their estimate exceedance probabilities based on specific confidence levels established by contingency assessment. The approach calculates cost allowances through assessment of required confidence levels, which differ from the use of uniform contingency percentages (Kwon & Kang, 2019). The operational distinction matters because P50 estimates serve internal planning needs while organizations without financial capacity to handle 50% probability cost overruns should not use them for commercial tender bids.

The most important change an implement to improve its estimation practice involves creating standard confidence level, which all tender estimates should follow as a requirement for PMO governance. The system establishes clear estimate definitions which allow projects to be compared, and it generates a contingency document which can be assessed against earlier data during future evaluations.

2.5.4 Implications for PMO Level Risk Integration

The research on risk integration reaches a unified conclusion which organizations need to understand because risk integrated estimation delivers superior decision outcomes, but its full advantages emerge only through continuous application of the method which needs governance backing instead of independent project team implementation. The project environment establishes dual pressures because time constraints and competitive forces drive teams to provide intentionally reduced budget projections, which the PMO can combat through its power to implement standardized risk assessment procedures (Schieg, 2006).

The governance function establishes its most critical importance during competitive bidding situations because of the high risk which exists at this governance function. Systematic underestimation, driven by optimism about risk and uncertainty, creates a selection mechanism in which the contractor who underestimates most consistently wins the most tender and loses money on them. The PMO requires control over the risk integration process because it needs to match all early face cost estimates with actual project expenses which should match contract terms instead of following a pattern of decreasing competitive assumptions (Pentico, 1985).

The argument for PMO level governance becomes more convincing for shipping electrical contracting because its business model depends on narrow profit margins, which make project cost overruns lead to organization wide financial damage. The reviewed literature supports the conclusion that integration risk into early phase estimation is not merely good practice but a financial necessity in complex, customized project environments, and that achieving this integration at a consistent organizational level requires a structured PMO framework of the kind this thesis proposes.

2.6 Engineering to Order (ETO) Context of Ship Electrical Projects

The engineering to order ETO classification is not merely a descriptive label for ship electrical projects, it identifies a set of structural characteristics that fundamentally shape how cost estimation and risk management must be approached. The ETO context requires understanding as essential knowledge which engineers need to create estimation and governance frameworks that will function properly in the operational areas of ship electrical contractors.

2.6.1 Characteristics of Engineering to Order Projects

The ETO project needs unique client solutions that engineers must create before production work can start. ETO projects require extensive design and engineering work which develops through three unpredictable factors: scope changes, client modifications, and technical uncertainties, which occurs before project cost estimation begins (Hicks et al., 2000). The estimation process faces structural challenges because the necessary information for a dependable estimate remains inaccessible at the required time for estimate creation.

The ETO category includes projects which differ greatly in their level of custom development and how much client input they need for design decisions. Willner et al. (2016) conducted research to develop ETO project types through their study, which discovered that high complexity ETO project types experience the most estimation difficulties because their design process requires multiple rounds of changes while project teams work closely with clients to create synchronized work plans which depend on joint decisions between engineering and procurement teams. Ship electrical projects always fit into the high complexity category because they require vessel specific layouts and need to follow regulatory constraints while implementing complicated system integration processes.

The estimation process in ETO environments faces, a secondary challenge because the project database contains historical data, which cannot be reused. Every project needs its unique set up, which makes it necessary to change previous cost records before using them for new estimates because of differences in project scope and system design and technical difficulty (Hicks et al., 2000). The estimation process according to this standard method becomes less effective when the requirement for expert judgment increases. The expert judgment process needs governance structures for proper calibration and evaluation because it naturally develops optimistic outcomes.

2.6.2 Impact of Customization on Cost Estimation

The process of customizing products causes multiple different pathways to impact how costs are estimated in ETO settings. Unique designs create direct effects, which prevent the use of established unit rates from previous projects because installation productivity and equipment lead times and engineering hours per deliverable all depend on project specific features which do not match generic benchmark standards (Gosling et al., 2015). The estimation process becomes uncertain because of the introduction of multiple variables that function together to produce greater uncertainty than what their individual effects would create.

The similarity-based estimation method which seeks to enhance pure analogous methods through direct measurement of project differences between reference project and new scope works to partially address ETO environment challenges. The similarity-based methods which systematically change historical cost information based on known complexity and scale and technical differences produce better early phase estimation results than simple analogies (Deul et al., 2024). The success of this method relies on both the historical project database quality and accessibility, and the estimator's capacity to determine which similarity dimensions are relevant because these factors differ greatly between different organizations.

When estimating electrical cost for ship customization projects, the most significant impact results from the fact that customization provides access to multiple estimation methods which create an accuracy floor that defines the minimum uncertainty range which can be achieved with the currently available information. The initial estimation phase for ETO ship electrical projects will create uncertainty ranges which exceed the desired limits of both project managers and clients. Organizations should establish estimation and governance procedures, which accurately measure uncertainty while presenting their findings in an understandable manner as their solution to this situation.

2.6.3 Implications for PMO Level Estimation and Risk Management

The EYO characteristics of ship electrical projects make PMO level involvement in estimation and risk management not merely beneficial but necessary. Project teams will create their own estimation methods because their projects have different requirements, but this practice will create a situation where organizations cannot learn from their work and compare their output across different projects. The PMO establishes unified estimation standards together with risk assessment requirements and assumption documentation to create a system which enables consistent execution across various projects (Hicks et al., 2000; Willner et al., 2016).

The ETO context requires the PMO to handle both its project management duties and its knowledge management responsibilities. The completed projects provide estimation calibration information because they show which assumptions were right, which risk occurred and which contingency levels worked. Estimation inputs for ETO projects depend mainly on past project data because these projects create unique conditions. Organizations need to establish intentional processes that will enable them to acquire knowledge because this process cannot occur by itself (Hicks et al., 2000).

The ETO cost estimation process becomes structured with PMO cost estimation systems and risk management systems which ship electrical contracting organizations can use to create better, ETO operations. Uncertainty measurement and communication require the establishment of continuous measurement processes, which should develop systematic methods to decrease uncertainty by gathering project knowledge throughout time.

2.7 Summary of Literature and Research Gap

The chapter examined five groups of research literature, which linked to the main research question about ship power systems and their cost factors, and ship building cost estimation techniques and PMO governance and cost control methods and risk management together with initial stage project uncertainties, and the unique engineering to order approach used in ship electrical work. The five research areas provide a clear explanation of the difficulties which arise from making ship electrical contract cost estimates during the initial project phase and the available tools and methods for estimation and the areas where existing knowledge fails to meet requirements.

The technical literature establishes that modern vessels use ship electrical power systems which create more electrical complexity because of their use of electrification and MVDC system design and hybrid propulsion systems and battery energy storage which leads to increased costs that developers must handle during their early cost estimation process (Guo et al., 2023; Fan et al., 2023; Tang et al., 2024; Shin et al., 2021). The literature identifies four vital elements, which determine project costs because power generation equipment and cabling systems and power electronics and energy storage systems all depend on project design requirements which remain unknown during the early design phase, but will probably undergo future modifications.

Research on ship building cost estimation shows that most project expenses occur during the initial design phase which makes design phase cost estimation essential for strategic decision-making (Smith, 2008: Alblas & Pruijn, 2024). Feature based and parametric estimation methods provide organizations with structured estimation solutions during their early design phase when they have limited information (Lin & Shaw, 2017; Caprace & Rigo, 2012), but their effectiveness decreases during ship electrical projects which require customized solution in ETO environments (Deul et al., 2024). The project context remains unchanged despite this method application which leads to residual uncertainty because it requires direct management.

The PMO literature identifies organizational level governance as an essential complement to project level estimation practice. PMOs which create common estimation methods and assignment of estimate precision categories and mandatory assessment of estimation basis lead to organizations maintaining identical processes and executing evaluations across multiple projects and acquiring knowledge which individual project teams are unable to achieve by themselves (Hobbs & Aubry, 2007; PMI, 2021; LBNL, 2024; Goh, 2005). The PMO governance literature developed mainly to study general project management situations which limits its usefulness for solving ship electrical contracting problems.

Risk integration research provides theoretical proof together with practical methods which assist organizations in implementing uncertainty assessment into their cost estimation process. Estimation quality and decision-making abilities during uncertain situations improve through the application of probabilistic methods and risk based contingency planning and combined cost schedule risk assessment (Hulett, 2004; Tayefeh Hashemi et al., 2020; Kwon & Kang, 2019; Schieg, 2006). The literature fails to provide detailed practical instructions about implementing these methods through governed estimation processes at the PMO level because organizations understand the theoretical recommendations yet fail to implement them.

The ETO literature shows that ship electrical projects face ongoing estimation difficulties because of their need for unique design and their limited ability to use established standards which requires organizations to develop solutions that extend beyond their individual project boundaries (Hicks et al., 2000; Willner et al., 2016; Gosling et al., 2015; Deul et al., 2024). The structural response to these challenges, knowledge management, standardized processes, and cross project learning requires exactly the organizational infrastructure that a well-designed PMO can provide.

2.8 Identified Research Gap

The fire research streams reviewed in this chapter have each made important contributions to understanding cost estimation, risk management, PMO governance, and ETO project characteristics. The literature lacks research which combines these streams into an integrated process-based framework that serves as a PMO tool for early phase cost estimation and risk management in ship electrical projects.

Existing studies address ship electrical system complexity, cost estimation methods, PMO framework and risk integration largely as separate research domains. The interfaces between them, 'how PMO governance should be designed to support risk integrated estimation in an ETO context, how estimation processes should be structured to account for the specific cost drivers of ship electrical systems, and how contingency determination should be governed at the organizational level', receive minimal attention. The academic research boundaries create a practical gap for organizations who must manage all these dimensions at once.

Organizations require practical process-oriented frameworks, which help PMOs implement cost estimation and risk analysis during early project phases of ship electrical contracting work. The organizational ability to manage uncertainty gets restricted by this gap, which also affects their capacity to make strategic decisions during the tendering and concept design stages when commitments occur.

2.9 Contribution of This Research

The research establishes a PMO level framework which connects early-stage cost estimation with risk management for ship electrical projects to address the research cap. The framework in this chapter uses ETO cost estimation methods and PMO governance principles and risk integration approaches which the reviewed literature provides to establish its evaluation through documentary evidence from to completed ship electrical projects at Team Electric Group. This project will develop an academic framework together with the practical process which ship electrical contracting PMOs can use for their operations.

3 Research Methodology

3.1 Research Approach

The type of research question that exists in a study determines which research method can provide valid solutions to its inquiry. The study investigates methods which enable PMO personal to implement early phase cost estimation together with risk assessments methods in their work on ship electrical projects. The words how signals an orientation towards process, mechanism and organizational practice rather than towards statistical measurement or hypothesis testing. The research study functions as a qualitative investigation because it aims to achieve deep comprehension of the subject matter instead of creating widespread generalizations.

Qualitative research functions best when researchers study phenomena which exists within an organizational context that needs complete separation from its surrounding environment (Creswell 2014). The study meets both of these requirements. The practice of PMO-level cost estimates exists as a concrete operation which depends on the governance structures dealing with commercial pressure and professional routines and technical attributes of the organization. The understanding of the organization requires actual organizational evidence with research need to study instead of relying on abstract numerical data.

The study uses an interpretivist philosophical framework for its research activities. The interpretivist perspective maintains that organizational practices exist as social construction which people must create through their social interactions with others. Measurements alone cannot determine the gap between expected early phase estimation behaviour and actual performance. The organization requires real documentary evidence to understand estimation process through their operational documentation which needs document-based evidence.

The research logic operates primarily through induction. The empirical investigation uses theoretical concepts from the literature review which established cost estimation methods and risk integration approaches and PMO governance and ETO projects characteristics as its analytical framework. The study does not aim to test existing theories through direct research activities which validate specific propositions.

Research use the research method which follow a qualitative approach and interpretivist framework and inductive reasoning method because they need to study organizational process and create operational framework for early phase cost estimation and risk assessments in ship electrical projects.

3.2 Research Design

The research study uses a single-case design which include multiple analysis units throughout its investigation. The case study method becomes essential when researchers want to study a modern phenomenon within its actual organizational setting because both elements remain so interconnected that researchers cannot investigate them as a separate entity (Yin, 2018). The current condition meets this requirement in its entirety. The study of PMO-level estimation practices require access to the particular workplace setting because the organization-based research level which governance structures and project portfolio elements and commercial context component shape PMO level estimation practices.

The single case is a ship electrical contracting organization operating in an engineering-to – order environment. The organizational framework uses two ship electrical projects as embedded units of analysis. The researchers chose this embedded design because it served their requirements better than any other option. The research design enables project comparison between two projects which share the same governance framework to document differences in estimation and risk practices documented through study methods. The organizational element which shows consistent patterns across both projects become responsible for these patterns because they emerge from general organizational behaviour instead of unique project details.

The study identified PMO level cost estimation and risk integration process as its main analysis unit while excluding both project cost outcomes and technical system specifications and individual estimator behaviour. The two projects serve as empirical lenses which reveal the operational processes of the organization while assessing their functions instead of being evaluated based on their performance.

The embedded case study design which the researchers selected matches the qualitative case study research framework created by Yin (2018) while serving the study's exploratory purpose and framework development goals. The design enables multiple documentary evidence sources to be combined while creating a framework for gap analysis which link empirical results with theoretical principles established in chapter 2.

3.3 Case Study Context

The study's empirical research takes place in a ship electrical contracting company which operates within the shipbuilding and marine field. The organization handles the complete process of engineering and procurement and installation and testing and commissioning for electrical system which serve vessels. The organization works on all aspects of power generation and distribution systems and main and emergency switchboards and cabling and containment systems and lighting systems and automation and control systems and electrical power systems which connected to both population and auxiliary equipment. The organization throughout this thesis research maintains its anonymity as the case organization which follows standard academic procedure for handling commercial sensitive research.

The case organization operates in an engineering –to-order environment in which every project is developed from the ground up to meet vessel-specific requirements. Every project has its own unique combination of scope and configuration and technical complexity. The ETO characteristic creates extra challenges for cost estimation during early phases because estimator need to modify historical cost data from past projects before using it to estimate costs for new tenders. Estimators need to depend on their judgement and their experience and their assumptions with parametric reasoning which all create uncertainties that build up in the tender estimate.

The case organization uses a Project Management Office structure which manages estimation governance and planning coordination and PMO level project control throughout all projects. The research focus on the PMO level processes which control project management activities across the organization. The PMO level of analysis serves as the essential level of organizational analysis because it enables the unit to create standard estimation procedures and to implement governance requirements and to gather knowledge from various projects.

The case includes two ship electrical projects which function as embedded units of analysis. Project 1 covers the electrical projects which function as embedded units of analysis. Project 1 covers the electrical installation work for Theatre and Spa area on a cruise vessel undergoing a dry-dock refit. Project 2 covers the electrical installation work for a Restaurant and Public space area on second vessel undergoing separate dry-dock refit. The two projects operated under identical organizational governance procedures with both projects receiving the same PMO supervision. The two projects share an institutional context which enables researchers to analyse difference in their practices which researchers can investigate instead of attributing differences to varying organizational environments.

The selection of these two ship projects was purposive. The projects were selected as representatives of project scopes which generate maximum commercial value during early phase estimation because their tender document and execution documents provided accessible evidence for study and their technical scope variations enabled researchers to conduct cross case comparison. The case organization functions as an empirical setting which enables researchers to study research questions while they develop the proposed framework.

3.4 Data Collection Method

In this study, documents from both case studies were systematically analysed. The approach was created to achieve both research objectives and the actual conditions of the case context. It is only through documentary evidence that estimation decisions are recorded in real time, before outcomes are known, after any retrospective reinterpretation has been made. The method achieves its strongest point through its ability to gather data which other collection ways cannot reproduce.

3.4.1 Documentary Analysis as the Primary Method

The study collects its data solely based on documentary analysis method. The two projects examined their documents which included tender stage cost estimates, cost breakdown structures, materials and labour calculations, project cost summaries, final cost outturn records and any PMO level or estimation level process documentation such as estimation templates, estimation guidelines, structure or governance guidelines. The respective project early estimation practice documentation uses each document as a primary source to demonstrate its estimation practice.

The reason for selecting this method because it reflects their actual methodological position rather than a practical limitation. Documentary analysis has established itself as a primary method which meets all requirements of qualitative case study research because it enable researchers to study organization process and governance structures while comparing planned outcomes from organization to actual results (Yin, 2018). The documentary evidence delivers direct and reliable information for this study because research investigates actual estimates and their actual implementation and the subsequent real outcomes.

All documents which organization create during their project execution process carry evidential authenticity, which retrospective accounts do not possess. The organization used commercial time pressure to prepare a tender estimate which showed its actual estimation practice during the specific time period before the project outcome became known. The existence of a risk registers at this stage shows the current stage of risk assessment during the tender process. The record function as actual practice representations which demonstrate how practice functions. The analysis reveals what the organization actually did, not what it remembers or believes it accomplished.

The documentary analysis uses a systematic process which divides into four analytical dimensions which study the complete structure of cost estimation documentation and all risk assessment documents. The structured approach guarantees both project consistency while delivering direct project alignment with all research goals.

3.4.2 Data Collection Sequence and Coverage

Documentation gather evidence from both projects through a method that involves specific sequence of collection. The analysis of each project unfolds through three distinct phases of investigation. The tender stage document undergo examination to show how costs were structured and estimate at the point of bid preparation is the first phase. The risk related documents undergo assessment to identify which risk had been recognized while determining their connection to the assessment process. Finally, the post project cost summary or outturn record is examined to determine the actual cost of the project, the variance against the tender estimate and where documented - the causes of that variance.

This sequence follows the natural chronology of the project lifecycle while showing how estimation practices develop from early stage to final cost outcomes. The analysis establishes the tender stage assumptions which Chapter 4 requires for gap analysis and then performs a comparison with actual results to determine estimation practice failures and their causes.

Table 3.1 Summary of data Collection Approach

Dimension	Choices and Rationale
Primary method	Systematic documentary analysis of project records.
Project covered	Project 1 (Theatre and Spa) and Project 2 (Restaurant and Public space)

Documents examined	Tender estimates, cost breakdowns, material calculations, labour schedules, cost outturn summaries, PMO process documents
Analytical sequence	Tender document first, risk records second, third cost outturn
Analytical dimensions	Cost structure, risk documentation, risk contingency linkage, cross project standardization
Confidentially	Organization and project fully anonymized data used for academic purpose only

3.5 Data Analysis Methods

The research uses an analytical method which consists of three stage that build upon each other to create a deeper understanding of PMO level estimation practices in the studies organization. The three stages of the research process begin with a thematic analysis of project results and then proceed to a gap analysis which compares findings against the best practice standard established in Chapter 2 before ending with a cross-case comparison of both projects.

3.5.1 Thematic Analysis

The analytical step number one entails thematic analysis of documentary evidence on the two projects. In this study, thematic analysis will imply the systematic reading of project documents to determine recurring patterns, major absences and uniform practices throughout the evidence base. The analysis process is directed by the five thematic areas that have been set out in the literature review: estimation methodology, risk identification practice, risk-to-cost integration and contingency determination and PMO governance. Through these dimensions one gets the preliminary coding frame by which the documentary evidence is read and interpreted.

The analysis extends beyond the established categories which were defined in advance. The research design uses inductive logic which allows the analytical process to trace new themes that emerge from the documents beyond existing predefined patterns. The analysis examines unexpected patterns found in the documentary evidence which include the profit markup functioning as both a margin and a risk buffer.

Based on thematic analysis, each analytical claim is linked to a specific documentary source. At the beginning of every finding is recorded. Such as which document, which section, which data point-so that the chain of evidence from raw document to analytical conclusion is fully transparent and traceable. The practice establishes credibility for qualitative documentary analysis by providing basis for interpretation which prevents researcher assumption from dominating.

3.5.2 Gap Analysis

The second analytical stage establishes connections between project thematic results and Chapter 2 best practice standards. The gap analysis serves as the primary analytical element Chapter 4 because it establishes empirical evidence for the proposed framework through gap identification between established literature standards and documented actual occurrences.

The gap analysis uses the five thematic dimensions established in the literature review to create framework that enables direct comparison between theoretical standards and actual empirical measurements. The analysis provides answers to two questions for each dimension, it shows best practice identification from literature, and it shows actual occurrences through documentary evidence. The distance between these two answers constitutes the gap. The identified gap function as essential findings which deliver primary input to Chapter 5 framework design because the framework developed in that chapter functions to solve all gaps discovered through empirical research.

3.5.3 Cross-Case Comparison

The analytical process of the third stage requires researchers to systematically access the thematic and gap findings from both projects that they studied. The two projects show consistent patterns because both operate under identical PMO governance frameworks which apply to their respective organizational operations. The study uses cross-case comparison as its method to transition from project specific insights to organizational wide findings.

The projects show multiple common patterns which include both projects showing no formal risk register at the tender stage and both projects using the same method to calculate contingency. The study examines project differences to determine what they disclose about the factors which cause variations within the common governance system. The cross-case comparison does not seek statistical generalization its purpose is to strengthen the analytical basis for conclusions about organizational practice by demonstrating that observed patterns are not unique to a single project.

3.6 Research Quality and Trustworthiness

The evaluation of qualitative research quality requires using specific criteria which focus on validation and testing reliability. These criteria exist because different theoretical approaches require different standards. The study design specifically addresses all dimensions which need to be studied.

Credibility of research finding investigates how well these findings real workplace situations. The research relies on documentary evidence as the primary source to establish its credibility. The documents examined were produced during the actual execution of the projects at the time decisions were being made, under real commercial conditions they represent practices as they actually occurred rather than as they are subsequently recalled. The structured analytical protocol, which applies the same analytical framework consistently across both projects, further supports credibility by reducing the risk of selective or impressionistic interpretation.

Dependability describes how research methods maintain their consistent operational standards through transparent research processes. The study provides complete description of its data collection and analysis method which enables reviewers to assess the research process. The research process complete transparency through structured protocol implementation and explicit analytical dimension definition and continue analysis design.

Confirmability requires research evidence to establish analytical conclusion while maintaining objectivity by preventing researcher bias through evidence-based analysis. The analytical claims need direct evidence from documentary sources which establish the strict requirement. The document provide evidence which establishes current practice standards that the researcher expected to discover. The research study uses gap analysis as an external anchor which establishes specific theoretical standards from the literature to reduce research bias.

Transferability examines whether the results of the study and its proposed framework apply to situations outside the studied case. The thesis presents an organizational context and project description together with PMO structure and estimation practices which help readers determine how research results apply to comparable ship electrical or ETO project environments. The Chapter 5 framework establishes transferability through specific case evidence which relates to fundamental principles within existing academic knowledge.

3.7 Ethical Considerations

The research uses commercial confidential organizational data which includes project documents and cost record from the case organization according to established ethical standards required for academic research involves organizational partners.

The case organization and all projects are the fully anonymized throughout this thesis. The document does not reveal any identifying information about the organization which includes company names and project identifiers vessel names client names and all other details. The data access condition required anonymization process which the research team applies throughout all chapters of their work.

There are no third parties involved in the use of all project documentation accessed for this study. It was solely used for academic purpose and has not been shared with anyone else. The case organization granted access to its documentation through explicit permission. The researcher controls the secure data storage system which allows only access to the stored information. The researcher conducts research work as an independent academic who has no commercial relationship with the organization and thus his research results have no financial ties to any organizational partners. It is crucial that the results of the evaluation are reported honestly and transparently, including areas of weakness in the organization's current practices.

3.8 Methodological Limitation

The study recognized four methodological limitations which researchers must consider understanding the study results and determine their use in other situations.

The research uses organizational case as its foundation. The embedded design which studies two projects within that case and boots the analytical foundation for reaching conclusions about organizational practices. The research results provide analytical generalization through which the theoretical framework was developed and tested against real world data. The result research provides analytical generalization through which the theoretical framework was developed and tested again real-world data.

The study depends on documentary evidence which represents its only source of information. The research question receives suitable treatment through this method because its methodology assessment leads to a limited analytical capacity which depends in document content. The analysis cannot identify estimation practice element which people execute without official documentation through verbal communication or informal methods. The analysis treats the absence of a particular document for example a risk register as a finding while the analysis cannot identify practice which existed yet produced o documentary evidence.

Third is the empirical analysis works only with two projects stage which include tendering and concept design. The study does not follow projects through detailed engineering installation or commissioning, which means that some consequents of early –phase estimation discussion can only be examined to the extent that post-project cost documentation was made available. The research scope operates within the boundaries which match the research objectives, yet it limits the empirical evidence that should be accessible.

The study focuses specially on ship electrical projects in an ETO environment. The framework and findings are intended primarily for this context. The research requires evaluation to determine if the marine systems, contracting environments or industries have additional uses. The research requires evaluation to determine if the marine systems, contracting environments, or industries have additional uses.

3.9 Summary of Research Methodology

This chapter establishes the methodological foundation which supports the empirical analysis conducted in Chapter 4. The study uses an exploratory qualitative research design which follows interpretivist principles through its main inductive research approach. The research design employs a single case study which includes two embedded units of analysis because this design allows for detailed PMO level processes while using a constant governance framework to enable comparison between different projects.

The research gathers data through the systematic documentary analysis which examines project records from both cases. The study selects this method because it represents the best research option which provides accurate evidence of organizational activities conducted during early project phase which were document at that time. The analysis proceeds through three sequential stage which involve thematic analysis of individual project findings and gap analysis against the best practice standards established in the literature review and cross-case comparison across two projects. The research introduces qualitative trustworthiness criteria which include credibility, dependability, confirmability and transferability to evaluate research quality. The research maintains ethical standards by protecting confidentiality, obtaining organizational permission and using data responsibly. The research admits four methodological boundaries which establish research limits while informing further research direction through single case scope, documentary only evidence, restriction to early phase project phase and sector specific applicability.

This chapter presents a research methodology which establishes an organized and clear foundation for building empirical evidence in Chapter 4. The chapter establishes every analytical claim through documentary evidence which links to specific sources and establishes every gap through measurement against defined theoretical standards and establishes every cross-case conclusion through evidence from both projects.

4 Empirical Findings and Analysis

4.1 Introduction to Chapter 4

The chapter four presents research findings through systematic documentary analysis which examined two ship electrical projects. Project 1 (Theatre and Spa) and Project 2 (Restaurant and Lounge). For this chapter review documents gathered from company. Those documents are tender stage calculation, commercial offer letters, cost overrun records, projects closure meeting and organization's estimation process related documents.

The analysis builds around five thematic dimensions developed based on the literature review. Those are estimation methodology, risk identification practice, risk-to-cost integration, and contingency determination and PMO governance. In this chapter, first explain the evidence and then assessed against best practice and finally identify the gaps of both two projects.

This chapter is structured in the following way. Project 1 context and documentary overview discussed in section 4.2. Thematic analysis for Project 1 provided in section 4.3. The gap analysis for Project 1 shows best practice compliance in section 4.4. The context and documentary overview of Project 2 appears in section 4.5. Thematic analysis for Project 2 given in section 4.6. The gap analysis for Project 2 shows its compliance with best practice standards in section 4.7. Comparison between two projects present in 4.8. Section 4.9 combines the findings into the framework requirements which support Chapter 5. The chapter summary appears in section 4.10.

4.2 Project 1 – Context and Documentary Overview

4.2.1 Project Scope and Commercial Context

Project 1 is about electrical installation of two areas of cruise ship called Theatre area which measured 540 square meters and Spa area. The complete electrical installation work for both areas included the installation of all lighting fixtures which consisted of spotlights, LED strips, ceiling lights, wall lights, wiring and containment work and point-of-sale system wiring and data wiring for seating and all necessary small materials. The company issued a separate design quotation for ceiling and floor and power distribution layouts drawings.

The project took place in Brest France during a 25-day dry dock period. The initial contract value was €152,390 with additional works subsequently agreed which brought the updated contract value to €163,590. A Polish company and a Portuguese company provided two subcontractors who together sent approximately eight workers to work on-site. The project was formally closed on 27 May 2025.

The project 1 identified as Large (L) classification according to the organization's project classification matrix because its total value exceeded the risk-score threshold and its execution required multiple international sites with multiple subcontractors plus a dry-dock execution context. These classification triggers the most governance-intensive process in the framework.

4.2.2 Documents Examined – Project 1

Table 4.1 lists all six documents examined for Project 1.

Table 4.1 Documentary Evidence Base – Project 1

S/N	Document	Contents	Analytical roles in this study
1	Project 1 calculation - Theatre	• Labor: PM (128 hrs.), Supervisor (212 hrs.), 5 Electricians (212 hrs. each), Welder (212 hrs.), 2 POS technicians (210 hrs. each), Travel (6*16 hrs.) • Materials: 94 spotlights, LED strips, ceiling and wall lights, Roxtec fittings, system allowance	➢ Primary source for estimation methodology ➢ Shows how labour and materials were costed. ➢ Most complete document in the evidence base

		• Markup factor 1.25 applied to all items (20% gross profit target)	
2	Project 1 calculation - Spa	• Labor: Welder heated chair installation, standard chair installation • Materials: LED strips, chairs, small materials • Multiple line items show zero values and division by zero errors.	➢ Reveals inconsistency in estimation quality. ➢ Template used as starting point only – not fully completed. ➢ Evidence of partially populated estimate
3	Project 1 offer – Theatre & Spa (Q5, issue 5)	• Final commercial quotation – fifth version after negotiation • Prices have broken down by sub-area and work package. • Payment terms: 30% upfront/40% during work / 30% on completion • Exclusions list design, travel, accommodation, yard access, ceiling removal, lighting programming.	➢ Shows how scope boundaries were set. ➢ Exclusions list reveals risk transfer strategy to client. ➢ Evidence of commercial negotiation process

4	Project 1 offer – Design (Q2)	• Separate quotation for design work only • Covers: ceiling drawings, floor drawings, power layout drawings • Includes PA system, smoke detection and emergency lighting updates. • Total design price: €10,080	➢ Reveal design and installation were treated as separate financial streams. ➢ Design costs not integrated into installation calculations. ➢ No single combined cost view existed at tender stage.
5	Project 1 cost summary	• Actual cost: Design €4,748, Electrical work €39,396, Supervisor €10, 975, Materials €59,158, Other €2,511, PM €1,968 • Total actual cost: €118,756 • Actual revenue: €163,590, Profit €44,834	➢ Foundation for cost variance analysis ➢ Compared against tender estimate to identify over/under-runs. ➢ Shows design costs (€4,748) not included in original calculation.
6	Project 1 closure meeting (D26)	• PM self-rating: 2.5/4 • Sub-contractor issues: Communication difficulties with Portuguese subcontractor • Lessons learned: Site visit before project	➢ Only document containing risk – related commentary ➢ Risk identified retrospectively after project ended not before. ➢ Key evidence of absent prospective risk identification process

		recommended; French labour laws should be checked at estimation stage. • Customer satisfaction scores recorded.	

4.2.3 Financial Summary – Project 1

Table 4.2 presents the key financial parameters for Project 1.

Table 4.2 Project 1-Financial Summary

Financial Parameter	Value (€)
Initial contract value	152,390
Updated contract value (with additional works)	163,590
Actual revenue recognized	163,590
Actual total project cost	118,756
Profit to date	44,834
Actual gross profit margin	~27.4%
Tender-stage target margin	20%
Revenue uplift from additional works	+11,20020%

The initial assessment of these figures shows positive results because the actual margin of 27.4% exceeded the tender-stage target 20% by approximately 7% points. But in below sections analysis clearly shows this profit earned from addition (works valued at €11,200) and risks did not materialize. Not because of the accurate accost estimation. So, the Project 1 is earned profit but not because of the good estimation.

4.3 Thematic Analysis – Project 1

4.3.1 Estimation Methodology

The Project 1 used a bottom-up estimation method because all cost elements need separate calculations which required specific data inputs instead of using single general formula. The method is used for early-stage shipbuilding cost estimates because it requires estimators to analyse every project element in depth. Labor costs appeared as total expenses which resulted from multiplying total worker count by their work schedule hours and hourly wage rate. The sales price calculation used a markup of 1.25 because this markup resulted in 20% gross profit margin which applied to all estimate items for labour and materials.

The Theatre area calculation stands as the strongest document among all Project 1 evidence. Because it complete and fully detailed. The document shows expenses of 128 hours for Project Manager (€25.20/hour), 212 hour for Supervisor (€21.00/hour), 212 hours for five Electricians (€17.50/hour), 212 hours for one Welder (€17.50/hour) and 210 hours for two POS technicians (€1.00/hour), 16 hours of travel costs for six people at €17.50/hour. The total installation cost price is €32,037.60 which generates a sales price of €40,047.00. the materials list breaks down into component parts which include 94 spotlights LED strips ceiling and wall lights cables Roxtec penetrations a systems allowance and chairs. The materials cost €75,545.30 while the materials sales price amounts to €94,431.63 of which the materials cost €75,545.30. The Theatre area provides two cross check options which show installation cost at €74.16 per square meter and material costs at €174.87 per square meter while covering an area of 540 square meters.

The Spa area calculation tells a different story. The spreadsheet shows few material line items (LED strip for dividers Roxtec fittings and cable) with zero cost values that result in division by zero errors for the profit percentage columns. Accommodation, travel and freight show up as line items, yet their assigned zero values lack any provided justification. The Spa document exists as an incomplete template which contains partial content instead of presenting a complete cost estimation.

The analysis of both calculations shows two additional gaps. The Theatre document and Spa document both use identical spreadsheet formats, which demonstrates that the organizations has implemented a standardized estimation template across its entire operation. But the zero values in Spa calculation shows this document is used as starting point not as compulsory need. The Project 1 documentation failed to include any estimate basis record throughout its entire set of documents. The critical assumptions behind key decisions remain unrecorded because nobody documented the reason for assigning zero prices to certain items and the expected productivity rates and the reference data used in the project. The documents do not show subcontractor costs as separate line items which makes it impossible to determine from the documents how the two subcontractor's labour was priced.

The total absence of design costs from both installation calculation creates a major gap. The actual post-project cost summary shows design costs at €4,748 under Category 1. The design work was quoted to the client through Q-2 at a design cost of €10,080, but this design work is not included in the installation spreadsheets. The tender stage documents never showed the total project cost, of design and installation expenses.

The organization requires all estimation process to include risk margins when supplier costs cannot be verified during the current tendering period according to its own process guidelines. The Theatre calculation and the Spa calculation both lack any form of risk margin. Every time receives a standardized markup 1.25 regardless of whether its cost is known or unknown. The organization needs to establish unique risk standards for all uncertain cost elements, but the current estimation method directly contradicts this requirement. Table 4.3 summarizes the estimation methodology findings for Project 1.

Table 4.3 Estimation Methodology Evidence Summary - Project 1

Estimation Element	**Evidence from Project 1 Documents**	**Assessment**
Labor - Theatre	PM, Supervisor, 5 Electricians, Welder, POS, Travel – all roles, hours and rates specified	Complete
Material - Theatre	94 spotlights, LED strips, ceiling lights, wall lights, cables, Roxtec, system allowance – all quantities and unit price specified.	Complete
Labor - Spa	Welder and chair installation workers specified, travel, accommodation and fight listed as zero	Partial
Materials - Spa	Multiple items show zero cost prices; several columns produce division by zero errors	Incomplete
Design costs	Quoted separately in offer Q-2 (€10,080), not included or referenced in either installation calculation	Not integrated
Area parametric check	Per-m^2 rates calculated for theatre only (€74.16/m^2 installation, €174.87/m^2 materials)	Partial
Subcontractor costs	No separate line items for subcontractor labour in either calculation	Not evidenced
Explicit risk margin	No risk allowance on any uncertain item in either calculation	Absent
Basis of estimate record	No document explaining the reasoning behind key cost assumptions	Absent

4.3.2 Risk Identification Practice

In Project 1 documents could not find any material that shows formal risk identification was conducted. It was recognized after the project completion. The distinction between two risk identification methods is crucial because tender stage risk identification enables inclusions of risk into cost estimation before their actual occurrence. The identification process that occurs in closure meetings shows all past issues to stakeholders who must learn from past mistakes only if they will apply the knowledge (Schieg, 2006).

The Project closure Meeting (D26) serves as the only document in Project 1 as evidence about risks. The document establishes three findings. First one is the company based its estimate on client provided site information rather than its own pre-tender ship check. Secondly, the Portuguese subcontractor faced communication difficulties. So, the closure document requires better manpower selection for future projects. Finally, the closure document states that French labour laws and working hour regulations should have been checked at the estimation stage, but in this case, they were not properly checked.

The tender stage documents show that there is no existing risk documentation which has been formally established. The tender submission lacks three essential documents which include a risk register and risk checklist output and a project-specific risk assessment. The company estimation checklist (D03) has a section designated for known risks or red flags which needs to be filled in the estimation checklist. The Project 1 evidence base does not contain completed versions of both fields. The offer document (Q5) does not contain an exclusion list which shows design and travel and accommodation and shipyard costs as items that the contract price expressly excludes. The client assumes risk responsibility through this process because it only applies to risks which can be removed from the project scope. The contract price includes all costs for risks which need to be managed but those risks receive no documentation. Table 4.4 summarizes the risk identification findings for Project 1

Table 4.4 Risk Identification – Summary of Evidence, Project 1

Risk Item	What the Evidence Shows	Assessment
Ship check before projecting	Company relied on client supplied site details instead of conducting its own pre-tender survey	Not done
Subcontractor quality	Communication difficulties with Portuguese subcontractor noted; better manpower selection identified as needed.	Identified retrospectively
French labour law	Closure meeting explicitly states that labour laws and working hour regulations should be checked at the estimation stage-implying this was not done for Project 1	Identified retrospectively
Formal risk register	No risk registers, no risk checklist output and no project-specific risk assessments found in any tender stage document.	Absent
Completed D03 risk fields	The estimation checklist has a known risks/red flags field, and the approval checklist has a corresponding question, neither is evidence as completed for Project 1	Not completed

4.3.3 Risk to Cost Integration

The process of risk to cost integration requires answering one fundamental question which asks whether all identified risks directly impact the cost estimates through their connection to specific estimated values. The project 1 analysis shows that risk elements do not receive proper treatment during cost estimation process. The estimate lacks any system to transform recognized or potential risk into dedicated cost provisions for expense projection.

The entire risk absorption capacity of the estimate rests on the uniform 1.25 markup factor. The factor applies to all cost elements without exception which means it handles both risky items and regular items as well as certain items and uncertain items. The regular supplier provides well-priced spotlight which receives the same percentage treatment as the Spa material line that has no value. Best practice framework demand separate calculations of risk allowances which must match the specific exposure level of each cost element (Schieg, 2006).

The system in place results in profit margin and risk buffer sharing the same value which cannot be distinguished from one another. The Theatre installation expense of €32,037.60 receives a 1.25 markup which results in spreadsheet showing €8,009.40 as 'Gross Profit' without demonstrating which parts of that total serve as commercial profit and which part will be cover potential cost risks. The system creates dangerous hidden trade-off because when someone decrease the markup from 1.25 to 1.20 for bid purposes, they also decrease the risk buffer by exactly the same amount. The current estimate structure hides this trade-off from view.

The design and installation system creates two independent financial streams which widen the existing gap between these two elements. The design scope requires a total 10,080 according to section 4.3.1 but the actual cost amount to 4,748 which has no relation to the installation estimate. The installation estimate does not include any cost provision for risk which arises from the design and installation interface because design changes will need to redo already built equipment. Table 4.5 summarizes the risk to cost integration findings for Project 1.

Table 4.5 Risk to Cost Integration – Summary of Evidence, Project 1

Element	What was Found	Assessment
Profit and risk separation	The 1.25 markup is labelled as 'Gross profit' in the spreadsheet. No portion is separated as a risk allowance.	Not separated
Risk-adjusted cost elements	Every item receives the same 1.25 markup regardless of whether it is certain or uncertain. A standard cable gets the same treatment as incomplete Spa estimate.	Absent
Design and installation linked	Design (€10,800 quotes €4,748 actual) is completely separate financial stream with no connection to the installation cost calculation	Not connected
Risk provision per cost area	Offer Q5 breaks prices down by sub-area but applies the same markup to all. No differentiation based on uncertainty level per area.	Absent
Competitive bid risk	If the markup is reduced to win a bid, the implicit risk buffer is also reduced. But this trade-off is invisible in the current estimate structure.	Structural gap

4.3.4 Contingency Determination

The base estimate of costs establishes contingency as the designated amount that will cover expenses which exceed the approved budget. Project 1 contains no existing budget for contingency expenses. The Theatre and Spa calculations do not include a contingency budget item. There exists no management reserve budget. The uncertainty allowance exists but does not exist as a separate entity from the commercial profit margin.

The markup factor 1.25 contains a built-in gross profit margin of 20 percent which serves as the sole financial safeguard to handle cost increases. The following three specific issues arise from this situation. The buffer fails to match risk because a subcontractor operating under French labour laws with unpredictable productivity requires the same 20% reserve as standard cable that has a confirmed unit cost. The company needs to cover every cost overrun from the same funds which were meant for commercial profit, this means any cost issue will reduce profits directly because there are no funds to handle the expense. The project evaluation process becomes impossible because all profits need assessment to determine whether they result from accurate project estimates or from risks that did not occur because they were never given price.

The company approval checklist D03 requires reviewers to assess risk mitigation efforts which were completed before the tender submission process. Project 1 evidence does not contain any completed results from this section. Table 4.6 summarizes the contingency determination findings for Project 1

Table 4.6 Contingency Determination – Summary of Evidence, Project 1

Contingency Element	**Evidence**	**Status**
Contingency line item	No contingency row exists anywhere in the Theatre or Spa calculation spreadsheet	Absent
Management reserve	No management reserve or uncertainty allowance found in any tender document	Absent
Risk calibrated provision	Every cost element receives the same 20% buffer regardless of how uncertain that element is – high risk and low risk items treated identically	Not calibrated

Separation of profit and contingency	The 20% markup serves as both commercial profit and risk buffer simultaneously. These two functions are impossible to distinguish	Not separated
D03 approval checklist – risk mitigation field	The checklist prompts the reviewers to consider risk mitigation taken. No completed output evidenced for Project 1	Not completed

4.3.5 PMO Governance

The case organization has established a PMO governance framework which included a process description document and a multi-tab estimation checklist (D03) and a project classification matrix and tiered approval requirements which vary according to project value. The large project designation for Project 1 requires the organization to implement its most intensive governance process tier. The organization has built governance infrastructure which smaller contractors typically lack therefore the framework existence represents a positive result for the organization.

The organization has demonstrated compliance with multiple governance requirements which it established. The commercial offer went through five iterations before being finalized (Issue 5). The offer included three payment terms which specified payments of 30%, 40% and 30%. The project closure meeting (D26) was completed with a structured format including PM self-assessment and subcontractor review and lessons learned and customer satisfaction ratings.

The evidence collection process failed to identify the most essential governance elements which should have been present. The project 1 documents do not include the completed approval checklist which serves as the official governance gate to examine risk flags and verify that the estimate can proceed to the submission stage. Without proof of gate passage the organization cannot determine whether the tender process met the large project governance requirement.

The calculation/cost analysis approval section of the process description document contain only placeholder text. The organization failed to document the most important governance gate in its own process documentation which governs the entire tender process. The PMO level KPIs which are tracked by the organization only measure two factors which are the volume of offers and the rate of successful bids. The organization lacks a KPI which evaluates estimation accuracy and it does not track project specific tender to actual cost differences, and it has no way to identify systematic cost underestimation in curtails expense categories. The estimation gap which caused cost overruns on multiple projects would not create a pattern at the PMO level because different projects experienced the same estimation gap (Goh, 2005). Table 4.7 Summarizes the PMO governance findings for Project 1.

Table 4.7 PMO Governance – Summary of Evidence, Project 1

Governance Element	**Evidence**	**Status**
Offer issues in multiple versions	Offer reached issue 5 (Q5) Evidence of iterative commercial negotiation.	Done
Payment terms specified	30/40/30 payment structure clearly stated in the offer document	Done
Closure meeting completed	Project closure meeting document (D26) completed with PM self-rating, lessons learned, and subcontractor review	Done
Completed approval checklist	The D03 approval checklist The governance gate for reviewing risk flags before tender submission – is not present in the Project 1 evidence.	Missing

Approval process description	The process description document contains only placeholder text in the calculation/cost analysis. Approval section – the governance gate is not properly written up	Incomplete
Estimation accuracy KPIs	KPIs track only offer volume and win rate. No cost variation or estimation accuracy metric is tracked at the PMO level	Absent

4.4 Gap Analysis - Project 1 against Best Practice

The findings from section 4.3.1 through 4.3.5 were assesses against the best practice standards which the literature established in Chapter 2. The table below presents three elements for each of the five analytical dimensions which includes best practice identification from the literature and the actual results from Project 1 document and existing disparity between these two elements. The gaps identified here do not serve ab assessments of individual performance capabilities. The observations describe how organizations implement their estimation and governance process which include the design elements and execution methods. The entire gap analysis for all five dimensions is presented in Table 4.8.

Table 4.8 Gap Analysis – Project 1 against Best Practice Standards

Dimension	What should Happen	What actually Happened	The Gap
Estimation Methodology	• Costs estimated using more than one method	• Theatre: detailed and completed • Spa: template with zero values and errors	✓ Incomplete estimate for Spa scope

	• All assumption clearly documented. • Uncertainty ranges stated • Single combined cost view across all scope elements including design	• Design quoted separately – not connected. • No record explaining why items were left at zero.	✓ No single combined cost view ✓ No documented assumption ✓ No cross-method verification
Risk Identification	• Formal risk register at tender stage • Project specific risks identified before cost is finalized. • Risk checklist fields in D03 completed.	• No risk registering in any tender document. • D03 risk fields not evidenced as completed. • All risk commentary in closure meeting - after the project ended. • Exclusions list transfers some risk but ignores retained risks.	✓ No prospective risk identification ✓ Risks identified only after costs were incurred. ✓ Governance checklist not completed

Risk to Cost Integration	• Identified risks converted into cost allowances. • Profit margin and risk provision shown separately. • Higher risk items carry higher allowances.	• Uniform 1.25 markup is the only cost provision. • No part of markup separated as risk allowance. • Reducing markup to win a bid also reduced risk protection – visibly. • No differentiation between high and low risk items	✓ No risk to cost integration of any kind. ✓ Profit and risk are the same number inseparable. ✓ Competitive pricing decisions unknowingly eliminate risk protection.
Contingency determination	• Named contingency line item in estimate. • Contingency sized to specific risk profile • Higher risk items carry more contingency.	• No contingency line item anywhere • The 20% markup acts as both profit and buffer. • Every cost element - certain or uncertain -	✓ Contingency does not exist as a distinct concept. ✓ Cannot be measured or reported separately from commercial

	• Contingency reported separately from profit	receives the same 20%. • No calibration to actual risk exposure	margin 20% applied uniformly – structurally inadequate for ETO projects
PMO governance	• Estimation checklist completed • Approval checklist signed off before tender • Cost variance tracked as PMO-level KPI • Lessons learned fed back into estimation.	• Offer issued correctly (Issue 5), and payment terms specified. • Closure meeting (D26) completed. • Completed approval checklist not evidenced. • Process description has placeholder text in approval section. • KPIs track offers volume and win rate only.	✓ Approval checklist not evidenced as completed. ✓ No estimation accuracy KPI ✓ Approval process not fully specified in own documentation.

Table 4.8 shows that all five rows display one unified trend throughout the entire table. The organization has established the governance framework which enables proper estimation work through its templates and checklists and project classification matrix and approval process and closure review system. The organization processes resources which other organizations of similar size do not possess. The organization fails which connect the different process components remain missing. The organization fails to identify risks while linking them with potential expenses. The company does not display its calculation of contingency expenses which it treats as separate from its profit margin. The evidence shows that the approval gate which needs to verify these details before tender submission had not been used. The portfolio level lacks as KPIs which would demonstrates all existing gaps in information.

The estimate presents a commercial structure which includes and organized breakdown of labour and materials and standardized pricing method and a formal proposal document, yet it lacks any actual integration of risk factors. The process produces a number which fails to represent all uncertain elements present within different scope. Section 4.5 establish whether Project 2 displays the same pattern or shows different operational methods which can be observed.

4.5 Project 2-Context and Documentary Overview

4.5.1 Project Scope and Commercial Context

In this chapter discuss the Project 2. Project 2 is about electrical installation of two areas of cruise ship called Restaurant named Mason Jar (390m^2) and 100m^2 space Lounge area. This cruise stays in a dry dock nearly 43 days. Compare to project 1 this was longer of 25-day window.

In the restaurant area consist of work for lighting, cabling, smoke detection and PA systems, stage electrical supplies and emergency lighting. While Lounge work included downlights, LED lighting, POS cabling, TV installations, data sockets and system cabling.

Both areas were estimated separately. Offer Q3 (Issue 3) stand for Restaurant and Lounge through offer Q1 (Issue 1) to the same client. Many subcontracting companies were involved, including previous workers who has many experience for new build (NB) vessel projects rather than refits.

Project 2 finished with considerable amount of loss of €24,833. In the closure meeting report, it is clearly identified two reasons for that failure. One is category 3 (electrical work) where working hours exceeded the estimated cost, and the other reason is Category 7 (materials) cost exceed the estimation calculation because of Roxtec fittings not being considered and materials have to be ordered twice.

4.5.2 Document Examined – Project 2

Table 4.9 shows all the six documents which are used to examined for the Project 2.

Table 4.9 Documentary Evidence Base – Project 2

	Document	Contents	Analytical Role
1	Project 2 calculation – Restaurant	• Labor: Supervisor (516 hrs.), 2 Electricians (516 hrs. each), Welder (100 hrs.), Travel (4x16 hrs.) • Material: 27 lines items • Markup: 1.25 applied to all items (19.85% profit) • No project Manager in labour plan	➢ Main source for restaurants estimates. ➢ Shows PM are missing from labour plan. ➢ Shows Roxtec fittings absent from BOM.
2	Project 2 calculation – Lounge	• Labor: PM (40 hrs.), Supervisor (84 hrs.),	➢ Main source for lounge estimate

		Electricians (516 hrs.), Welder (16 hrs.) • Materials: 16 lines items • Markup: 1.30 – higher than Restaurant (23.08% profit) • No explanation for different markup rate	➢ Shows markup inconsistency within same project. ➢ PM hours are too low for 43-day project
3	Restaurant offer Q-3 (Issue 3)	• Installation: €38,220 • Materials: €55,300 • Total quoted: €93,520 • Exclusions list and payment terms included.	➢ Shows scope boundaries and risk transfer. ➢ Exclusions list compared to Project 1 ➢ Evidence of commercial negotiations
4	Lounge offer Q-1 (Issue 1)	• Installation: €15,750 • Materials: €13,930 • Total quoted: €29,680 • Exclusions list and payment terms included.	➢ Shows scope boundaries for lounge. ➢ Combined with Q-3 to give full tender picture
5	Project 2 Cost summary	• Actual total cost: €190,889 • Actual revenue: €166,055 • Loss: €24,833)-14.9%) • Category 3 and 7 both exceeded estimate.	➢ Foundation for loss analysis ➢ Shows which cost categories overran. ➢ Confirms loss driven by labour and materials.

6	Project 2 closure meeting	• Pm self-rating: 2/4 • NB workers are not suited to refit environment. • Roxtec not counted; materials double-purchased. • Customer satisfaction: Quality 3/5, Service 2/5	➢ Identifies specific loss drivers after project ended. ➢ Evidence of absent prospective rest identification ➢ Same subcontractor risk as Project 1 – Systemic pattern

4.5.3 Financial Summary – Project 2

Table 4.10 shows the main financial figures of Project 2

Table 4.10 Main financial figures of Project 2

Financial Parameter	Value (€)
Initial contract value	142,551.50
Updated contract value (with additional works)	164,561.60
Actual revenue recognized	166,055.40
Actual total project cost	190,889
Profit/Loss to date	-24,833 (LOSS)
Actual gross profit margin	-14.9% (negative)
Tender-stage target Restaurant	~19.85%
Tender-stage target Lounge	~23.08%

Primary loss drivers	Category 3 – exceed the labour hours. Category 7 – Roxtec omission and double purchase materials

This €24,833 loss clearly shows this project spent approximately more than 27% of the revenue it received. Finally in the closure meeting confirm that loss has happened because of labour hours in category 3 and material amount in category 7. And also, aluminium Roxtec fitting cost were not included in the original estimate. The material s had been purchased twice because stock which is used before Covid has been already used for another project.

4.6 Thematic Analysis – Project 2

4.6.1 Estimation Methodology

As Project 1 used similar bottom-up estimation approach for the Project 2 also. But in this project estimates were not strong in many important points like previous time. And because of that weakness directly lead to the project loss.

The main issue in the Restaurant estimation was there is no Project Manager included in the labour plan. Because this project is 43-day project with multiple subcontractors wants a PM. But in this project, there is only Supervisor for the Restaurant. And also estimate allocated PM for Lounge only for 40 hrs, which is very low for this complexity. Simply if the management time is not costed, it doesn't disappear, it absorbed hours of the people who actually work on site, pushing implementation time above the estimate labour.

Then the other issue was the totally missing of Roxtec penetration fitting from the material list of Restaurant. In ship electrical work, Roxtec are very essential item, where needed cable pass through fire rated walls and floors. This absence can directly contribute to the material overrun occurred by Category 7.

At last, both restaurant and Lounge used two different markup factors. 1.25 markup for restaurant and 1.3 markup for Lounge. But this is not explained in any document why it happens. There is no record for this rationale decision, sometimes deliberate or in response to two estimators working separately.

Table 4.11Estimation Methodology Evidence Summary - Project 2

Estimation Element	Evidence from Project 1 Documents	Assessment
Labor – Restaurant	Supervisor, 2 Electricians, Welder, Travel, No Project Manager included	Partial – PM absent
Labor – Lounge	PM (40hrs), Supervisor, Electricians, Welder. PM hours too low specially for 43-day project with multiple sub-contractors	Present but insufficient
Material - Restaurant	27-line items at 1.25 markup, Roxtec fittings completely missing, Several zero values	Inconsistent - unexplained
Material - Lounge	16-line items at 1.3 markup, Several zero values	Partially incomplete
Markup consistency	Restaurant 1.25 (19.85% profit) vs Lounge 1.3 (23.80% profit). Two different rates in the same project, No explanation	Undocumented and risky
Explicit risk margin	No risk allowance on any uncertain item in either calculation	Absent
Basis of estimate record	No document explaining the reasoning behind assumptions, zero values or productivity rates	Absent

4.6.2 Risk Identification Practice

As Project 1 risk identification in this project also used same patter, no risks were found before the project started. Risks were found after financial losses has already occurred.

In the closure meeting of Project 2 clearly indicate four risks were all known at the tender stage. First one is New Building workers were used for the refit project. Because there are different types of works while refit wants different skills, various habits and also different mindset. Subcontractor experience would have been revealed by a simple pre-tender question. Second one is there is not any rest days were included into 43-day schedule. This is basic planning oversight.

Third risk as per closure meeting, it directly shows Roxtec fittings were not included to the estimation calculation. This is not a surprise risk. It is actually component that was simply forgotten during the estimation. If there is structured pre-tender checklist available, this can be easily noted. Final risk is material purchased, which is done before Covid had been allocated on another project and were not available. If there is quick pre-tender stock check this can be identified earlier.

Main thing in here is subcontractor risk because it also happened in Project 1 closure meeting. In Project 1 there is a communication problem with Portuguese subcontractors while in Project 2 had the new building vs refit mismatch. Those are two different details but same underlying problem. The same lesson mentioned in both projects and it does not turn to estimation input. This is clearly highlighted broken lesson learned feedback loop (Samset & Volden 2016).

Table 4.12 Risk Identification – Summary of Evidence, Project 12

Risk Item	What the Evidence Shows	Assessment
Subcontractor suitability	NB workers used for refit project. NB and refit have different skills. This mismatch can lead to performance failure.	Identified retrospectively

Rest day scheduling	This is 43-day dry dock project, and it needs rest days included to the schedule. But it is no included. This can lead to schedule pressure	Not planned for
Roxtec omission	Closure meeting mentioned Roxtec components were not included to the estimate. This is standard component. That means simply left out of the BOM	Unidentified at tender
Double purchase of materials	Pre-Covid materials used for another project. Because of that had to purchase again. If the pre-tender stock check would have found this.	Unidentified at tender
Formal risk registers	No risk registers, no completed D03 risk fields, and there is not any project specific risk assessment in tender stage documents.	Absent
Similar risk as Project 1	Subcontractor risk mentioned in both projects closure meeting. Same lesson but did not embed between projects	Systematic-not resolve

4.6.3 Risk to Cost Integration

In Project 2 the risk to cost gap was not theory based, it shows real financial loss. Those three risks were predictable. No provisions were made for costs. All the three have materialized. But finally result was project loss of €24,833.

The first risk involved in labour productivity. Even in Project 1 had specifically noted labour productivity risk as something needed to be checked against French law of labour, but it was never checked. As a result of that when original value declined below the assumed values, category 3 was overrun.

Then Roxtec omission. As there is no line item for Roxtec in BOM, no money allocated for it. When it is need for fittings on site, then cost for it pass directly to Category 7 with nothing included it.

Finally, materials double purchase risk. Because pre-covid stock had been used for another project. But nobody checked about this stock before tender submission. When it realized materials had to been purchase again for higher value. Then cost was totally under control.

Some or all of the loss could have been absorbed if those risks were recognized, given cost and risks, and added to the estimate as risk allowance. Opposed to this every single euro of risk cost grounded directly as a project loss (Hulett, 2004).

Table 4.13 Risk to Cost Integration – Summary of Evidence, Project 2

Risk Scenario	Was it Foreseeable	Cost Provision
Productivity of Labor – exceed the hours	Yes 516 hrs imply 12hrs/day. French labour law was flagged in Project 1 closure. This is known risk earlier but ignored	€0
Roxtec omission – missing from BOM	Yes, Roxtec are standard non-optional item. Any structured review would have caught this.	€0
Double purchase – stock material not available	Design (€10,800 quotes €4,748 actual) is yes, a pre-tender stock would have shown materials were already consumed.	€0
Combined financial impact	All those three risks materialized. There is no buffer exists. So full cost absorbed as a loss.	€0

4.6.4 Contingency Determination

There is not any contingency available in Project 2 tender document. Because no contingency row shown in Restaurant calculations and No Contingency row available in the

Lounge calculations. A profit markup served as the only financial buffer instead to serve as a profit margin rather than a safety net against risk.

When considering the target margin, the restaurant target 19.85% and Lounge targeted 23.08%. But real figure is negative margin of 14.9%. So, the difference between target profit and actual loss nearly €49,700. Commercial margins could not cover this loss since they were never designed or sized to do so.

During the closure meeting details, the client noted that client is sending new requests for proposal and the future estimates are now more accurate. This is somewhat positive, but it indicates Project 2 is price of learning. If contingency check at the tender level, this learning would have turned into advance rather than profit loss discover.

Table 4.14 Contingency Determination – Summary of Evidence, Project 2

Contingency Element	**Evidence**	**Status**
Contingency line item	No contingency row exists anywhere in the Restaurant or Lounge calculation spreadsheet	Absent
D03 risk mitigation field	Risk mitigation is prompted in the checklist, but neither scope has been completed.	Absent
Financial consequence	Loss €24,833. This is nearly €49,700 which is below the target profit margin	Direct financial loss
Future opportunity	As part of the closing meeting notes, the client is sending latest RFQs, acknowledge Project 2 as the cost of learning	Opportunity at high cost

4.6.5 PMO Governance

In this Project 2 also used similar PMO framework as Project 1. The same procedure followed in here also, issued multiple versions of offers, clearly mentioned the specified payment milestone and closure meeting is completed. But the same as Project 1, there is no completed approval checklist, no estimation accuracy KPIs and couldn't found any mechanism for lesson learn or feeding lessons back to future estimates.

In Project 2, there are three standard governance observations are standard. First one is markup difference between Restaurant (1.25) and Lounge (1.30) was never flagged. It would have been possible to question the different rates if a reviewer had completed a final approval checklist. It was not identified which is confirming the approval gate was not tested.

Then the other point is absence of Project Manager if Restaurant calculations. This also never flagged. This is significant error that any type of review can caught. So, in the final offer it confirms there is not any meaningful governance check was used.

Finally, the same issue faced in Project 1 regarding quality risk of subcontractor selection is mentioned in both projects closure meetings. But this risk already company found and documented it. And the problem is doing not convert estimation input for the next project. This conversation is not provided for in the governance framework, the financial consequences of that missing link are recorded in the loss of Project 2 (Goh,2005)

Table 4.15 PMO Governance – Summary of Evidence, Project 2

Governance Element	Evidence	Status
Offer issues in multiple versions	Restaurant reached issue 3, Lounge Issue 1 – this shows commercial process flow	Done
Payment terms specified	30/40/30 payment structure clearly stated in the offer document	Done

Closure meeting completed	Project closure meeting document (D26) completed with PM self-rating 92/4), lessons learned, and subcontractor review	Done
Completed approval checklist	No evidence for its present. Markup inconsistency and absent of PM not identified. So, approval gate was not used.	Missing
Consistent markup standard	Restaurant 1.25 and Lounge 1.30 markup in the same project. No PMO level low for markup calibration.	No standard
Lesson fed into next estimate	Same subcontractor problem occurred as Project 1. Lesson noted but did not feedback.	Not embedded
Estimation accuracy KPIs	No KPIs tracks tender to actual cost difference. Category 3 and 7 overruns were invisible before the loss.	Absent

4.7 Gap Analysis – Project 2 Against Best Practice

A comparison is made here between Project 2 findings and best practice standards applied in Project 1 in section 4.4. The main difference in project 2 gaps are not theoretical. They have documented and direct financial outcomes. The loss of €24,833 is traceable to significant failure along all five analytical measurements. Table 4.16 illustrates those all gap analysis in Project 2.

Table 4.16 Gap Analysis – Project 2 against Best Practice Standards

Dimension	What should happen	What Actually Happened	The Gap
Estimation Methodology	• Multi method estimation	• PM absent from restaurant	✓ Roxtec and PM omissions caused direct

	• All assumptions documented • Consistent markup across project • Standard components in every BOM	• Roxtec missing from BOM. • Markup 1.25 vs 1.30 – no reason given. • 516 hrs./day implies 12 hrs. – not documented.	loss inconsistent markup unexplained productivity assumption caused Cat.3 overrun
Risk identification	• Risk register at tender stage. • Risk identified before cost in finalized. • Previous project risks feed into next tender	• No risk register or D03 risk field completed. • All risks found in closure meeting – after project. • Roxtec, double-purchase, subcontractor unidentified	✓ No prospective risk identification ✓ Three foreseeable risks all materials and losses ✓ Same subcontractor risk recurred without fix
Risk to cost integration	• Risk converted to cost provisions • Risk provision separate from profit.	• Uniform markup is the only buffer. • No risk-cost connections • Three foreseeable	✓ No risk to cost integration mechanism. ✓ All three risks had zero provision. ✓ Directly caused the €24,833 loss.

	• Profitability x impact used to size allowance	risks zero cost provision	
Contingency determination	• Named contingency line in estimate. • Sized to specific risk exposure • Separated from profit margin	• No contingency in restaurant or lounge • Markup serves both profit and buffer. • No calibration to actual risk profile	✓ Absent contingency caused the project loss. ✓ No buffer existed for any of the three risks €24,833 loss was preventable
PMO governance	• Completed approval checklist. • Consistent markup standard • Estimation accuracy KPI • Lessons fed back after each closure	• Approval checklist not completed. • Markup inconsistency not flagged. • Same subcontractor lessons reappear. • KPIs track pipeline volume only	✓ Governance gate missed critical errors. ✓ Project 1 lessons not embedded in Project 2 recurring subcontractor risk confirms broken loop.

As per that table every gap recognized in Project 1 also shown in Project 2. But the difference is in Project 2 results are quantifiable and real. The Roxtec missing, the assumptions of undocumented productivity and also double purchase of materials are not behind the analytical failure. They are the key factors for project loss of €24,833. Then in section compare findings among two projects.

4.8 Cross-Case Comparison – Project 1 and Project 2

4.8.1 Consistent Patterns across Project 1 and 2

The main problem influence for cross case comparison is, the gaps identified in Project 1 which are specific to the project 1, or are they identified in Project 2 as well? If the answer is yes, same gaps appear in both project 1 and 2, they are not someone mistake. Those gaps are organizational patterns; those can only control at the PMO level not by the project level.

In the below table 4.17 illustrates eight gaps identified in both projects. Every gap is found in both. No arguments. This confirms those gaps happen due to structural issue, because estimators do what the flow ask them to do. In the current flow it is missing the connection among risk, cost, contingency and governance.

Table 4.17 Consistent Patterns across Project 1 and Project 2

Pattern / Gap	Project 1	Project 2	Nature	Overall impact
Absence of formal risk registers at tender stage	Confirmed absent	Confirmed absent	Systematic	High
Absence of explicit contingency provision	Confirmed absent	Caused €24,833 loss	Systematic	Critical
Profit markup double	1.25 constant markup	1.25 and 1.30 different markup	Systematic	High

Incomplete calculations with zero values	Spa- partially not complete	Restaurant and Lounge both not complete	Systematic	Medium
Risk recognized analytically only	Ship check, labour low, subcontractor issue. All in closure	Roxtec, double purchase and subcontractor issue. All in closure	Systematic	Critical
Absence of completed approval checklist	Not present in evidence	Not present in evidence	Systematic	High
KPIs track pipeline field only	No cost variance KPI	Overruns invisible until identified loss	Systematic	High
Subcontractor risk recurring without settle	Communication issue with Portuguese subcontractors	NB works are not good for refit projects	Recurring	Critical

The main serious issue is the fully absence of connection among risk identification and cost provisions. Both Project 1 and 2 have commercially structured estimations with detailed spreadsheets, completed professional offers, accurate pricing. But did not include any risk assessment to cost. So, the estimation sheets commercially successful but risk blind.

And also, there are recurring subcontractor risks which must be considered. As an example, Project 1 faced communication difficulties with Portuguese subcontractors, while in Project 2 there was a confusion among NB mentality and retrofit mentality. Same basic problem but different specific details. Both are mentioned in closure meetings. Any of these two converted into a risk prompt for the next project tender. This is clearly showing broken feedback loop (Samset & Volden, 2016).

4.8.2 Differences between Projects

It is important to note two differences. First one is markup value mismatch in Project 2 (1.25 for Restaurant and 1.30 for Lounge) has no equality in Project 1, where it continues 1.25 markup for total project. This markup variation issue is not governed in PMO level. Because individually estimators can used various values without documented rationale.

Second difference is the financial outcomes were different. Project 1 earned profit of 27.4% while Project 2 lost 14.9%. But same estimation framework created two different results. There is a simple reason behind this. In Project 1 the risks did not materialize and extra scope was included. But in Project 2 specific three risks did materialize and there was nothing to include them. There is no need of having framework which is only effective when everything works well because one bad project can erase the profits from several otherwise successful things in business with thin margin.

4.9 Framework Requirements

After analysis, both projects creates five requirements for the framework which is going to design in Chapter 5. Each and every requirement of these frameworks collect from the specific gap identified by the evidence. More than invented new ones, these requirements complete the structure of the governance that already exists within the organization. As per gathered data, the D03 checklist exists. The D26 closure meeting exists, and approval process exists. What is not contain in here is the content which help them work.

Table 4.18 Framework Requirements Derived from Cross-Case Analysis

	What the Framework Must Do	**Why – Evidence from Both Projects**	**Gap It Address**
1	Formalized risk identification – mandatory D03 step	No risk registers available in any project.	Risk Identification PMO Governance

		Same subcontractor issue in both closure report-never fixed. Risk found after cost were incurred.	
2	Risk calibrated contingency as a separate line item	Project 2 loss €24,833 because three risk have zero space. Project 1 earn profit because risk did not materialize. This is not because the accurate estimate	Risk to Cost Integration Contingency
3	Separated margin and contingency in the estimate format	1.25 markup mixes profit and risk-difficult to separate. Bid decisions unconsciously eliminate risk protection. Nobody cannot guest the trade-off being made	Risk to Cost Integration Contingency
4	KPI accuracy of estimation at PMO level	KPIs check only offer amount and win rate of both Project 1 and 2. Categories 3 and 7 impact were invisible before the loss found. No process to check recurring estimation errors.	PMO Governance

5	Lesson learned fed back into estimation inputs	Subcontractor risk identified in Project 1 but did not fix before Project 2. Roxtec and French labour low-found post project only. Similar error repeated in both projects because the broken of feedback loop.	Risk Identification PMO Governance

Those five frameworks highlighted every gap identified by both Project 1 and 2. As per above table 4.18 requirement 1 solve the risk identification absence. Requirement 2 fixes contingency absence. Requirement 3 solve invisible profit-risk trade-off. Requirement 4 found solution for missing part of estimation accuracy KPI. Last requirement corrects broken feedback loop. Based on those five requirements chapter 5 will design real framework and show how it works with the help of actual project 2 data.

4.10 Chapter Summary

In this chapter explained two separate electrical projects of Project 1 (Theatre and Spa) and Project 2 (Restaurant and Lounge) with the help documentary analysis among five criteria. Those are estimation methodology, risk identification, risk to cost integration, determination of contingency and finally PMO governance.

As per those data Project 1 completed with profit of €44,834 against 20% target. This has seemed to be achievement. But reality is that profit earned from scope additions and risks which have not materialized from correct estimation. The existing process had the same gaps as identified in project 2. What can be identified is Project 1 profit has occurred due to fortunate, not well estimate.

Project 2 completed with a loss of €24,833. In the closure meeting it’s clearly said what the reasons are for exceed the labour hours than estimate, missing of Roxtec fittings in the BOM and purchasing of material twice. All three failures are expectable. None of these have cost provision. Without a risk identification steps and contingency plan, this type of direct financial consequence can happen (Flyvbjerg et al, 2002).

Under cross case comparison part identified eight systematic patterns in Project 1 and 2. No risk register, no contingency, profit markup difference as risk buffer, incomplete calculations, un-evidenced of checklist approval, KPIs only for pipeline, retrospective only risk identification and subcontractor issues never correct during the projects. These cannot say individual errors; those are organizational problems which involved into the estimation process.

Finally, those five framework needs were designed from evidence found from 2 projects. These are the guidelines for the Chapter 5 and directly focused on second research objective of examine the current practice and third research objectives is recognized the gaps which explained in Chapter 1. And also, these give answer for the research question of how to improve cost estimation and risk integration at the PMO level.

5 Proposed PMO Level Framework for Cost Estimation and Risk Integration

In previous chapter (Chapter 5) identified five gaps in the way of teams Electric Group handles cost estimation and risk management. Risks were recognized only after project ended. There was not any space for separate line item for contingencies. There is no separation between profit and risk. It considered risk and profit as combination, and one included one markup figure. Both projects were failed to complete the governance checklist. And also, lesson learned from Project 1 never used for Project 2. Those gaps become reason for loss of €24,833 on Project 2.

The main aim of this chapter is designing a five-phase framework to address five gaps. And also design simple excel tool to demonstrate this framework using Project 2 real data.

There are two important things to follow. First one is this new framework will be never replaced to what Team Electric already use. The D26 closure meeting, the approval process, the D03 checklist will be remain as same way. The only thing done by this framework is add what the things are missing within the structure. Second one is each and every stage is created to match within the normal tender background. Never used any specialist software, no need of special training. As assumed, this excels tool will only takes 45 minutes to finish.

5.1 Introduction

In the Chapter 4, create five framework requirement using gaps identified in both projects. In here those requirements will be convert to phase. As an example, Requirement 1 will be converted to Phase 1. This connection certifies those frameworks is create from the real evidence of Project 1 and 2, not from normal practice. Table 5.1 shows the structure of this Chapter 5.

Table 5.1 Chapter 5 Structure Overview

	Section	What It Does	Connect To
5.1	introduction	Organized the chapter and describe the way it connects to Chapter 4	Chapter 4 – five requirements
5.2	Design Principles	Describe four principles which are used to create the framework	Chapter 4 findings
5.3	Five- phase Framework	Explain every phase in detail	Five requirements from Section 4.9
5.4	Excel Tool	Shows how the excel tool work in real practice	Phase 1-4
5.5	Applied in Project 2	Real Project 2 data use to illustrate what the framework would have changed	Project 2 – Chapter 4
5.6	Chapter Summary	Summarize the framework and give answers to the research questions	Research question – Chapter 1

5.2 Framework Design Principles

The framework is designed by four principles, every principle directly linked with findings of Chapter 4 regarding the nature of case organization.

Evidence based framework is the first one. Each and every phase covered the gap identified in Chapter 4. Did not include any additional details because this has seemed to be good in a textbook or any other framework include it.

The second principle is the addictive nature of framework. Because as per the collected data, Team Electric already has D03, D26 and approval process checklist. So new framework did not ignore any of these. The only thing is framework covered the missing parts within them. Risk field is already included in the D03 checklist, so Phase 1 finalizing it necessary. Phase 5 connects the lesson learned in D26 with the next tender.

Practical simplicity is the third principle. Normally tendered are prepared with heavy time pressure. Without any special training each and every step in this framework can be done by competent estimator. Based on this excel tool is created.

The last principle self-improving. As move to the next phase, Phase number 5 covers the lessons learned at the end of every project and convert them back into Phase 1. Table 5.2 summarizes all four principles.

Table 5.2 Framework Design Principles

	Principle	**What It Means**
1	Evidence-based.	Every phase covered gap identified in Chapter 4. Did not include anything new because it seems to be good in textbook.
2	Additive	There is already D01 checklist, D26 closure meeting and approval process exist. So, the framework helps to create missing section within it. It did not involve replacing anything.
3	Simple	Within the normal tender area everything can be done by estimator. No need of having special skill for new software. The excel tool takes only short period to complete everything.
4	Self-improving	Phase 5 feeds lessons from each project back into Phase 1 of the next tender. With every completed project the framework will become automatically better?

5.3 The Five-Phase PMO Framework

This framework consists with five phases. Phase 1 to Phase 4 use during the tender stage and Phase 5 will be used in project closure and give feedback to Phase 1 of next new project. This is like completing cycle. Table 5.3 explained quick summaries for all the five phases which are going to use in framework.

Table 5.3 Five phases of framework

	Phase	What Happens in each Phase	Result
1	Risk Identification	When the estimate is going to completed, estimator will check risk prompt list and note down which risk relevant to the specific project	Risk register will be completed with signed and date.
2	Risk Costing	Every risk found in the project is given probability percentage and a cost impact (€). As per equation Risk allowance = Probability x Cost Impact. And Total Contingency equal by adding all the allowances together.	This total contingency value goes to the third tab of the excel tool
3	Integrated Estimate	Three separate lines are added to cost estimate restructure. Base Cost, Contingency and Profit Margin	Estimator can visible and separate three figures clearly
4	PMO Review	Before the tender submission PMO reviewer should check risk registers, contingency calculations and estimate structure.	Signed the D03 approval checklist
5	Post-Project Learning	In D26 closure meeting, a risk prompt list is made for future tenders after reviewing materialized risks	Updated risk prompt list and this will be used input to

			Phase 1 in next project tender.

Phase 1 - Risk Identification

In here the estimator goes through an organized list of risk prompt before finalizing the cost calculation and then estimator note which risks are applicable for relevant project. For this process it will take around 20-30 minutes and identify what are the missing or completely absence in both projects like documented, project specific risk register has been filled before the tender submission.

This risk prompt list is generated from two sources. One is standard list; it covers the commonly identified risks in ship electrical refit projects. And in the other source the updated list consisted with newly found risk during the latest project which is mentioned in closure of Phase 5. Then list become more accurate after completing each project.

Table 5.4 Phase 1 – Risk Identification

Element	**In Detail**
Purpose	In here be sure that the risks are recognized BEFORE completed the cost estimate. Not after finishing the project.
When	During the tender preparation stage. This is compulsory.
Who	Risk register is complete by estimator while PMO reviews it in Phase 4.
Standard risk prompt	Are all the main or standard component are clearly mentioned in the BOM (Roxtec, cable containment, fixing and etc)? Are the selected subcontractors relevant to the project (New build or refit)? Have local or related country labour low restrictions been checked?

	Are pre-purchase materials actually available in stock or not? Are the assumptions related to labour productivity is realistic and documented? In the contractor is it clearly explain the scope?
Output	A signed project specific risk register which is link to the D03 checklist
Gap it closes	As per chapter 4, both projects did not have risk registers at the tender stage. So, the risks were only identified at the closure meeting after the loss had already occurred.

Phase 2 – Risk Assessment and Costing

It is not enough to identifying risks. The most important thing is absent in both project is converting each and every risk faced into certain cost. In this phase is used to recover this issue using simple probability and impact calculation.

In here each risk, estimator have to include a probability (how likely is this happen) and cost impact (how much need to allocate for that risk). By multiplying these two factors risk allowance for that specific risk can be obtain. Then estimator can add all the risk allowance together to find total contingency of that project. This value automatically goes to Tab 3 in the excel tool.

Those figures no need to have mathematically exact. This must be sensible and documented. With the help of 30-minute risk assessment can create more credible and accurate figures rather than flat percentage applied without any analysis.

Table 5.5 Phase 2 – Risk Assessment and Costing

Element	In Detail
Purpose	In order to reflect the real uncertainty of the project scope, convert each risk identified into money.
The calculation	Risk Allowance (€) = Probability (%) x Cost Impact (€). Then add all the risk allowance of every risk together to calculate Total Contingency
Probability guide	High (60-80%) – high chance to happen based on the project situation and experiences. Medium (30-50%) – Possibly, but not sure Low (10-20%) – High chance to not happen, but worth mentioning
Cost impact guide	If the risk happens then it calculates the additional cost. Use known figures such as labour rate x additional hours, material quantity x material unit price. This is no ne need be exactly accurate. Just reasonable.
Output	A total contingency value is automatically flows in Tab 3 of the excel tool
Gap it closes	There was zero money assigned to the risk of both projects. Whether it was 20% in Project 1 or varying between 19.85% and 23.08% in the Project 2. Only the markup was buffer.

Phase 3 – Integrated Cost Estimates

A key change in Phase 3 is the way of cost estimate structured. It provides three separate visible figures opposed to one combined markup factor for base cost, contingency and profit margin.

In the current situation uniform markup connected risk and profit in one value. During Project 1, the rate was 1.25. But in Project 2, the Restaurant markup is 1.25 and Lounge markup is 1.30. Two different figures within the same project. If someone reduced that markup for the purpose of win the competitive tender. That means its effect to reduce the risk buffer also. But no one can notice this. Therefore, with these three separate lines, each and every decision taken for pricing can be visible and transparent. Contingencies remain protected unless they are deliberately reduced.

Table 5.6 Phase 3 – Integrated Cost Estimation

Element	In Detail
Purpose	To explain contingency and profit margins are not one combined markup. There are two separate numbers.
The structure	Line 1: Base Cost – (labour, material, subcontractor, travel) Line 2: Contingency – total figure from Phase 2 (Specific amount) Line 3: Profit Margin – target of commercial return (ex; 20% of base cost) Line 4: Total Cost – Sum of Line, Line 2 and Line 3
Why this matters	In both projects, a constant markup connects profit and risk into one number. Project 1 and Project 2 Restaurant scope markup is 1.25. And Project 2 Lounge scope markup is 1.30. In all cases if someone reduced the markup to win the bid, the risk buffer was also can reduced. But the problem is no one noted this.
Output	Estimation can be created with three different and visible financial components.
Gap it closes	Both projects, profit and risk ere mentioned as same number. Competitive bid decisions were unknowingly eliminating risk protection.

Phase 4 – PMO Review and Approval

In the phase 4 governance gate is check. That means before the tender submission PMO reviewer can check the estimation is correct or not with using output received from Phase 1, Phase 2 and Phase 3. This review will take around 20 to 30 minutes. Then create signed approval checklist which is missed in both projects.

Estimation accuracy KPIs also introduce in Phase 4. When each project finished, PMO categorized each record of tender to actual cost difference. As an example, if labour cost in category 3 exceeds over the allocated budget on project after project, this variation or pattern can be visible. Then PMO can add this as permeant risk to future tenders.

Table 5.7 Phase 5 – Post Project learning

Element	**In Detail**
Purpose	In here be sure that the lesson learned from each project closure become risks prompt for next tender. Then same mistake cannot happen again and again
The process	At D26 closure – which risk materialized? Is there any new risk which has not happened previously on the prompt list (add new risk to the list for future tender) Update risk prompt list at the end of each project. Then this can be starting point of Phase 1 in new project. Take around 15 minutes after every closure meeting.
Real example	In the Project 1 closure it shows French labour low must be followed while in Project 2 closure it says Roxtec was not estimated. Under this phase 5 both of these risks become permeant risk and added to the prompt risk list. This can be used in the future project Phase 1.

Output	In the D03 template the updated risk prompt list is stored. Now this can be used for next tender.
Gap it closes	The same problem of subcontractor selecting occurred in both project closure meeting. But it was never converted into estimation. By this Phase 5 this connection can be mandatory.

5.4 Excel Tool Demonstration

This excel tool is simple practical demonstration of Phase 1 to Phase which are explained in above. It is a one workbook with four tabs. In this excel sheet, when the estimator enters related data in first tab, it directly flows to other tabs. So, no need adds details manually.

The excel tabs are created in a natural order of the framework. Tab 2 shows risk registers feed to contingency calculation tab 3. Cost estimate Tab 1 is fed by tab 3. Tab 4 (summary dashboard) is based on all the three tabs can finally create the one-page overview that the PMO reviewer work in Phase 4.

It is structured same way as the company existing company spread sheet for base cost section like hours in to rate for the labour and quantity into unit price for material price. This way make tool to easily adopt. There are few new sections are added. There are on Tab 3, Tab 2 and the Tab 1 (three summary at the bottom)

Table 5.8 Excel Tool – Four Tab Structure

Tab	Name	What It Contains	Output
1	Cost Estimate	Labor by role (hours x rate), materials by item (unit price x quantity). Structure is same as the existing spreadsheet.	Total tender prices with three visible components.

		At the bottom, three separate totals are included (Base cost, Contingency from tab 3, profit margin)	
2	Risk Register	Risk prompt list from the earlier project closure. Estimators mark every risk Applicable/ Not applicable / Uncertain. If the risks are applicable all the description, category and likelihood recorded.	Signed project specific risk register
3	Contingency Calculation	Enter Probability (%) and Cost Impact (€) for each risk in Tab 2. Tool automatically calculates Risk Allowance – Profitability x Impact, Total contingency goes to Tab 1	Total contingency – automatically connect Tab 1
4	Summary Dashboard	One page summary with Base Cost, Contingency, Profit Margin, Total Price, all risks covered and at what provisions. This is the finally PMO sees in Phase 4.	One-page PMO sign-ff document

5.5 Applying the Framework to Project 2

In this section explain the framework using Project 2 data. Because that project loss €24,833. There is a simple question, what can be the outcome if the framework is used at the tender stage?

All the key issues lead to loss in Project 2 were already analyse. In the risk register, all the three risk have clearly appeared in the Phase 1. The probability and cost impact would have given in under Phase 2. Risk allowance can be calculated.

Table 5.10 illustrates the Phase 2 calculation used in Project 2 with the help of reasonable estimates under the closure meeting documents.

Table 5.9 Phase 2 Risk Calculation – Project 2 Retrospective Application

Risk	**Probability**	**Cost Impact (€)**	**Risk Allowance (€)**
Absence of Roxtec fittings from BOM	High – 70%	€5,000	€3,500
Exceed the estimated labour hours – French labour low	Medium – 50%	€8,000	€4,000
Consuming per-purchase materials for other projects	Low – 30%	€4,500	€1,350
Subcontractors do not familiarize with refit projects	Medium – 40%	€6,000	€2,400
TOTAL CONTINGENY			€11,250

As per the table, total contingency is €11,250. This can appear in separate line in the estimate under Phase 3. The tender price would have been approximately €11,250 exceed than actually submitted. Table 5.10 compares the actual output with the framework-adjusted outcome.

Table 5.10 Financial Comparison – Actual Outcome vs Framework Adjustment Outcome

Financial Parameter	**Without Framework**	**With Proposed Framework**
Tender price submitted	€164,562	€175,812 (+€11,250 contingency)
Actual project cost	€190,889	€190,089 (same as without framework)

Contingency available	€0	€11,250
Cost overruns to absorb	€26,327 (full loss, no buffer)	€15,077 (reduced by contingency)
Project outcome	Loss - €24,833	Loss reduced to -€13,583

After using framework did not totally eliminate the loss. The actual cost overrun of €26,327 exceeds the €11,250. Any way loss have been controlled to €13,583 from €24,833. Most important benefit is company would have understood what is going wrong or make loss before signing the tender rather than not after the project ends with loss.

This is the benefit of this framework. It cannot sure profit gain. Purpose of this is to ensure company understands organization's potential cost exposure before signing to contract price.

5.6 Summary of Findings

In this thesis it discusses the possible ways of improving cost estimation and risk integration at PMO level in ship electrical projects. The analysis is initiated on real world examples of two projects where it has documented loss of €24,833. And based on those it has focused on understanding the reasons for the losses how to avoid such situations going forward.

In the second chapter, it discusses the previous literature done on the research area, where it highlights the difficulty of cost estimation in ETO environments due to the variations in different projects, scope incompleteness during tender stage and time constraint. Specifically, from previous literature it shows that risk management and cost estimation are unusually considered as two individual activities which ultimately creates commercially structured risk blind estimations. Therefore, this separation in cost estimation and risk management is identified as the research gap that needs to be addressed in this thesis.

In the third chapter it discusses the methodology used in achieving the previously discussed research gap. Research is based on a qualitative case study design where it analyses the completed documentaries of two ship electrical projects. The main reason for selecting this methodology instead of surveys or interviews was to understand actual workarounds that organizations followed during the cost estimation process.

Within the fourth chapter it discusses the research findings which were found based on the analysis done on five different areas including estimation methodology, risk identification, risk-to-cost integration, contingency determination, and PMO governance. It was identified that both the projects shared the same gap which is risk integration was identified only after the project had ended. There were no contingency plans in place. The profit markup was utilized to cover commercial margin as well as risk contingency, approval checklists were incomplete, and KPI were limited only for pipeline volume tracking. Likewise, eight systematic patterns were observed in both the projects, indicating that these reflect organizational practices rather than isolated individual errors.

In chapter five it proposes the refined solution, a five-phase PMO-level framework. Here each phase focuses on one gap identified in research findings. This framework is straightforward, additive and self-improving over time. The excel tool demonstrates its functionality using real project 2 data. And the retrospective app of the framework indicated that loss could have been reduced from €24,833 to approximately €13,583 if the framework had been used.

5.7 Answer to the Research Question

The research question was: How can cost estimation and risk integration at the PMO level be improved to support better decision-making and cost predictability during the early phases of ship electrical projects?

The answer to the research question is five practical structural changes, each linked to the gaps identified in the research findings.

First, risk identification needs to take place before finalizing the cost estimations. In this analysis it was noticed that both the projects did not have tender stage risk register. All the associated risks were identified during the closure meeting after costs had already been incurred. Therefore, as a fix for this, the first change is having a mandatory risk register in the early phase. D03 explains the required checklist for the risk register.

The second proposed change is converting identified costs into a cost allowance using probability and impact. As per the existing process of the two organizations, none of the projects have given a monetary value to their risks, instead they were either neglected or quietly absorbed to the uniform markup.

The third solution is separation of cost estimates into three sections as base cost, contingency, and profit margin. In the current practice, profit and risk were merged together into a single markup. Due to this, when markup is reduced during bidding to win a bid, risk protection level also reduced without being visible.

The fourth suggestion is to improve KPI and track tender to actual cost variance by category as a standard KPI. In project 2 category 3 and category 7 overruns which caused the loss were not visible till they resulted in financial loss.

The fifth point is D26 closure findings should be formally linked to the D03 checklist. In both the projects, subcontractors' risk was raised as concern in closure meetings, however it was never considered as an estimation input. This failed feedback loop is a major cause that will lead to repetition of the same mistake.

Above suggested changes do not require sophisticated software, specialist training or restructuring. Rather they depend on a simple tool and consistent discipline to use them on every tender.

5.8 Recommendations for Team Electric Group

In this study it has recommended five practical solutions for Team Electric Group. Out of those five, the first two can be implemented immediately without incurring any cost and the rest are built based on the first two. Table 5.12 summaries the research objectives along with their completion status and Table 5.13 summaries the five recommendations.

Table 5.11 Research Objectives – Summary of Completion

	Research Objective	Where Addressed	Status
1	Review the literature about cost estimation, risk management, PMO governance and ETO features	Chapter 2	Completed
2	Explore existing PMO level practice in early –phase cost estimation and risk identification of the Teams Electric.	Chapter 4 – Section4.3 and Section 4.6	Complete (both projects explore with five dimensions)
3	Discover gaps between current practices and standard best practices	Chapter 4 – Section 4.4, Section 4.7, Section 4.8 and Section 4.9	Complete (identified eight gaps and five requirements)
4	Create a process- based framework connecting cost estimation and risk management at the PMO level	Chapter 5 – Section 5.3	Complete (five phase framework design)
5	Create a simple excel based tool illustration demonstrating the way of framework can used	Chapter 5 – Section 5.4 and Section 5.5	Complete (four tab excel tool applied for Project 2)
6	Provide recommendation to boost PMO level estimation and risk management	Chapter 6 – Section 5.8	Complete (five recommendation to Team Electric)

Table 5.12 Recommendation for Team Electric Group

	Recommendation	What This Means in Real world	Priority
1	Add risk register step to D03 checklist	Use the risk prompt list from Tab 2 of the excel tool. Make it a compulsory field – not optional. Costs nothing and takes 20-30 minutes per tender.	Immediate – no cost
2	Restructure estimate to show three separate lines	Revise the calculation spreadsheet with three separate numbers for Base cost, Contingency and Profit Margin. Tab 1 of the excel used as a template	Immediate – low effort
3	Add estimation accuracy KPI at test D26 closure	Record the tender to actual cost variance by category at the next closure meeting. Add it as standard field in the D26 format. Explore every subsequent closure.	Short term 1-3 months
4	Check retrospective risk review for both projects	For both projects use Phase 2 methodology to calculate what the contingency should have. Then compare it's against actual outcomes. This structures the first version of the organization's calibrated risk profile.	Short term 1-3 months
5	Standardize D26 to D03 feedback step	At every D26 closure and it takes 10 to 20 minutes to review which risks materialized and update the risk prompt list. Assigned this as a named PMO responsibility so it does not depend on individual memory.	Medium term 3-6 months

The above recommendations are presented in order of priority. The first two changes only require adjustments to the existing templates and can be implemented promptly prior to the submission of next tender. The next two solutions are built upon the initial changes, and they are capable of producing the first set of meaningful data. The last and the fifth recommendation is the most significant one when considering a long-term plan. It focuses on self-improvement of the framework across the entire project portfolio.

5.9 Contributions of This Research

This study provides three main contributions as follows.

From academic perspective, it gives a practical, evidence-based framework that links risk management with cost estimation at the PMO level in ship electrical ETO contracting. As reviewed by the literature this area is not explored sufficiently. The five-phase framework which is built from real world scenarios addresses that gap successfully rather than relying on generic models.

When considering the practical contribution to the industry, the Team Electric Group can introduce the four tabs excel tool immediately to their estimation process. It is generated using real project data, does not require specialist training and demonstrates the framework application in real world scenarios.

Further this study proves that documentary analysis of company project records is a successful analytical methodology. Without interviews, this method was able to reveal important findings with the systematic analysis done covering multiple dimensions including two projects. The results were also confirmed by the organizations, validating the success of the documentary analysis approach.

5.10 Limitations of This Research

During this study, four research limitations were identified.

With related to sample size, only two projects from one organization were considered for the analysis. Therefore, the findings could be limited to Team Electric Group. Due to that results cannot be generalized to overall industry contractors without further analysis with increased sample size.

Secondly, this study solely depends on documentary data without any interviews or any other kind of data collection methods. This may have caused the missing of some important details which may not be included in the documentary but may have been discussed during meetings. For reference, why markup was 1.25 in one calculation and 1.30 in another. Documents describe what happened, but not always the reason behind it.

Third, the framework has not yet been validated in practice. While its retrospective application to protect 2 suggests that it is plausible, real evidence would require implementation across multiple future projects and systematic evaluation of the outcomes.

The final limitation identified is, this study solely focuses on early project phases from tender preparation and cost baseline approval. The interim and final phases including engineering, procurement, and installation fall outside the scope. The research study focuses on cost predictability in early project phase but not the full project lifecycle.

5.11 Directions for Future Research

This section highlights the future research areas that can be explored in the cost estimation process.

The first point is longitudinal implementation research. As an extension to this research findings, Team Electric Group could implement the five-phase framework and monitor whether the estimation accuracy is improving over the time or not. After successful implementation for around ten projects, with systematically recorded statistics over time, it would be possible to assess the effectiveness of the framework application.

Secondly, this study can be expanded to industry wide comparative research. The gap identified in Team Electric Group may also exist among small to medium size ship electrical contractors where organizations which have governance infrastructure but lack integrated processes for incorporating risk into cost estimation. A multi company analysis would help to determine whether these findings are common to all and also it would be useful to assess the transferability of this framework.

The last point is to expand the analysis including quantitative validation. Currently probability and impact values in phase 2 are solely based on the judgment of the estimator. When the company is maintaining a portfolio of projects with their recorded variance data, it would be able to calibrate those estimates against the actual historical data, resulting in having better accuracy in contingency calculation over the time.

5.12 Closing Reflection

This study was initiated with a simple observation: a company that performs well, with a skilled and experienced workforce and a structured governance framework incurred losses on a project due to risks that were clearly foreseeable at the tender stage. The need for Roxtec fittings is a key requirement that every ship electrical estimator must know. During the previous project closure meetings, French labour law risk was already identified and likewise risk of double purchasing would have been easily identified through a basic stock check.

However, none of the above happened as the personnel who were involved in the process have thought those carefully. With the existing framework, these points were not made to check by anyone before submitting the tender. The process had all required components including D03 checklist, D26 closure meeting, governance structure, but it was missing the part that combines risk management to the cost estimation and also it was missing the method where they utilize the lessons learned from one project as inputs for the next one.

This finding was verified and accepted by the company when they were questioned about missing risk registers. They also mentioned the requirement of risk identification in the early bidding process which lacks in the current methodology where risks were only identified during the closure meeting. The research arrived at the same conclusion solely based on the documentary evidence, without any other external inputs.

The five-phase framework which was suggested in this study fills that gap giving the missing mechanism. Working on ship electrical projects in dry dock environments is a complex task which is time pressured. Even though this framework doesn't make cost estimation easy, it helps to build the process of making risk identification and systematic risk pricing, visible and cumulative. And each project helps to improve the predictability of subsequent projects.

For an organization that operates with margins of 2% - 6%, a single unrecognized cost wipes out the profit from multiple successful projects. Therefore, a simple, straightforward, structured and self-improving procedure is not merely a theoretical concept, it is an actual business necessity.

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Appendices

Appendix 1: PMO Cost Estimation and Risk Integration Tool – Tab 1 Cost Estimate

	A	B	C	D	E
1	PMO COST ESTIMATE — Project 2 (Restaurant Mason Jar & Lounge)				
2	*Team Electric Group / Document: D03 Calculation / Date: 2025*				
3					
4	RESTAURANT — Mason Jar (390 m²) | Offer Q-3 Issue 3 | Markup: 1.25				
5	**Cost Item**	**Hours / Qty**	**Rate / Unit (▮)**	**Cost Price (▮)**	**Sales Price (▮)**
6	Supervisor	516	▮21.00	▮10,836.00	▮13,545.00
7	Electrician 1	516	▮17.50	▮9,030.00	▮11,287.50
8	Electrician 2	516	▮17.50	▮9,030.00	▮11,287.50
9	Welder	100	▮17.50	▮1,750.00	▮2,187.50
10	Travel (4 persons × 16 hrs)	64	▮17.50	▮1,120.00	▮1,400.00
11	**Labour Subtotal — Restaurant**			**▮31,766.00**	**▮39,707.50**
12	Materials — Restaurant				
13	Downlights (various)	94	▮45.00	▮4,230.00	▮5,287.50
14	LED Strip Lighting	80	▮12.00	▮960.00	▮1,200.00
15	Cables — Power & Data	1	▮8,500.00	▮8,500.00	▮10,625.00
16	Cable Containment	1	▮2,200.00	▮2,200.00	▮2,750.00
17	Sockets & USB Outlets	40	▮35.00	▮1,400.00	▮1,750.00
18	PA & Smoke Detection Integration	1	▮3,200.00	▮3,200.00	▮4,000.00
19	Emergency Lighting Units	12	▮180.00	▮2,160.00	▮2,700.00
20	Stage Electrical Supplies	1	▮4,500.00	▮4,500.00	▮5,625.00
21	**Roxtec Penetration Fittings**	**0**	**▮0.00**	**▮0.00**	**▮0.00**
22	Roxtec Penetration Fittings ⚠ MISSING FROM ORIGINAL BOM	1	▮1,800.00	▮1,800.00	▮2,250.00
23	**Materials Subtotal — Restaurant**			**▮28,950.00**	**▮36,187.50**
24					
25	LOUNGE (100 m²) | Offer Q-1 Issue 1 | Markup: 1.30				
26	**Cost Item**	**Hours / Qty**	**Rate / Unit (▮)**	**Cost Price (▮)**	**Sales Price (▮)**
27	Project Manager	40	▮25.20	▮1,008.00	▮1,310.40
28	Supervisor	84	▮21.00	▮1,764.00	▮2,293.20
29	Electricians (516 hrs each × 2)	1032	▮17.50	▮18,060.00	▮23,478.00
30	Welder	16	▮17.50	▮280.00	▮364.00
31	**Labour Subtotal — Lounge**			**▮21,112.00**	**▮27,445.60**
32					
33	ESTIMATE SUMMARY				
34	**Component**			**Cost Price (▮)**	**Sales Price (▮)**
35	Base Cost — Labour (Restaurant)			▮31,766.00	▮39,707.50
36	Base Cost — Materials (Restaurant)			▮28,950.00	▮36,187.50
37	Base Cost — Labour & Materials (Lounge)			▮21,112.00	▮27,445.60
38	TOTAL BASE COST			**▮81,828.00**	**▮103,340.60**
39	**CONTINGENCY (from Tab 3 — Risk Calculation)**			**▮24,833 (LOSS)**	**▮24,833 (LOSS)**
40	**PROFIT MARGIN (20% of Base Cost)**			**▮16,365.60**	**▮20,668.12**
41	★ TOTAL TENDER PRICE				**#VALUE!**

Tab1_Cost_Estimate | Tab2_Risk_Register | Tab3_Contingency | Ta

Figure 1:PMO Excel Tool – Tab 1 Cost Estimate

Appendix 2: PMO Cost Estimation and Risk Integration Tool – Tab 2 Risk Register

RISK REGISTER — Project 2 | Phase 1: Risk Identification | D03 Mandatory Step

Estimator: ________________ *Date:* ________________ *Signed:* ________________

STANDARD RISK PROMPT LIST — Complete before finalising the cost estimate

#	Risk Item	Category	Applicable?	Likelihood	Notes / Evidence
1	Roxtec penetration fittings — are they included in the BOM?	Scope Completeness	YES — MISSING	HIGH	⚠ NOT in Restaurant BOM. Direct cause of Cat.7 overrun. Must be added.
2	Standard components checklist — all items confirmed in BOM?	Scope Completeness	YES	HIGH	Restaurant BOM has 27 items — several zero values unexplained.
3	Subcontractor suitability — refit vs new-build experience?	Subcontractor Risk	YES	HIGH	NB workers used on refit. Mismatch caused performance issues. Same risk as Project 1.
4	Labour law constraints — French working hour regulations checked?	Labour Risk	YES	HIGH	516 hrs/electrician implies 12 hrs/day. French law restricts this. Not checked.
5	Labour productivity assumption — documented and realistic?	Labour Risk	YES	HIGH	12 hrs/day assumption not documented or flagged in estimate.
6	Pre-purchased material stock — is it actually available?	Inventory Risk	YES	MEDIUM	Pre-Covid stock consumed on other projects. Double-purchase required.
7	Rest days in schedule — built into 43-day dry dock plan?	Schedule Risk	YES	MEDIUM	No rest days planned. Contributed to schedule pressure.
8	Project Manager in labour plan — included for Restaurant scope?	Estimation Gap	YES	HIGH	PM absent from Restaurant calculation. 43-day multi-subcontractor project.
9	Markup consistency — same rate applied across all scope areas?	Governance Risk	YES	MEDIUM	Restaurant 1.25 vs Lounge 1.30. No documented rationale.
10	Client scope definition — is scope clearly fixed in contract?	Scope Risk	NO	LOW	Exclusions list provided. Scope boundaries defined in Q-3 and Q-1.
11	Design information completeness — site check completed?	Scope Risk	NO	LOW	Vessel drawings available. No additional site check flagged.
12	Currency and exchange rate risk	Commercial Risk	NO	LOW	Project priced in EUR. No currency exposure identified.

LEGEN RED = High likelihood — must be costed in Ph | AMBER = Medium likelihooc | GREEN = Low likelihood — monitor

Tab1_Cost_Estimate | **Tab2_Risk_Register** | Tab3_Contingency | Tab4_Summary_Dashboard | ⊕

Figure 2:PMO Excel Tool – Tab 2 Risk Register

Appendix 3: PMO Cost Estimation and Risk Integration Tool – Tab 3 Contingency Calculation

CONTINGENCY CALCULATION — Project 2 | Phase 2: Risk Assessment & Costing

Formula: Probability (%) × Cost Impact (€) = Risk Allowance (€) | Sum of all allowances = Total Contingency

Risk Scenario	Probability	Cost Impact (€)	Risk Allowance (€)	Assessment
Roxtec fittings absent from BOM — scope completeness	70%	€5,000.00	€3,500.00	HIGH — standard component completely missing
Labour hours exceed estimate — French labour law (12 hrs/day assumed)	50%	€8,000.00	€4,000.00	HIGH — flagged in Project 1 closure, ignored in P2
Pre-purchased materials consumed — double purchase required	30%	€4,500.00	€1,350.00	MEDIUM — pre-tender stock check not done
Subcontractor unfamiliar with refit environment (NB workers)	40%	€6,000.00	€2,400.00	MEDIUM — same risk as Project 1, not resolved
PM absent from Restaurant labour plan — coordination risk	50%	€3,500.00	€1,750.00	HIGH — 43-day multi-subcontractor project, no PM costed
Markup inconsistency 1.25 vs 1.30 — no PMO standard applied	20%	€1,500.00	€300.00	LOW — governance gap, no commercial impact if rates held
Schedule overrun — no rest days in 43-day dry dock	30%	€2,500.00	€750.00	MEDIUM — workforce productivity risk unaddressed
★ **TOTAL CONTINGENCY**			**€14,050.00**	**→ Flows automatically to Tab**

RETROSPECTIVE COMPARISON — What Happened vs What Could Have Happened

Parameter	Without Framework	With Framework Applied	Difference	Note
Tender price submitted	€164,562	€175,812	+€11,250	Contingency added to tender price
Actual project cost	€190,889	€190,889	—	Same — risks still materialised
Contingency available	€0	€11,250	+€11,250	Risk buffer existed
Financial loss	€24,833 (LOSS)	~€13,583 (LOSS)	Loss reduced by €11,250	Partial absorption of overrun
Risk awareness before contract	NONE	FULL	Critical difference	Company knew risks before signing

Tab1_Cost_Estimate | Tab2_Risk_Register | **Tab3_Contingency** | Tab4_Summary_Dashboard

Figure 3:PMO Excel Tool – Tab 3 Contingency Calculation

Appendix 4: PMO Cost Estimation and Risk Integration Tool – Tab 4 Summary Of the Dashboard

PMO SUMMARY DASHBOARD — Project 2 | Phase 4: Review & Approval			
This dashboard provides the one-page PMO sign-off view. Review all sections before submitting the tender.			
PROJECT INFORMATION			
Project Name	Restaurant Mason Jar & Lounge — Cruise Vessel Refit		
Dry Dock Duration	43 days		
Offer References	Q-3 Issue 3 (Restaurant) | Q-1 Issue 1 (Lounge)		
Project Closed	3 October 2025		
Classification	Large (L) — Multi-subcontractor, international, dry dock		
FINANCIAL SUMMARY			
Component	**Cost Price (▯)**	**Sales Price (▯)**	**Note**
Base Cost — Labour & Materials	▯81,828.00	▯103,340.60	From Tab 1 Cost Estimate
Contingency (Risk Allowance)	▯24,833 (LOSS)	▯24,833 (LOSS)	From Tab 3 — sum of risk allowances
Profit Margin (20%)	▯11,250.00	▯11,250.00	Target commercial return
★ TOTAL TENDER PRICE		**#VALUE!**	
		▯175,812.00	
RISK REGISTER STATUS — Phase 1 & Phase 2 Verification			
Risk Item	**Likelihood**	**Allowance (▯)**	**Status**
Roxtec fittings absent from BOM	HIGH	▯3,500.00	✓ Costed
Labour hours — French labour law	HIGH	▯4,000.00	✓ Costed
Double-purchase of materials	MEDIUM	▯1,350.00	✓ Costed
Subcontractor — NB vs rent mismatch	MEDIUM	▯2,400.00	✓ Costed
PM absent from Restaurant plan	HIGH	▯1,750.00	✓ Costed
Schedule — no rest days planned	MEDIUM	▯750.00	✓ Costed
PMO APPROVAL CHECKLIST — D03 Sign-Off			
Risk register completed and signed? (Phase 1)	☑ YES		
Contingency calculated from risk register? (Phase 2)	☑ YES		
Base cost, contingency and margin shown separately? (Phase 3)	☑ YES		
Standard components confirmed in BOM? (Roxtec etc.)	☑ YES — added to estimate		
Labour productivity assumptions documented?	☑ YES — 8.5 hrs/day used		
Markup consistent across all scope areas?	☑ YES — PMO standard applied		
Estimate reviewed and approved by PMO?	☐ PENDING — Reviewer signature required		
PMO Reviewer: ______________________	**Signature:** ______________________		**Date:** _____

Tab1_Cost_Estimate | Tab2_Risk_Register | Tab3_Contingency | **Tab4_Summary_D**

Figure 4: PMO Excel Tool – Tab 4 Summary of the Dashboard

Appendix 5: Declaration of the Use of Artificial Intelligence

As a part of writing and formating this thesis, artifical intelligece tools were used to support. The following supportive tasks were made by using with the help of AI.

Language and Grammar: ChatGPT GPT-4 model was used to applied to test and correct grammar, spelling and senetency fluency in already written text.

- Tables: Used AI as supportive field for structurring and formatting of tables in Chapter 4 and 5. The author checked all the content of the table (figures, details), edited and checked with primary data gathered from Project 1 and Project 2
- Framework Development: For the Chapter 5 - Framework development using AI support. Based on empirical findings, the author made all the decisions regarding the framework, its five phase and it's content.
- Excel Tool: To design and format the excel based tool for PMO cost esstimation and risk integration which is explained in Chapter 5 get the support from AI. All the added data in the excel tabs (cost values, risk details, profitability values and etc) were based on real values from the documents received from the company.
- A refernce list was formatted with the help of AI tool according to the APA 7th edition guidelines. The AI was applied in order to provide uniformity in how the reference list has been formatted a per the required citation style. The author checked, selected and confirmed all the references used in the thesis.

All the data, findings, analysis and conclusiosns are own by author. All AI –support content was for the reference, edited and checked by author. As per university guidelines this paper used artificial intelligence as an instrument.