# Qualitative System Dynamics Approach to Modelling Cost Escalation Determinants in Nigerian Public Sector Projects


## Abstract

**Purpose**- Cost escalation has been identified as one of the most significant challenges and recurring issues in the delivery of social and economic infrastructure in the Nigerian public sector. Like many other countries in the global south, the Nigerian public sector projects suffer from poor cost performance. Thus, this study aims to analyse the dynamics of construction cost escalation determinants and produced a conceptual system dynamic model that captures the intricate interactions among these determinants.

**Design/methodology/approach**- The study includes a literature review and qualitative approach using semi-structured interviews. Data was obtained from 17 stakeholders involved in the delivery of Nigeria public sector projects, including Project managers, Architects, Civil engineer, Quantity surveyors, and Construction managers. The data was analysed using a coding framework informed by case study approach, the principles of thematic analysis and saliency analysis framework, enabling the modelling of intricate interactions among various determinants of cost escalation.

**Findings**- The findings revealed a complex and dynamic interaction among the determinants, indicating that an isolated solution to cost escalation, particularly in developing countries like Nigeria, is unlikely. Instead, a holistic, system-oriented approach that considers the interplay of multiple determinants is necessary for effective cost escalation management. One of the determinants identified was the lack of technical competence among professionals involved in the delivery of public sector construction projects. Additionally, the analysis of the causal loop diagram revealed intervention points in the project delivery process to counter cost escalation. This study postulates that a key intervention strategy involves enhancing the competencies of construction professionals through synergistic collaboration between various stakeholders: public sector entities, professional bodies, statutory regulatory bodies, and policymakers.

**Research limitations/implications**- Since the findings are rooted in Nigerian public construction projects, their relevance to privately financed projects might be limited. Also, the study focuses solely on the construction stage, without extending to the post-construction phase. Furthermore, the themes and their causal links were derived from viewpoints of experts from the Nigerian context. Future studies could enhance the external validity of the research results by examining their applicability in other contexts and by integrating the later phases of public sector construction projects, such as facilities management operation, to offer a more holistic view of the problem.

**Originality**- The study presents a collaborative and holistic approach to address cost escalation in Nigerian public sector projects by modelling the complex interactions among various determinants influencing cost escalation within a dynamic framework and identifying critical intervention points in the project delivery process.



**Keywords:** system dynamics; modelling; construction projects; cost escalation; Nigeria; public sector.


## 1. Introduction

Over the years, various countries globally have seen substantial public sector infrastructure investment, leading to significant economic growth. Nigeria, for example, has enjoyed an average economic growth rate of 2.25% over the previous decade

(National Bureau of Statistics, 2022). The construction sector, a significant contributor to the global GDP, plays an essential role in the advancement of many developing countries, including Nigeria. This sector provides crucial public sector infrastructure, including roads, railways, airports, hospitals, schools, office buildings, and hydroelectric facilities, underpinning significant economic and social transformations. In 2022, Nigerian construction activities represented approximately 10.75% of the nation's GDP (Aina, 2023).

Public sector projects in Nigeria, being one of the largest areas of construction investment, form the cornerstone of the country's economic and social development. Nevertheless, this sector is characterized by frequent cost escalations, ranging from 23.6% to as high as 300% (FMW&H, 2019; Eze, 2022; Sahabi, 2024). For example, the Abuja-Kaduna-Kano road project, which has seen over 500% cost increases since its initiation in 2018 and is still about 60% complete, exemplifies this situation (Sahabi, 2024).

Researchers worldwide have made concerted efforts to identify and understand the persistent factors leading to cost escalation in public construction projects. Some scholars, primarily using a quantitative approach, have tried to find viable solutions without considering the complex interrelationships among the different determinants (Le-Hoai *et al.,* 2008; Rahman et al., 2013; Alinaitwe *et al.,* 2013; Larsen *et al.,* 2015; Khabisi *et al.*, 2016; Famiyeh *et al.*, 2017; Sinesilassie *et al.,* 2017; Al Amri and Marey-Perez, 2020, Idrees and Shafiq, 2021; Asiedu and Adaku, 2020). Other researchers have focused on cost escalation in specific types of projects, such as buildings, highways, or general infrastructure (Kaliba *et al.,* 2009; Love *et al.,* 2015; Leo-Olagbaye and Odeyinka, 2018; Mahmud *et al.,* 2021; Andric *et al.,* 2024). For instance, Asiedu and Adaku (2020) used a survey-based approach to investigate the causes of cost overrun in public sector infrastructure projects in Ghana, thereby overlooking the complex interactions between these factors. In light of this, other studies like Mahmud *et al.* (2022) and Asiedu and Ameyaw (2021) utilized system dynamics to explore the underlying causes of cost overruns underscoring the value of this method in addressing the issue. For instance, Mahmud *et al.* (2022) study examined the drivers of cost overrun from a contextual perspective (using a blend of qualitative data from interviews and textual data from literature sources), resulting in a model that encapsulates the interactions among the many drivers. However, this study focused solely on highway infrastructure projects. Similarly, Asiedu and Ameyaw (2021) created a conceptual system dynamics model to probe the factors related to the risk of cost overrun, with a specific focus on Ghana. An effective approach for overcoming construction cost escalations is to explore the interactions among the key determinants. The advantage of this approach is that it provides a viable platform for understanding and dealing with these intricate interactions (Olatunji *et al.*, 2018).

The aim of this study is to analyse the determinants of construction cost escalation, explore their dynamics and develop a conceptual SD model that illustrates their interactions. This study divulges from existing literature in two significant ways. First, while previous studies have largely focused on identifying and cataloguing the factors

contributing to cost escalation (in specific type of project or general construction project), this study extends this by developing a SD model (based on a novel coding framework), a novel approach that provides a more comprehensive understanding of the dynamic and interrelated nature of these factors. Second, our study is grounded in the specific context of Nigeria, a developing country where cost escalation in public construction projects is particularly pronounced and understudied. By focusing on this context, the study offers invaluable insights that could inform policy and practice not just in Nigeria, but also in other similar contexts.

## 2. Literature Review

### *2.1 Public Construction Projects*

Public construction projects, underpinning the infrastructure landscape of both developing and developed countries, are critical engines of economic growth and social stability. These projects encompass a broad spectrum of initiatives, financed, owned, operated, and directly provided by the public sector for societal benefit. Examples include economic infrastructure projects such as highways, railways, airports, seaports, oil and gas facilities, dams, and bridges, as well as social infrastructure projects such as hospitals, schools, public libraries, and government buildings (Idrees and Shafiq, 2021). The effectiveness of these projects is intrinsically linked to their ability to adhere to cost, time, specification, and sustainability parameters, all of which are critical components of project success (Ibrahim *et al.*, 2006). Given the increasing public demand for robust infrastructure amidst fiscal constraints, the ability of governments worldwide to successfully deliver such projects is of paramount importance. The success of these projects is often contingent upon the political landscape, and any form of political instability can significantly impede project performance (Mahmud *et al.*, 2021).

To put this into a specific context, Nigeria's construction sector has seen substantial public sector investment in recent years. For example, in 2022, the commitment to public sector projects constituted 35% of the total fiscal budget, amounting to N5.96 trillion from a total of N17.13 trillion. This commitment has led to the commencement of 11,800 new projects and the continuation of existing ones. Notably, the Ajaokuta-Kaduna-Kano (AKK) gas pipeline and storage project, which is approximately 70% complete, carries an estimated budget of $2.8 billion (Addeh and Orizu, 2023). The surge in investment can be attributed to Nigeria's stable political environment, which is actively seeking to bridge the country's infrastructure gap.

### *2.2 Concept of cost escalation in public construction projects*

Meeting budget expectations is crucial for the successful completion of any construction project, as cost performance is a significant indicator of an organization's productivity and profitability. However, cost escalation is a major hindrance to the successful execution of public infrastructure projects worldwide, especially in developing countries, including Nigeria. These countries often experience the most severe instances of cost escalation, sometimes exceeding 100% of the original budgeted estimates (Durdyev *et al.*, 2012). Such escalations are not confined to specific types of projects but occur in all

forms of construction projects regardless of the location (Mahmud *et al.*, 2022). For example, Flyvbjerg et al. (2004) found that 9 out of 10 construction projects globally suffered from cost escalation, with an average variance of 28%. In addition, Andric *et al.* (2024) revealed an average of 3.3% cost escalation in infrastructure projects in South Asia. A wide variety of issues contribute to cost escalation, including poor contract management, insufficient risk management, unrealistic cost estimates, rework and scope creep, corruption, political instability, strategic misrepresentation, optimism bias, and inherent risks and uncertainties.

In public construction projects, cost escalation is often characterised by a marked difference between the final project cost and the original contract cost- a definition endorsed by researchers like Flyvbjerg *et al.* (2003), Gkritza and Labi (2008), Cantarelli *et al.* (2012), Ahiaga-Dagbui and Smith (2014), Love et al., (2015), Flyvbjerg *et al.* (2018) and Catalao *et al.* (2019). A key variable in this definition is the baseline: the original contract estimate, which can be set at different points in time, such as the formal decision to build, the project definition phase, or contract approval (Mahmud *et al.*, 2022). It is crucial to acknowledge that the initial project cost estimate is dynamic and can fluctuate throughout the project's lifecycle, adding an extra layer of complexity when evaluating project overruns (Khabisi *et al.*, 2016). Flyvbjerg *et al.* (2018) define cost escalation as, "the amount by which actual cost exceeds estimated cost, with cost measured in the local currency, constant prices and against a consistent baseline".

Globally, the problem of cost escalation in public construction projects has been widely acknowledged, with overruns ranging from 7.9% to over 500% (Flyvberg *et al.*, 2003; Odeck, 2004; Okon, 2009; Cantarelli *et al.*, 2012; Olivio and Shaver, 2014; Amadi, 2016; Asiedu *et al.*, 2017 and Locatelli *et al.*, 2017). This variation is detrimental to public sector capability, with political and economic consequences and impact on future projects, and thus presents an impediment to their successful provision. The variations are mainly attributed to a complex combination of numerous context specific determinants.

### *2.3 Determinants of cost escalation in public construction projects*

It is widely acknowledged in the global construction management literature that a multitude of determinants can impact the cost performance of public construction projects. These variables, due to their notorious influence on project cost, have been rigorously scrutinized and extensively documented. The reasons, though diverse, show some common themes as presented in Table I.

**Table I. Summary of previous studies on determinants of cost escalation in public construction projects**

Indeed, the studies show a multitude of causes behind cost escalation in public construction projects. However, it is crucial to view these causes from a systemic perspective due to the inherent complex and dynamic nature of the determinants and indeed the projects. These factors- scope changes, payment delays, price and exchange rate fluctuations, poor project management, and design changes or errors etc.- do not

operate in isolation. They are interrelated and their impacts are often multiplicative rather than merely additive.

### *2.4 Systems approach to construction cost performance*

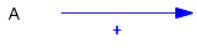
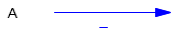
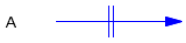
System thinking, a subset of SD, is lauded for its capabilities in providing detailed analysis and insights into the complex, dynamic, and holistic nature of intricate systems. Its strength lies in its ability to qualitatively model these systems by thoroughly capturing the interactions between different variables, thereby revealing the latent causes and effects embedded within these relationships (Shoar and Payan, 2022). An integral part of the system thinking method is the concept of feedback structures, which employs feedback loops to conceptualise the interactions of variables within the system being studied (Richardson, 1999). Fundamentally, these causal feedback loops, which are either reinforcing (positive) or balancing (negative), along with their inherent delays, serve as the basic building blocks of all systems. Collectively, they create a dynamic hypothesis that fosters insight and understanding of the system's behaviour (Asiedu and Ameyaw, 2021). Sterman (2000) clarifies that the type of loop present in a system—reinforcing or balancing—is determined by the number of negative signs encompassed within all the links that constitute the loop. A reinforcing loop (indicated by  or  ) is prevalent when the number of negative signs is even or non-existent  , whereas a balancing loop (indicated by  or  ) is evident when the number of negative signs is odd (  ). Delays, which are symbolized by a double line  , represent the time lag between cause and effect in a system and are often sources of instability and potential instability. These delays, owing to their ability to obscure the linkage between cause and effect, induce dynamic complexity, which may, in turn, result in unstable system behaviour. A simple example, showing the different types of links and feedback loops, is illustrated in Figure I.

**Figure I. Example of reinforcing and balancing loops**

System Dynamics (SD) has been effectively employed in various construction management studies to comprehend and illustrate the intricacies and dynamics of complex systems. For instance, Ogunlana *et al.* (1998) used SD to explore performance enhancement within construction organizations. The SD model they developed illuminated the complex interdependencies between various internal factors, providing deeper insights that allowed for more effective organizational improvements. Wang and Yuan (2017) applied SD to study the dynamic nature of various risk factors on schedule delay in infrastructure projects, thereby facilitating effective risk assessment. Further, Nasirzadeh *et al.* (2008) employed SD to model diverse risks on construction project objectives, providing a holistic view of the risk landscape. The developed model offered a tool for stakeholders to better assess and manage project risks, enhancing the chances of project success. Similarly, Al-Kofahi *et al.* (2020) applied SD to understand the effects of change orders on labor productivity in highway projects. This study showed how changes in one part of the project can have ripple effects, leading to significant impacts

on labor productivity and overall project performance. Both Mahmud *et al.* (2022) and Asiedu and Ameyaw (2021) used SD to understand cost overruns in construction projects. Their research offered insights into the dynamics and interrelationships of cost overrun factors, providing stakeholders with a more holistic understanding of the problem, and aiding in the development of more effective cost management strategies.

These examples illustrate the potential of SD as an analytical tool to provide a comprehensive, nuanced, and dynamic understanding of factors influencing construction projects performance.

## 3. Research Methodology

This study adopts a System Dynamics (SD) approach, particularly leveraging Causal Loop Diagrams (CLDs) to create a conceptual model that captures the intricate determinants of cost escalation in public construction projects. SD is vital due to its ability to provide deeper insights into the cause-and-effect interactions within complex systems and suitability to model dynamic relationships between various factors which are critical in understanding cost escalation in public construction projects (Gisladottir *et al.* 2022). In addition, as emphasised by Leon *et al.* (2018), SD allows for a better understanding of these interactions by capturing feedback loops which is pivotal in determining system behaviour. This aligns with the recommendations by Asiedu and Ameyaw (2021) and Mahmud *et al.* (2022), which underscore the potency of SD in revealing interrelations among key variables and tracing causal pathways in a system.

The creation of CLDs is informed by diverse data sources, including textual sources and expert cognition gleaned through interviews (Mahmud *et al.,* 2022). The latter, due to its richness and contextual relevance, is particularly valuable. Consequently, this study uses a qualitative approach that focusses around semi-structured interviews, given their ability to deeply probe and provide nuanced insights into the issue at hand. This methodology aligns with the study's intent to dissect the complexity of cost escalation determinants and their interconnected dynamics, thereby generating robust knowledge to enhance the effectiveness of cost management in public construction projects.

### *3.1 Data collection*

The current study employs qualitative data gathered through interviews with key stakeholders in the public construction sector in Nigeria because it allows for in-depth exploration of the participants' experiences and perceptions regarding the challenges facing the cost performance of public construction project development in Nigeria (King and Harrocks, 2010).

#### 3.1.1 Interview procedure

The interviews were conducted through a through 2-stage semi-structured process guided by structured protocols designed in line with established procedures for qualitative research (Kvale and Brinkmann, 2009; Rwashana et al. 2014). This approach ensures the reliability and trustworthiness of the study findings (Bryman, 2012). The interview guide for the first phase consisted of four sections, with questions exploring the interviewees' perceptions of the cost performance challenges in the delivery of public construction

projects in Nigeria, their role within their respective organisations, nature of their organisations and their years of experience as shown in Table II.

**Table II.** Interview guide

In the first phase of the interviews, 17 participants were interviewed to explore their experiences and views on the challenges facing the public sector construction projects in Nigeria, with particular focus on the key determinants influencing cost escalation. This formed the basis for the development of the CLDs. The sample size aligns with those employed in similar studies such as Amadi and Higham 2017 (16 interviewees) and Johnson and Babu, 2018 (8 interviewees)).

In preparation for the interview process, a gatekeeper from the Federal Ministry of Works and Housing (FMW&H) was identified and engaged to navigate bureaucratic challenges and facilitate access to key informants. This approach aligns with the recommendation of Singh and Wassenaar (2016), who emphasised the pivotal role gatekeepers play in overcoming barriers to accessing stakeholders and data, particularly in contexts where such access is inherently challenging, such as in developing countries like Nigeria. Subsequently, an interview information sheet was distributed to prospective participants. This document outlined the aim of the research study, underscored the significance of their contributions, and highlighted the importance of their involvement in achieving the study's objectives. Participants responded positively through their respective organisations, confirming their willingness to participate in the interview process. The interview protocol was shared in advance with the organisations, allowing them to disseminate the guide to the respective respondents so as to adequately prepare for the interview.

Each interview lasted an average of one hour, ranging from 40 minutes to 1 hour and 20 minutes. Before commencing the interviews, participants were asked for their consent to record and document the conversation, as well as to be quoted anonymously in academic outputs. This step adhered strictly to the principles of safeguarding participant confidentiality, as recommended by Saunders (2009). All participants agreed to the recording request. Interviews were recorded using a voice recorder and supplemented with note-taking when necessary, and subsequently, a detailed report of the interview was prepared, in line with best practices outlined by Bryman and Bell (2015).

The second phase involved 9 participants engaged to validate the developed model, in line with the recommendation of Rwashana et al. (2014). The validation process aimed to enhance the quality of the developed model and ensure that the perspectives of the participants were accurately reflected. Further detail of the validation process is provided in section 3.3.

### *3.1.2 Sampling approach*

The participants possessing between 15 to over 20 years of experience were selected purposively using predefined criteria which included their knowledge with and involvement in public sector projects in Nigeria, their capacity to provide reliable information, and their geographical location as advocated by Arcury and Quandt (1999);

Kolb (2008); Creswell (2013); and Asiedu and Ameyaw (2021). The adoption of a purposive technique avails the study of insights from stakeholders well-versed in Nigerian public construction project development and delivery.

In particular, the participants in this study were key stakeholders involved in the delivery of public sector projects in Nigeria, selected based on the stakeholder categorisation established by Mansfield et al. (1994) and Mahmud et al. (2021). These stakeholders included officials from government agencies, experts from contracting organisations, and consultants from consultancy firms, all integral to the public project delivery process. Stakeholders from contractor and consultant organisations were located in Abuja, the Federal Capital of Nigeria, and possessed a strong reputation for executing significant public construction projects, such as roads, housing, hospitals, and government office buildings. Representatives from the public client side were selected from the Federal Ministry of Works and Housing (FMW&H) headquarters in Abuja. All participants were chosen for their substantial experience in managing public sector construction projects, ensuring the inclusion of expert perspectives as recommended by Mansfield et al. (1994). This selection process ensured access to invaluable insights from key stakeholders, covering a significant breadth and depth of information to address the research problem comprehensively.

**Table III. Summary of interviewees' background information**

As detailed in Table III, participants' backgrounds are presented, including their organisation type, the code assigned to each participant, and their years of working experience. The codes were assigned according to the sequence in which the interviews were conducted. For instance, Int_01 represents participant 1, Int_02 represents participant 2, and so on. Notably, while all interviews adhered to the same procedure and protocol, further probing for more insightful clarification on issues relevant to the phenomenon under investigation was permitted (Mahmud *et al.*, 2021; Mahmud *et al.*, 2022). This approach ensured the reliability and trustworthiness of the findings of the study.

### *3.2 Data analysis and result*

This study leveraged a coding framework (refer to Figure II) originally conceptualized by Mahmud *et al.* (2023) to systematically analyse qualitative data obtained from stakeholder interviews. Advance tools such as Computer Aided Qualitative Data Analysis Software (CAQDAS) - Nvivo 12, and SD software, Vensim, were instrumental in facilitating this analysis. The adopted coding framework was a synthesis of well-established coding frameworks, case study approach, principles of thematic analysis, and saliency analysis (an extension of thematic analysis). The comprehensive process of coding has been outlined in Table IV, elucidating each step.

**Figure II. Coding framework**
Adapted from Mahmud *et al.* (2023).

**Table IV. Summary of the Coding Process**

Note: Adopted steps of the thematic analysis framework: Step I- Familiarisation with the data; Step II- Generation of initial codes; Step III- Searching for themes; Step IV- Reviewing themes; Step V- Defining and naming of themes.

The detailed description of the analysis process is subsequently presented below.

### *i. Identifying codes and discovering themes in the data*

Firstly, the transcriptions from the interviews were carefully coded to identify the information pertinent to our research problem, culminating in the generation of a multitude of codes. Some of these codes were crafted using the original expressions derived from the interviewee's discourse (open statements that succinctly hint at a particular concept). For instance, the phrase "lack of adequate preparation" was used verbatim to represent the thematic construct of "Poor project planning".

*"I would attribute the lack of adequate preparation before project's commencement as one of the primary reasons for our current predicament reasons. This singular planning oversight has instigated the need to broaden the project's scope to include certain elements that were overlooked prior to the commencement of the construction work".*

Some codes were derived from empirical literature, particularly when an interviewee statements hinted at a concept, albeit indirectly. This strategy was particularly beneficial when decoding remarks that subtly implied known issues in the field but did not explicitly name them. For instance, the following alludes to "long process of review and payment", thus representing the broader theme of "Bureaucratic process".

*"When a contractor completes a certain task, they receive a certificate of work done, which is then sent to the responsible authorities such as the ministers, ministry directors, consultants, the Accountant General of the Federation. After approval, it often takes a significant amount of time before the contractor receives payment for the certified work, even when the budget his already approved and funds are readily available, due to the lengthy chain of the entire process".*

Recognizing these two (2) types of statements was crucial to ensure comprehensive coding, irrespective of whether the concepts were directly mentioned. An iterative revision process ensured the developed codes encapsulated all the information pertinent to the research problem. Ultimately, patterns within the numerous codes began to emerge, hinting at potential themes that represented similar concepts.

### *ii. Categorising and aggregating codes into refined themes from all interview data*

The second stage involved grouping the previously generated codes (in step 1) that were indicative of a particular theme or associated with similar concepts. Nodes depicted as child nodes, representing related concepts like *"incomplete information in tender documentation"*, *"lack of adequate preparation"* and "*non-consideration of future development"*, were aggregated together. This cluster then formed a broader theme such as *"Poor project planning",* demonstrated in a hierarchical manner as depicted in Figure III. The final coding tree, however, evolved iteratively as shown in Table V. This stage also involved the revision and reorganization of codes and coded data extracts, with the associated themes further refined and finalized based on the consolidated coded information for each theme.

**Figure III. Nvivo screen that shows hierarchical grouping of themes**

In the final theme identification process, not only the frequency but also the salience of the information within the data was considered. This approach ensured that critical insights pertinent to the study were not overlooked due to their infrequency. For instance, themes highlighted by expressions such as “this is a big issue”, “the major reason” etc. were deemed significant and relevant despite their lack of recurrence. Themes that were neither recurrent not emphasised were ignored. For example, the statement below illustrates such as emphasis.

*“The major reason contractors face is being caught in a predicament where the prices of materials and even equipment spare parts have surged significantly since the initial contract award”* [Int_08].

**Table V. Coding tree for the theme “Poor project planning”**

### *iii. Identifying causal relationships between aggregated themes*

After identifying the themes (in step 2), we delved further into the data to identify causal relationships evident in interviewee statements. This analysis centred on statements suggesting causal connections between two themes or codes within the same context. These causal connections, stemming from participants' mental models, were pivotal in understanding the dynamics of the system. To bolster the identification of causal relationships, several strategies were employed: first, we utilized Nvivo 12's relationship feature, linking these relationships directly to the data. This revealed which participant's perspective was represented by each relationship; second, we searched for indicative terms (e.g., “because”, “then”) suggesting causal dynamics; third, we incorporated the overall understanding of an expressed causal relation from the interviews.

For instance, the statement below contain indicator that suggest a causal relationship between *“modification of project scope and project duration”***.** *“Int_11*” represents the 11th interviewee, while *“MPS-PD”* denotes the causal relationship between *“modification of project scope and project duration”*.

*“Indeed, for you to introduce additional tasks that means, contract duration has to be extended, because these supplementary works will also take some time to be completed” [Int_11- MPS-PD]*

Furthermore, coding charts were established for each causative statement. Each chart detailed the supporting data extracts, bolstering the validity of the identified relationships. These charts were allocated Reference Identification Codes (RIC) representing thematic categories and their associated causal relationships. Furthermore, Data Source Identification (DS ID) codes linked each relationship back to its original data source and specific interviewee.

For example, a coding chart highlighting a relationship between *“project funding issues and payment delay”* with corresponding RIC and DS ID codes is presented in Table VI. This chart includes data extracts supporting the identified causal relationship.

**Table VI. Coding chart**

***Supporting data extract***

*“Contractors are confronted with payment issues, posing significant financial challenges as the respective*

*payment clauses are often not honoured by the client. This is primarily due to the government's difficulties in securing adequate funding for all public projects. Given the sheer number of projects that require funding, it results in inconsistent payments to contractors" [Int_06- PFI-PD$_I$].*

### *iv. Transforming the coding charts into CLDs*

In this phase, themes and causal relationships recorded in the coding charts were transformed into distinct causal links. These links were then connected to form CLDs. By leveraging the coding chart- created from individual causal relationships identified within each data item- and the entire dataset, we were able to ascertain deeper insights into the system's structure and behavior. Each causal relationship detailed in the coding charts underwent individual analysis to extract the inherent causal links. Derived from these links were cause-and-effect representations, signifying the collective interpretation of the individual mental models. An exemplar of this, highlighting the causal relationship between *"project quality issues and rework"*, is visualized in a word-and-arrow diagram presented in Figure IV. The transformation was facilitated using Vensim PLE 10.1.5 system dynamics software.

**Figure IV. Transformation of coding charts into CLD**

Subsequently, a composite CLD was constructed by integrating all the cause-and-effect representations, enabling a holistic understanding the key factors influencing cost escalations in Nigerian public construction projects. This holistic representation is illustrated in Figure V. The resultant interconnections produced five (5) feedback loops. Of these, four were identified as reinforcing (or positive) loops, while one emerged as a balancing (or negative) loop.

**Figure V. Composite CLD**

### *v. Retaining links between CLDs and data source*

In this final stage, the CLDs was linked to their original data source using a data source reference table. This table ensured the data's transformation into causal links and CLDs remained connected to its source, bolstering confidence in the final CLD. It is essential to maintain this connection between the DS and CLDs, which was done using two identifiers: the RIC and DS ID code. Each causal relationship gets a RIC for its thematic representation and a DS ID code for the participants perspective. The reference table displays causal relationships in one column and associates them with their DS ID codes and RICs in others. By referring to this table and CLD, one can match a causal relationship to its data source, first through the RIC identifying the relationship, then the DS ID code pointing to the participant's input.

The DS ID code and RIC serve as guides to trace the exact data extracts that contributed to the creation of specific sections of the CLD. This is particularly crucial when one needs to trace how distinct segments of data are represented in the CLD. To undertake this process, we consider the RIC linked to the data segments in the table. This RIC aids in providing the list of related DS references for these data segments.

Table VII provides an example, demonstrating the connection between *"project funding issues and payment delay"* and its corresponding RIC and DS ID code.

**Table VII. Data source reference table**

### *3.3 Model Validation*

After the initial development of the model, validation of the CLD and its underlying conceptual thinking was conducted by nine (9) participants, as shown in Table VIII who took part in the first phase interview session. This validation process aimed to ensure that participants' perspectives were accurately represented. Printed copies of the initial model were provided to each participant, along with explanations of the objectives of the validation exercise and instructions on how to respond.

During the exercise, participants were asked to review the model and scrutinize the existence of the all variables and causal relationships. They were also prompted to identify any were significant causal factors that may have been missing from the model. Additionally, participants assessed the polarities of the cause and effect relationships, rectifying any found to be inappropriate.

Furthermore, participants were encouraged to scrutinize, reaffirm or suggest revisions to any variable (determinant) in the model. For instance, participant 02 recommended renaming the variable "*poor project planning*" to "*inadequate project preparation and planning*" to better reflect real-life contexts and provide a broader understanding of the theme. Moreover, participants 06 and 09 highlighted instances where projects were discontinued due to contractors failing to fulfil their contractual obligations and poor performance, despite having received payment resulting in the causal relationship between "*non-performance of contractors and breach of contractual agreement*", and "*project termination*".

Consequently, these suggested modifications were incorporated to enhance the model, resulting in the final validated model version presented in Figure VI.

**Table VIII. Experts involved in CLD validation**

**Figure VI. Conceptual model of the influencing determinants of cost escalation**

## 4. Discussion

Figure VI presents a comprehensive conceptual model illustrating the complex interplay of the determinants leading to cost escalation in public construction projects in Nigeria. The model consists of 29 variables, each symbolizing a key determinant. These determinants are interconnected through 42 arrows, depicting the causal flow among them. Crucially, these interconnections result in five feedback loops within the system. Out of these, four are reinforcing loops, which, as posited by Meadows (2008), reflect processes that perpetuate and magnify, contributing to rapid growth or decline within a system. This phenomenon implies that a small change in one aspect can set off a cascade of events that amplify the original change, leading to significant cost escalations (Sterman, 2000). Conversely, the model also includes a balancing loop, which aligns with the stabilizing process identified by Kim and Andersen (2012). This process aim for equilibrium, and if any deviation arises, a balancing loop acts to counter and mitigate its

impact, nudging the system back to its baseline state.

The model unveiled a convoluted web of interactions within Nigeria's public construction project system, emphasizing the role of reinforcing and balancing loops. Reinforcing loop R1 through R4 illustrates escalating cycles of complications, triggered by challenges related to project funding within the framework of public construction projects (Ofori, 2013). As shown in R1, exacerbation of these complications is notably influenced by project cost, political instability and undue political interference (Chadee *et al.,* 2023; Aibinu and Odeyinka, 2006). These factors notably impact contractor payments, culminating in cash flow challenges (Omopariola *et al.,* 2020), which sequentially lead to project delays, increased project durations, and ultimately escalated project costs (Mahmud *et al.,* 2022).

The repercussions of financial constraints and political influences are accentuated, especially in the backdrop of waning political will to fund projects (Chadee *et al.,* 2022). The ramifications further convolute with the integration of Loops R2, R3, and R4, where external and internal factors such as adverse weather conditions (Mahmud et al., 2021), scope modifications, cost of construction materials, and inadequate project preparation and planning (Flyvberg *et al.,* 2003; Ahiaga-Dagbui *et al.,* 2015) come into play. These elements elucidate how unforeseen external events combined with project mismanagement can escalate project delay and costs (Koushki *et al.,* 2005). Notably, when delay become substantial, the propensity of altering project outcomes increases, which further extend the project duration (Mahmud *et al.,* 2022). This prolonged duration affects the cost of construction materials (Andric et al., 2024), particularly in public sector projects where contract terms are heavily influenced by macroeconomic variabilities such as foreign exchange rates and inflation (Olatunji *et al.,* 2018). As a result, project costs are amplified (Xie *et al.,* 2022). This network of reinforcing loops creates a complex and intertwined ecosystem of factors that perpetuate an upward spiral in project costs.

Conversely, the Balancing Loop B1 acts as a reprieve, offering a counteractive dynamic to the reinforcing loops. This loop analyses how quality-related challenges, which are often exacerbated by ineffective technical teams (Asiedu and Ameyaw, 2021; Ameyaw *et al.,* 2012) and mistakes and omission in contract documentation (Omoregie and Radford, 2006; Asiedu and Ameyaw, 2021), necessitates the rectification of defects or rework. Such rework, while potentially costly and time-consuming, becomes more manageable and effective when backed by a proactive and supportive government. especially with the backing of a supportive government. By addressing and correcting defects promptly, the overall quality of the project is improved, which in turn helps to mitigate the cost escalations that are driven by the reinforcing loops (Mansfield *et al.,* 1994). Furthermore, Loop B1 emphasises that the efficient management of project quality- through rigorous quality control measures, adequate training of technical teams, and thorough contract documentation, can significantly reduce the incidence of defects and the need for costly rework. When complemented by political support, the project challenges can be reduced, thus contributing to the successful completion of the project.

## 5. Leverage points and intervention strategies

CLDs have proven instrumental in elucidating the intricate dynamics of complex systems, serving as valuable tools in identifying leverage points and strategizing system interventions that could yield long-term improvements. In system thinking, leverage points represent crucial areas in a dynamic system where minor interventions can induce profound transformations in the system's behaviour (Fisher and Riechers, 2019). The CLD under review, accompanied by five distinct feedback loops (as illustrated in Figure 3), offers policymakers a roadmap to potential leverage points that, when acted upon, could influence the effective execution of public sector projects in Nigeria.

As Figures VI and VII suggest, strategic interventions should be designed to stimulate beneficial systemic shifts. A potential leverage point emanates from enhancing the technical competence of construction professionals. The trajectory of this intervention underscores its potential ripple effects on various system variables, such as quality of work, the accuracy of project estimates, the efficiency of project preparation and planning, and the standards of design outputs. This leverage point finds substantial support in the existing literature, with numerous studies including those by Asiedu & Ameyaw (2021), Aje (2012), Ameyaw *et al.* (2012), and Osei-Tutu *et al.* (2011), highlighting the role of technical competence in escalating costs of construction projects. For example, Asiedu and Ameyaw (2021) attributed the poor cost performance of public construction projects in Ghana on the technical expertise gaps among consultants. Nweze (2016) echoed these findings, postulating that the challenges in executing complex projects in developing countries like Nigeria greatly jeopardizes the success of public construction initiatives.

Therefore, to improve the outcomes of public construction projects, there is a critical need to enhance the capacity of construction professionals. This enhancement can be achieved through effective synergy between the public sector, professional bodies, statutory regulatory bodies, and policymakers. Instituting robust training initiatives and strengthening existing codes of ethics, aimed to promote ethical behaviour and professional standards, can play a pivotal role in steering public construction projects towards success (Asiedu and Ameyaw, 2021; Nweze, 2016).

**Figure VII. Uses tree of lack of technical competence**

## 6. Conclusion, contributions and limitations

The pervasive challenge of cost escalation in Nigeria's public construction domain is a multifaceted conundrum, with roots stemming from a myriad of determinants. While previous studies predominantly investigated these determinants in a siloed manner, this study underscores the paramount importance of examining these determinants in the light of their synergetic relationships. A notable exception is a prior study by Mahmud *et al.* (2022) that specifically focused on highway projects instead of general public projects. This study applies systems thinking to comprehend the underlying factors affecting the cost performance of public construction projects in Nigeria, thereby extending the

conventional investigative approach. It provides a broad integrated view of the dynamics of cost escalation issues in public sector construction projects, thus accommodating the different viewpoints of stakeholders. Through a robust data coding framework, a conceptual model was developed that underscores the intricate interplay of these determinants. Among the several interrelated factors, lack of technical competence stood out as a significant factor exerting substantial influence on other causal determinants.

The model was instrumental in identifying critical intervention areas within the intricate dynamic system to enhance project performance. Enhancing the technical competence of professionals engaged in Nigeria's public construction projects was proposed as a crucial strategic intervention. Effective collaboration among the public sector, professional bodies, statutory regulatory bodies, and policy-makers, complemented with the provision of high-quality training offers a viable approach towards improving the competence of construction professionals.

While the study provides valuable insights, it has its limitations. The reliance on qualitative data means the conceptual model lack mathematical rigor, suggesting a need for further research to develop a mathematical model. Such a model could facilitate a more profound understanding of the collective impact and dynamic behaviour of the determinants. The sample size poses another constraint, potentially influencing the broader applicability of the results. Moreover, since the findings are rooted in Nigerian public construction projects, their relevance to privately financed projects might be limited. Also, Similarly, the study focuses solely on the construction stage, without extending to the post-construction phase. While this focus is crucial for understanding the determinants of cost escalation during construction, it does not address how these factors might influence or be influenced by later stages of the project lifecycle, such as facilities management operations. Lastly, the themes and their causal links were derived from viewpoints of experts from the Nigerian context. Future studies could enhance the external validity of the research results by examining their applicability in other contexts and by integrating the later phases of public sector construction projects, such as facilities management operation, to offer a more holistic view of the problem.

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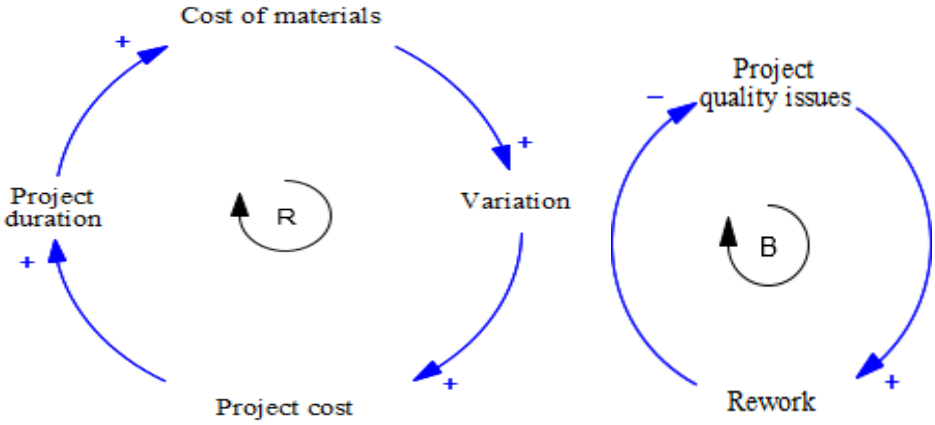



**Figure I. Example of reinforcing and balancing loops**

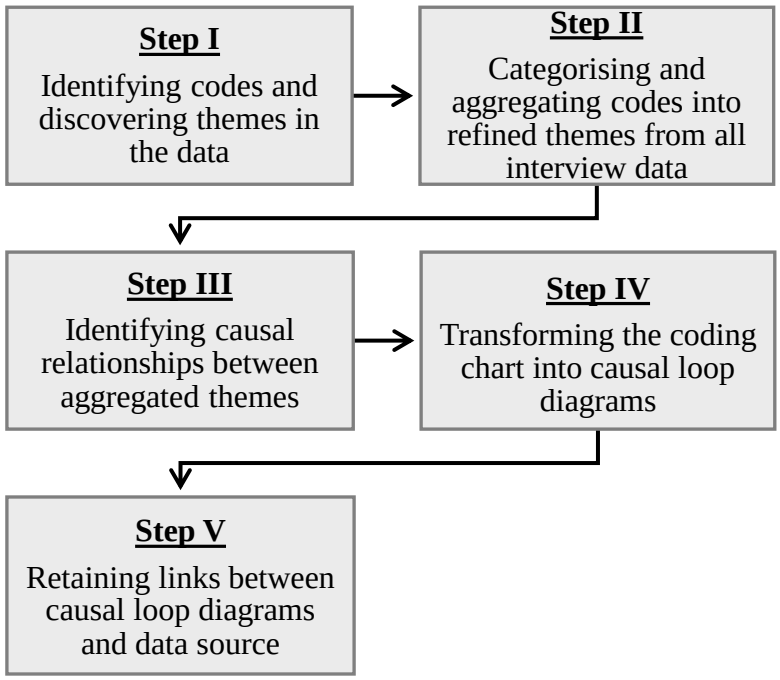
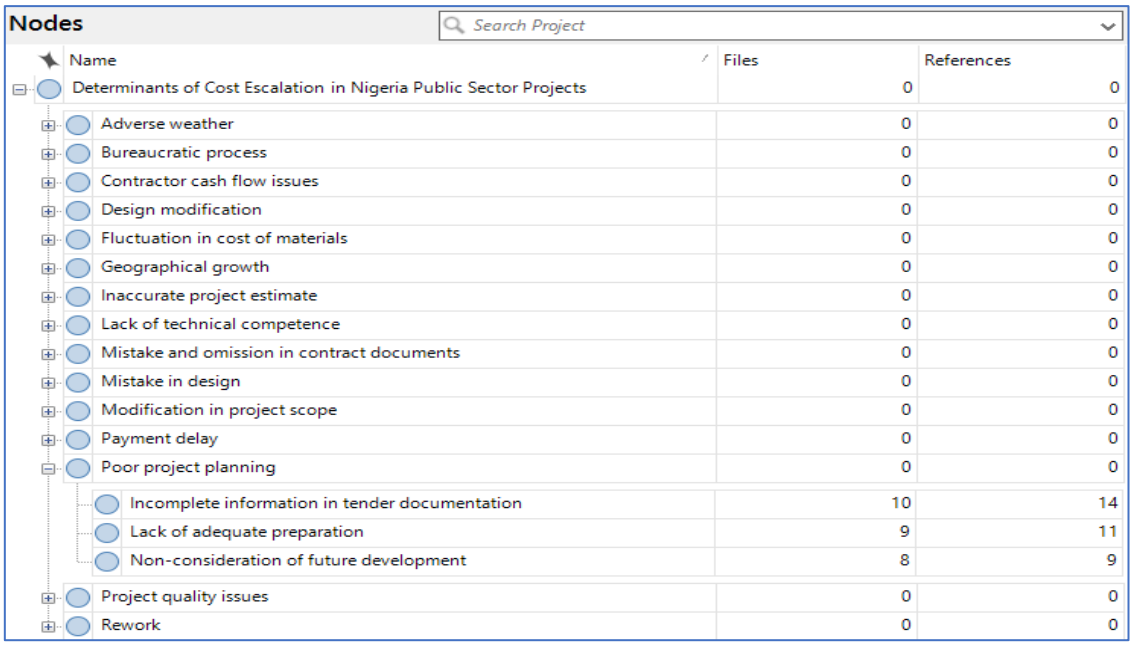



**Figure II. Coding framework**

Adapted from Mahmud *et al.* (2023)




| Name | Files | References |
|---|---|---|
| Determinants of Cost Escalation in Nigeria Public Sector Projects | 0 | 0 |
| Adverse weather | 0 | 0 |
| Bureaucratic process | 0 | 0 |
| Contractor cash flow issues | 0 | 0 |
| Design modification | 0 | 0 |
| Fluctuation in cost of materials | 0 | 0 |
| Geographical growth | 0 | 0 |
| Inaccurate project estimate | 0 | 0 |
| Lack of technical competence | 0 | 0 |
| Mistake and omission in contract documents | 0 | 0 |
| Mistake in design | 0 | 0 |
| Modification in project scope | 0 | 0 |
| Payment delay | 0 | 0 |
| Poor project planning | 0 | 0 |
| Incomplete information in tender documentation | 10 | 14 |
| Lack of adequate preparation | 9 | 11 |
| Non-consideration of future development | 8 | 9 |
| Project quality issues | 0 | 0 |
| Rework | 0 | 0 |

**Figure III. NVivo screen that shows hierarchical grouping of themes**

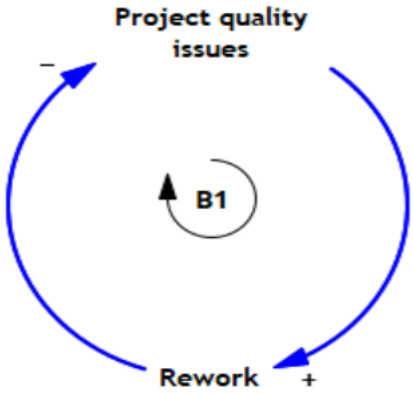



**Figure IV. Transformation of coding charts into CLD**

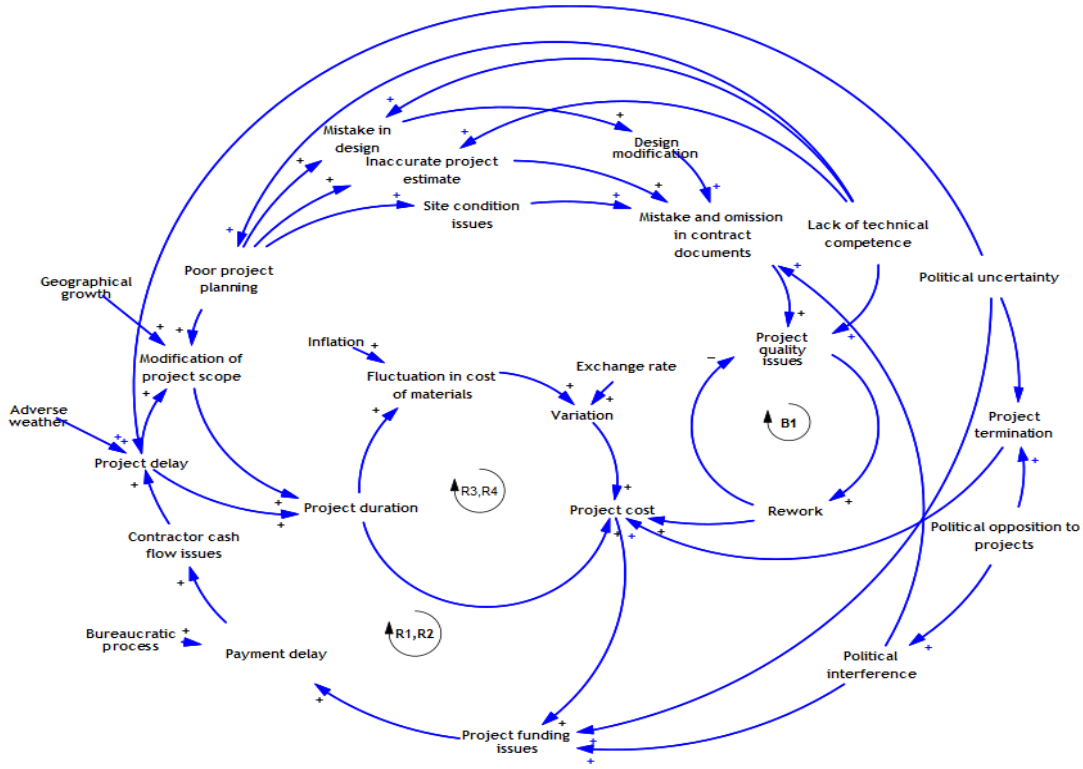



**Figure V. Composite CLD**

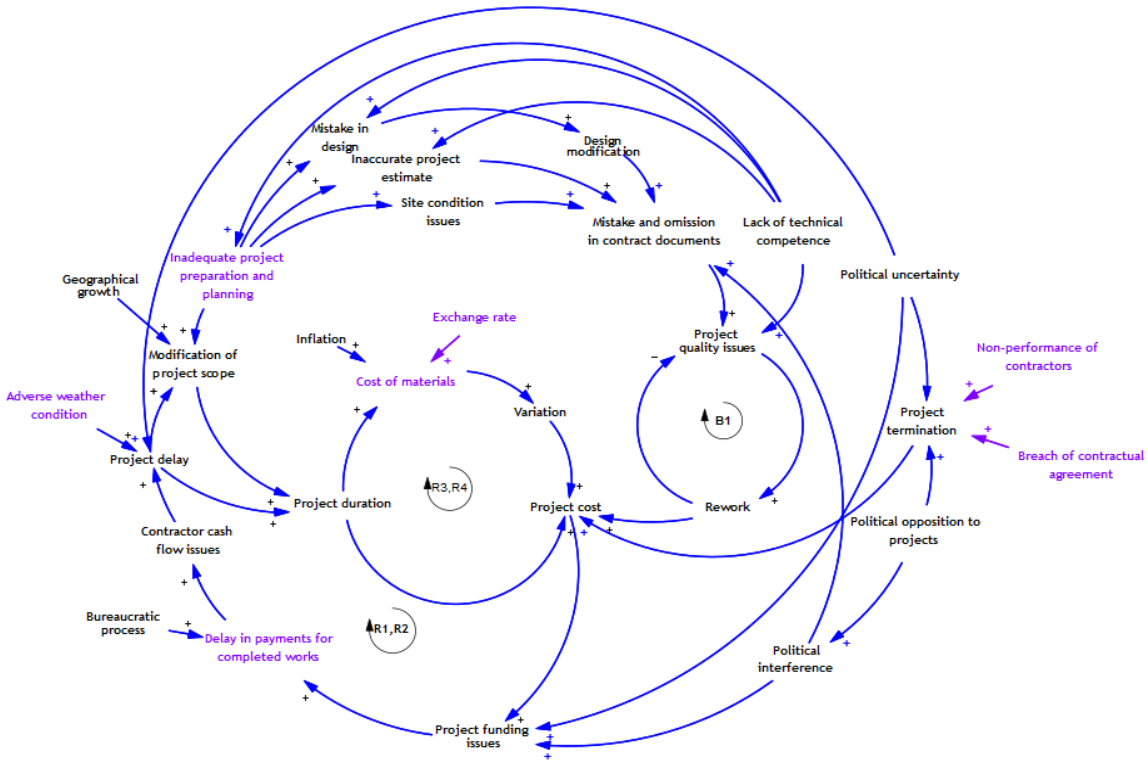



**Figure VI. Conceptual model of the influencing determinants of cost escalation**

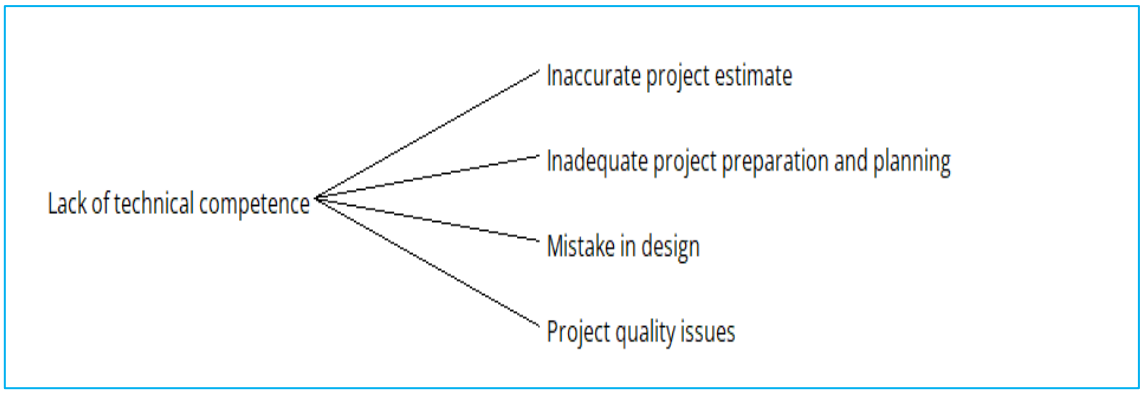



**Figure VII. Uses tree of lack of technical competence**

**Table I. Summary of previous studies on determinants of cost escalation in public construction projects**

| Researchers | Country | Top determinants of cost escalation |
|---|---|---|
| Andric *et al.* (2024) | South Asia | Fluctuation of prices of resources, fluctuation in money exchange rate, increase in loan interest rates, increased implementation cost, increased consultancy cost and increased land acquisition and resettlement cost. |
| Mahmud *et al.* (2021) | Nigeria | Delay in progress of work, political instability, adverse weather, social issues, delay in payments to contractors, and modification of project scope |
| Idrees and Shafiq (2021) | Pakistan | Legal issues, technical errors, and poor project management |
| Alinaitwe *et al.* (2013) | Uganda | Changes in scope, delays in payments to contractors, poor monitoring and control, high inflation, and interest rates |
| Larsen *et al.* (2015) | Denmark | Errors or omissions in consultant material, errors or inconsistencies in project documents, late user changes affecting the project or function, lack of preliminary examination before design or tendering, and inexperienced or newly qualified consultants |
| Shanmugapriya and Subramanian (2013) | India | Escalation of material prices, frequent breakdown of construction plants and equipment, rework, shortage of materials, and fluctuation in money exchange rate |
| Le-Hoai *et al.* (2008) | Vietnam | Difficulties in financing the projects by the clients and contractors, change in design documents, poor site management and supervision, and labour cost increases |
| Niazi and Painting (2017) | Afghanistan | Corruption, delayed progress payments, contractor financing difficulties, security, changes made during construction, and market inflation |

| | | |
|---|---|---|
| Kaliba *et al.* (2009) | Zambia | Unfavourable weather, changes in scope of projects, environmental issues, schedule delays, civil unrest, pressure from the government at a local level, technical difficulties, and inflation |
| Mahamid and Bruland (2011) | Palestine | Material price fluctuations, insufficient time for estimate, experience in contracts, size of contract, and incomplete drawings |
| Wanjari and Dobariya (2016) | India | Price escalation of raw materials, delay in planned activity, and lack of adequate coordination between the construction parties |
| Love *et al.* (2015) | Australia | Scope changes, and errors and omissions in contract documents |
| Leo-Olagbaye and Odeyinka (2018) | Nigeria | Changes in scope, defective design, changes in initial project design, delay in the availability of design information, and adverse weather conditions |
| Anigbogu *et al.* (2019) | Nigeria | Inflation, fluctuation of prices, exchange rate, changes in policies, variation, delays in payment, design changes, corruption, and unforeseen ground conditions |
| Shimete and Wall (2017) | Namibia | Scope changes, contractor inexperience, contractors' cash flow and financial difficulties, inaccurate estimates, and poor project planning |
| Belachew *et al.* (2017) | Ethiopia | Material price fluctuations, cost underestimates, delays in supply of raw materials, inadequate review of contract documents, and lack of coordination |

**Table II. Interview guide**

| Theme | Interview question |
|---|---|
| **Interviewee** | What is your role within your organisation? |
| **Organisation** | What is the nature of your organisation, and how successful is it in delivering public sector projects? |
| **Working experience** | How long have you been involved in public sector project development? |
| **Cost performance challenges** | Based on your experience, what are the key challenges affecting the cost performance of public sector projects? |

**Table III. Summary of interviewees' background information**

| S/No | Type of Organisation | Interviewee Code | Years of Working Experience |
|---|---|---|---|
| 01 | Contractor | Int_01 | 24 |
| 02 | Contractor | Int_02 | 21 |
| 03 | Contractor | Int_03 | 18 |
| 04 | Contractor | Int_04 | 15 |
| 05 | Contractor | Int_05 | 12 |
| 06 | Contractor | Int_06 | 19 |
| 07 | Client | Int_07 | 14 |
| 08 | Client | Int_08 | 16 |
| 09 | Client | Int_09 | 20 |
| 10 | Client | Int_10 | 22 |
| 11 | Client | Int_11 | 18 |
| 12 | Client | Int_12 | 15 |
| 13 | Client | Int_13 | 17 |
| `14 | Client | Int_14 | 16 |
| 15 | Consultant | Int_15 | 19 |
| 16 | Consultant | Int_16 | 18 |
| 17 | Consultant | Int_17 | 20 |

**Table IV. Summary of the Coding Process**

| Description of the Process | Main Tool | Input | Output |
|---|---|---|---|
| Identifying codes and discovering themes in the data | Steps I, II, and III of thematic analysis framework and CAQDAS | Raw text of individual transcript data | Definition of the problem and establishment of system boundary, generation of codes and preliminary idea of themes and corresponding codes and coded extracts. |
| Categorising and aggregating codes into refined themes from all interview data | Steps IV and V of thematic analysis framework and CAQDAS | Preliminary idea of themes and corresponding codes and coded extracts | List and categories of themes and supporting data extracts |
| Identifying causal relationships between aggregated themes | Steps IV and V of thematic analysis framework, causal links and CAQDAS | Categories of themes, further analysis of data extracts to identify causal relationships among the codes | Coding charts of each causal relationship, coding dictionary and causal relationships data extracts |

| | | | |
|---|---|---|---|
| Transforming the coding charts into CLDs | CLDs and vensim software | Coding charts | Individual CLDs and final CLD |
| Retaining links between CLDs and data source | CLDs, data source ID and reference ID codes, and coding dictionary | Final CLD and coding charts | Data source reference table, and CAQDAS |

Note: Adopted steps of the thematic analysis framework: Step I- Familiarisation with the data; Step II- Generation of initial codes; Step III- Searching for themes; Step IV- Reviewing themes; Step V- Defining and naming of themes.

Adapted from Mahmud *et al.* (2023)

**Table V. Coding tree for the theme "Poor project planning"**

| Coded theme | |
|---|---|
| **Poor project planning** | **Coded data extracts example** |
| Incomplete information in tender documentation | *The client potentially could have made significant strides towards cost-efficiency by issuing a detailed tender. Providing comprehensive information to the contractor in the early stages could have facilitated more accurate pricing and likely minimized the incidence of subsequent modifications and cost adjustments.* |
| Lack of adequate preparation | *In my perspective, inadequate planning before the project's kick-off is a significant reason for the substantial challenges we are facing currently. This single planning oversight led to the expansion of the project scope, accommodating various elements that were initially overlooked at the start of the construction work.* |

**Table VI. Coding chart**

| | | |
|---|---|---|
| ***Data Source ID:* [Int_06]** | | ***RIC: PFI-PD$_I$*** |
| **Main Statement:** There is always a delay in payment to contractors when there is no adequate funding provided to the project by the Government. | | |
| ***Causal structure*** | *Cause variable:* | *Project funding issues* |
| | *Effect variable:* | *Payment delay* |
| | *Relationship type:* | *Positive* |
| ***Variable behaviour*** | *Cause variable* | *Shortage of funds* |
| | *Effect Variable* | *Increased delay in payment* |
| ***Information Source:*** *Comments observed from all the interviewees relevant to the causal relationship about the technical factors of cost overrun with indicators such as "because", and also the general understanding of a causal expression by the interviewee* | | |
| ***Themes:*** *Project funding issues, delay in payment to contractors* | | |

**Table VII. Data source reference table**

| Cause Variable | Relationship Type | Effect Variable | DS ID Code | RIC |
|---|---|---|---|---|
| Project funding issues | Increase/+ | Payment delay | Int_06 | PFI-$DP_l$ |

**Table VIII. Experts involved in CLD validation**

| S/No | Type of Organisation | Interviewee Code | Years of Working Experience |
|---|---|---|---|
| 01 | Contractor | Participant 01 | 24 |
| 02 | Contractor | Participant 02 | 21 |
| 03 | Contractor | Participant 03 | 18 |
| 04 | Consultant | Participant 04 | 20 |
| 05 | Consultant | Participant 05 | 19 |
| 06 | Consultant | Participant 06 | 18 |
| 07 | Client | Participant 07 | 20 |
| 08 | Client | Participant 08 | 18 |
| 09 | Client | Participant 09 | 17 |