

Analysis Challenges of Engineering, Procurement, Construction and Commissioning (EPCC) Contract of East Coast Rail Link (ECRL) Using Principal Component Analysis Method

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DOI: <https://doi.org/10.30880/peat.2024.05.02.076>

Article Info

Received: 27 June 2024

Accepted: 18 July 2024

Available online: 25 November 2024

Keywords

Challenges, Engineering, Procurement, Construction and Commissioning, East Coast Rail Link, principal component analysis

Abstract

The East Coast Rail Link (ECRL) project in Malaysia has faced significant challenges due to fluctuating development costs and design changes driven by government shifts, particularly impacting the Engineering, Procurement, Construction, and Commissioning (EPCC) phases. The rigid EPCC contracts hinder the project's adaptability to changing needs, causing misalignments, disputes, cost overruns, and delays. This thesis identifies these challenges, proposes solutions, and evaluates their impact on project timelines and stakeholder relationships using a mixed-method approach, including literature review and stakeholder surveys analyzed with SPSS software. Key challenges include design changes, cost overruns, interdependence of stakeholders, regulatory compliance, technical specifications and integration, and timeline delays. Solutions proposed involve enhancing client participation, increasing contract flexibility, and robust risk management, aiming to improve project efficiency and alignment with client expectations.

1. Introduction

An EPCC contract details the responsibilities for engineering, procurement, construction, and commissioning in a project. For Malaysia's East Coast Rail Link (ECRL), Malaysia Rail Link Sdn. Bhd. (MRL) owns the project, with China Communications Construction Sdn. Bhd. (CCCC) as the main contractor (MRL et al., 2024). The contract covers detailed design, sourcing materials, construction activities, and final testing to ensure everything works as planned before handing over to MRL.

The 665 km ECRL project aims to improve connectivity and economic growth but has faced challenges like cost increases due to design changes and government shifts. Coordination issues among stakeholders, cost overruns, quality control, environmental concerns, and regulatory problems have also arisen. Despite these difficulties, the project, which began in 2017, is crucial for reducing travel time and boosting economic sectors along its route. Completion has been delayed, with the Kota Baru to Gombak section expected by December 2026 and the Gombak to Port Klang section by December 2027 (Sulhi Khalid & Izzul Ikram et al., 2021). Effective risk management and adaptive strategies are essential for the project's success.

The objectives of this study are to identify the critical challenges of the Engineering, Procurement, Construction, and Commissioning (EPCC) contract for the East Coast Rail Link (ECRL) project, to determine potential solutions for these challenges, and to analyze the sustainability performance of the EPCC contract.

This research investigates the challenges of Engineering, Procurement, Construction, and Commissioning (EPCC) contracts, focusing on the East Coast Rail Link (ECRL) project in Malaysia. It explores the reasons for selecting an EPCC contract with the China Communications Construction Company (CCC) for the ECRL project. Using a Microsoft Forms questionnaire, the study surveys ECRL project stakeholders to identify key challenges of EPCC contracts. It also proposes practical solutions to mitigate these challenges and improve the implementation of EPCC contracts in large-scale infrastructure projects. While acknowledging limitations such as the study's specificity to the ECRL project and potential survey data constraints, the research aims to provide valuable insights for enhancing the execution of EPCC contracts in the ECRL initiative.

2. Literature Review

2.1 EPCC project life cycle

The East Coast Rail Link (ECRL) project in Malaysia follows a structured project life cycle, with Malaysia Rail Link (MRL) as the project owner. As in Fig. 1, in the initiation phase, MRL defines the project's purpose and scope and assembles the team, following approval by the Malaysian Prime Minister. During planning, MRL collaborates with the main contractor, China Communications Construction Company (CCCC), to establish detailed plans. In the execution phase, CCCC leads in implementing these plans, managing engineering, procurement, and construction. MRL oversees the project to ensure alignment with plans while CCCC handles daily operations. The monitoring and controlling phase involve both parties addressing any deviations. In the closure phase, MRL oversees the project's completion, with both parties working on documentation, evaluation, and formal closure. The project's success depends on the effective collaboration and coordination between MRL and CCCC, each playing distinct but interdependent roles.

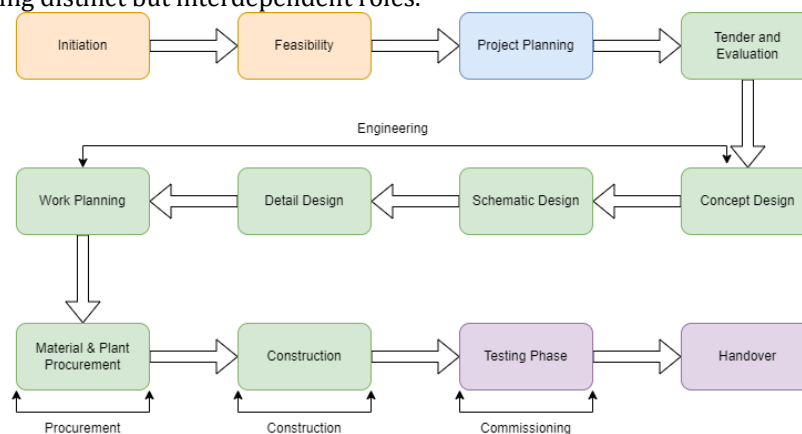


Fig. 1 : Typical EPCC Project Life Cycle (Bell et al.,2022)

2.2 Challenge faced in EPCC contract

EPCC projects face multiple challenges including the interdependence of activities, overlapping phases, fragmented work, complex organizational structures, and uncertainty in predicting outcomes. Major companies use a matrix organization for project management, which, while effective, is inherently complex. Project activities are highly interdependent, impacting each other reciprocally. Information transfer and iterations are crucial, but work fragmentation, involving numerous participants like owners, design firms, and suppliers, complicates the process. This fragmentation can lead to adversarial relationships and delays, especially in negotiations, approvals, and international procurement (De la Garza et al., 1994). As in Fig. 2, overlapping phases in engineering, procurement, and construction increase the risk of schedule and cost overruns due to incomplete information and frequent changes. Studies highlight that project changes and rework contribute significantly to delays and failures, with rework accounting for 12.4% of total project costs. Managing these interdependencies and overlaps is crucial to effectively execute EPCC projects (Austin. S et al., 1994).

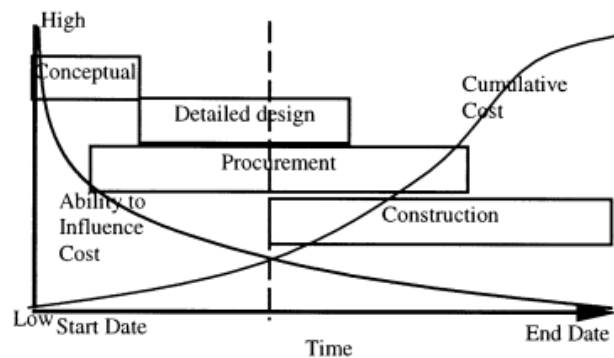


Fig. 2 : Overlapping Phases (Austin. S et al.,1994)

2.3 Factors contributing to challenges of EPCC in the ECRL project

The East Coast Rail Link (ECRL) project in Malaysia faces various challenges in its EPCC contracts, including design changes, government shifts, cost overruns, environmental assessments, and land acquisition complexities. Additional difficulties arise from geopolitical factors, stakeholder interdependence, project management complexities, and regulatory compliance. Technical specifications, integration issues, and potential timeline delays further complicate the project. Successfully addressing these challenges requires proactive risk management, transparent communication, and adaptive project management strategies. The ECRL's unique context, scale, and diverse contributing factors highlight the necessity for careful navigation to ensure successful execution of EPCC contracts.

2.4 Principal Component Analysis for data analysis

Principal Component Analysis (PCA) is a statistical technique that transforms a large number of variables into a new set of orthogonal variables called principal components, which capture the maximum variance in the data. It is especially useful for dimensionality reduction, enabling researchers to identify key patterns and relationships while discarding noise or irrelevant information. PCA simplifies the analysis and visualization of complex datasets, making it easier to interpret and draw meaningful conclusions. It can also uncover hidden structures or clusters within the data (Greenacre et al., 2022).

PCA is well-suited for analysing complex and multidimensional datasets, such as those in large infrastructure projects like the East Coast Rail Link (ECRL). It reduces the dimensionality of data while preserving variance, effectively handling numerous variables related to engineering, procurement, construction, and commissioning challenges. By identifying the most significant factors contributing to the overall variance, PCA highlights key issues needing attention.

PCA offers a systematic and objective approach to data analysis, minimizing subjective bias and ensuring findings are based on empirical evidence. It also facilitates effective data visualization through graphical representations like scree plots and biplots, enhancing the clarity and comprehensibility of complex information.

Overall, using PCA in analysing the ECRL project's EPCC challenges provides robust insights and recommendations for project management and decision-making.

2.5 The sustainability of an Engineering, Procurement, Construction, and Commissioning (EPCC) contract in the construction industry

The sustainability of Engineering, Procurement, Construction, and Commissioning (EPCC) contracts in the construction industry involves balancing economic, environmental, and social dimensions. Economically, it focuses on cost management and financial viability for effective project delivery. Environmentally, it includes adherence to regulations and the adoption of green practices. Socially, it emphasizes community engagement, job creation, and worker safety. Additionally, considering the entire project lifecycle, including long-term operation and adaptability, is crucial. Balancing these factors ensures the overall sustainability of EPCC contracts in construction (Werbach et al., 2011).

3. Methodology of Study

Methodology is defined as a scientific method to solve research objectives through data collection by using different techniques, supplying an interpretation of collected data and making conclusions for the study. Quantitative method is used in this research to analyse the challenges of engineering, procurement, construction and commissioning (EPCC) contract of the East Coast Rail Link (ECRL) project in Malaysia. The preliminary data of the challenges of EPCC contract in terms of ECRL project will be gathered from literature review. Then, a survey will be conducted by distributing questionnaires to the respondents.

3.1 Methodology Framework

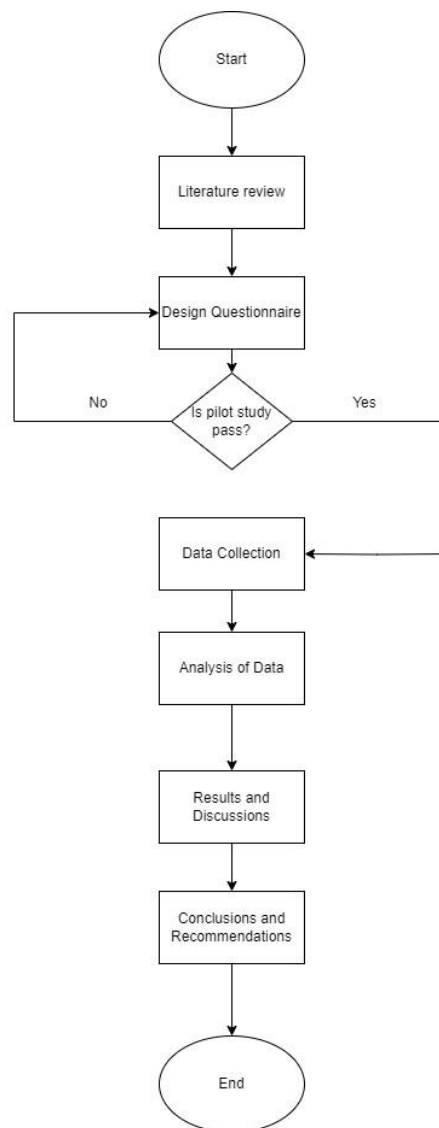


Fig. 3: Flow chart of Methodology

3.2 Literature Review

The literature review for this research involved analysing theses, journals, articles, and other relevant resources. Insights into the challenges of EPCC contracts in the East Coast Rail Link (ECRL) project in Malaysia were extracted and summarized in a table. This information serves as the foundation for designing the questionnaire to systematically explore EPCC challenges which related to the ECRL project. The review also examines the conceptual framework and application of EPCC in the Malaysian context, contributing to a comprehensive understanding of the topic.

3.3 Design Questionnaire

A questionnaire is a research tool with a series of closed-ended or open-ended questions designed to collect data for analysis. In this study, a closed-ended questionnaire will be used, divided into three sections: demographic profile, general perspectives, and challenges associated with the EPCC contract in the East Coast Rail Link (ECRL) project in Malaysia. The questions are based on insights from the literature review, focusing on EPCC challenges in the ECRL project. The questionnaire will be reviewed by an expert in engineering technology in rail transportation before being distributed to organizations involved in the ECRL project.

3.4 Challenges of Engineering, Procurement, Construction, Commissioning (EPCC) contract of the East Coast Rail Link (ECRL) project in Malaysia.

Challenges of the EPCC contract for the ECRL project in Malaysia were identified from a literature review of journals, articles, and theses and summarized in a table. The research uses a Likert Scale in the questionnaire to rate these challenges. The Likert Scale, developed by Rensis Likert in 1932, is a reliable method for gathering opinions, insights, and behaviors. Typically, a five or seven-point scale is used, allowing respondents to express their agreement with statements. In this research, a five-point Likert scale is used, with choices ranging from strongly agree to strongly disagree (Ndukwu et al., 2020).

3.5 Pilot Study

A pilot study is a small-scale preliminary study conducted to assess the feasibility of the main study's critical components. It helps predict a suitable sample size for the full-scale project and improve various aspects of the study design (Cadete et al., 2017). A pilot study is crucial for enhancing the quality of the questionnaire. At least 12 experts are required for a pilot study. Therefore, the questionnaire is distributed to lecturers in the engineering technology and rail transportation field at UTHM. Feedback from these experts is used to refine the questionnaire to meet the study's objectives.

3.6 Population Study

A population study collects data from a group of people sharing common characteristics, such as education, employment field, and work experience, relevant to the research criteria (Rafeedalie et al., 2019). Due to the impracticality of collecting data from every individual in a large population, this study focuses on organizations involved in the ECRL project in Malaysia. Target respondents include the project owner, government agencies, contractors, and consultants. The exact population size is unknown, but an estimate of 31,549 has been derived from Human Resources metrics reports and Loss Time Injury (LTI) records from the organizations involved in the ECRL project.

3.7 Sample Study

Sampling is a method of inferring information about a population based on a subset of that population, reducing the cost and workload for researchers. It is crucial that the selected sample represents the entire population without bias. To achieve this, the sample selection must be random, ensuring equal chances for all individuals in the population to be included. This research uses the Taro Yamane method, developed in 1967, to determine the sample size (Imperial et al., 2016). The formula that used to determine the sample size is shown below:

$$n = \frac{N}{1 + Ne^2} \quad [3.0]$$

Where,

n = Required sample size.

N = The population size.

e = Margin error which is usually 0.10, 0.05, 0.01

The specific number of staff currently involved in the East Coast Rail Link (ECRL) project in Malaysia is unknown due to fluctuations based on project phases, construction progress, and other factors. Numerous organizations' involvement further complicates defining an exact population size. Therefore, the sample size is derived from various documentation sources, including human resource metrics reports and loss time injuries (LTI) reports from all organizations involved in the ECRL project. The recorded population size for this study is 31,549, which will be used to determine the required sample size for the research.

The margin of error (e) of sample size are taken as 0.10. The minimum sample sizes were obtained by calculating using all these values.

Value obtained,

$$N = 31,549 \quad [3.1]$$

$$e = 0.10 \quad [3.2]$$

The number of sample sizes calculated by substituting the values of [3.1] and [3.2] into formula [3.0]. The number of sample size obtained are shown below:

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{31549}{1 + (31549)(0.10)^2}$$

$$n = 99$$

By using the Taro Yamane method above, sample size that obtained is 99. Hence, the number of sample size that needed for this study is 99 respondents.

3.8 Quantitative Data

Quantitative data consists of numerical values that can be counted or expressed numerically. It is typically analysed through numerical comparisons and statistical reasoning to ensure accuracy and eliminate bias (Davidson et al., 2019). In this research, quantitative data is gathered by distributing questionnaires to a specific sample group. The study employs a 5-point Likert scale to capture respondents' opinions and their level of agreement, providing a comprehensive quantitative perspective.

3.9 Analysis of Data

Data analysis involves inspecting, rearranging, modifying, and transforming data to uncover valuable insights and information. Accurate analysis is crucial for decision-making and achieving the research's objectives, ensuring integrity to avoid misinterpretation of scientific findings (Chapman et al., 2018).

In this research, Statistical Package for the Social Sciences (SPSS) version 28 is utilized for data analysis. SPSS is a comprehensive software package used for scientific data analysis, market research, surveys, and data mining. It efficiently handles large datasets, processes complex information, and generates appropriate outputs.

Graphical representations are used to present analyzed results in a clear and understandable manner for users (Noels et al., 2018).

Principal Component Analysis (PCA) is employed in this research to identify critical challenges in the EPCC contract within the ECRL project in Malaysia.

3.10 Reliability Analysis

Reliability Analysis is a technique used to assess the consistency of measures in research. Cronbach's alpha, introduced by Lee Cronbach in 1951, is a commonly used method in reliability analysis to measure internal consistency. It is particularly useful for assessing the reliability of multi-question Likert scales in questionnaires, indicating whether the test accurately measures the variable of interest (Chetty et al., 2015).

Cronbach's alpha can be computed using the Reliability Analysis function in SPSS software version 28. The alpha coefficient ranges from zero to one, where a value exceeding 0.7 is generally considered reliable for research purposes (Laerd et al., 2019).

3.11 Determine potential solutions for challenges of Engineering, Procurement, Construction and Commissioning (EPCC) contract of the East Coast Rail Link (ECRL) project in Malaysia

Based on analysed results, potential solutions can be determined for the challenges of the EPCC contract of the ECRL project in Malaysia using suitable methods such as conducting a literature review to gather existing knowledge and best practices, proposing potential solutions based on the literature findings, and obtaining verification or recommendations from experienced project managers about the proposed potential solutions. This approach ensures that the solutions are well-informed and practical, thereby improving the performance of project management in future large-scale projects in Malaysia.

3.12 Comparative analysis for sustainability performance of the EPCC contract against alternative project delivery methods.

A comparative analysis of EPCC contracts, Design-Build (DB), and Design-Bid-Build (DBB) methods reveals valuable insights into their sustainability performance (Yu et al., 2017). Through SWOT analysis and comparative evaluation, key findings highlight the unique strengths and weaknesses of each project delivery method. Recommendations for improving the sustainability of EPCC contracts include enhancing comprehensive planning, fostering innovation, and adopting best practices from DB and DBB methods. Leveraging the strengths and addressing the weaknesses of each method can improve the sustainability performance of EPCC contracts, aiding future sustainability improvement studies.

4. Data Analysis

Data analysis will presents the results of the case study analysing the challenges of the East Coast Rail Link (ECRL) project. A questionnaire, developed from insights in the literature review and refined by expert feedback, was distributed to construction parties involved in the project. The sample size was determined to represent these parties accurately. Reliability analysis was conducted to ensure data consistency. Principal Component Analysis (PCA) using SPSS software was then performed, allowing for a comprehensive examination of the challenges faced during the ECRL project.

4.1 Reliability Analysis

Reliability analysis is a measurement technique used to evaluate the consistency of measures. In this study, Cronbach's alpha was employed to determine the reliability of the multi-question Likert scale in the questionnaire. Therefore, SPSS software was utilized to perform the reliability analysis and ensure the consistency of the parameters. Table 4.1 shows the table of Cronbach's Alpha value. The Cronbach's Alpha value for the 10 challenges of EPCC contract is 0.754. Based on analysis, the obtained value that exceeding 0.7 indicates that the challenges of EPCC contract are acceptable and reliable (Laerd et al., 2019).

Table 1 Cronbach's Alpha Value

No.	Challenges of EPCC contract of the ECRL project	Mean	Standard Deviation	Cronbach's Alpha
1	Design Changes	4.10	1.050	
2	Government Changes	3.72	0.790	
3	Cost Overruns	3.50	0.734	
4	Land Acquisition	4.10	1.032	
5	Interdependence of Stakeholders	3.89	0.919	
6	Communication barrier	4.23	0.854	0.754
7	Project Management Complexity	3.74	0.832	
8	Regulatory Compliance	3.37	0.760	
9	Technical Specifications and Integration	3.04	1.170	
10	Timeline Delays	3.75	1.235	

4.2 Quantitative Data Results Summary

The survey questionnaire addresses the challenges of the EPCC contract in the East Coast Rail Link project in Malaysia. It lists 10 challenges identified from the literature review. Respondents evaluate each challenge using a Likert Scale from 1 to 5, indicating their level of agreement with each challenge. Table 2 shows results summary based on number of respondents.

No.	Challenges	Scale					Total number of respondents
		1	2	3	4	5	
1	Design Changes	0	13	14	28	51	106
2	Government Changes	0	7	31	53	15	106
3	Cost Overruns	0	11	35	56	4	106
4	Land Acquisition	1	12	9	37	47	106
5	Interdependence of Stakeholders	0	13	8	58	25	106
6	Communication Barrier	0	8	5	47	44	106

7	Project Management Complexity	4	9	3	85	5	106
8	Regulatory Compliance	0	16	37	51	2	106
9	Technical Specifications and Integration	9	37	7	47	6	106
10	Timeline Delays	6	18	7	41	33	106

4.3 Dimensionality-Reduction Using Principal Component Analysis

Principal Component Analysis (PCA) is a technique used to reduce the dimensionality of large datasets. Using SPSS statistics, PCA was applied to the 10 identified challenges of the EPCC contract to derive new, critical challenges, following certain assumptions to ensure accurate results. Table 3 shows the value of total variance of initial eigenvalues that contributed by 10 challenges and the cumulative percentage of initial eigenvalues.

Table 3 Total variance of initial eigenvalues

Component	Initial Eigenvalues		
	Total	% of variance	Cumulative percentage
1	4.315	43.145	43.145
2	1.691	16.906	60.051
3	0.997	9.965	70.016
4	0.841	8.412	78.428
5	0.749	7.494	85.922
6	0.494	4.942	90.864
7	0.377	3.767	94.631
8	0.280	2.803	97.434
9	0.175	1.747	99.181
10	0.082	0.819	100

Based on Table 4.5, the principal component correlation matrix indicates that two eigenvalues are greater than 1, which suggests these components can be used for further analysis. The first principal component has the highest eigenvalue of 4.315, accounting for 43.145% of the variance. The second principal component has an eigenvalue of 1.691, explaining 16.906% of the variance. The total cumulative percentage of variance for eigenvalues greater than 1 is 45.603%. Additionally, principal components three to eleven have a total eigenvalue of 3.994, accounting for 40% of the variance.

4.4 Scree Plot

Based on Fig. 4, principal components 1 and 2 have eigenvalues greater than one and can be used for further analysis. Eigenvalues for principal components 3 to 10 are close to zero and can be eliminated from the analysis. Thus, only principal components 1 and 2 are considered for further analysis. The component scores of the coefficient matrix for components 1 and 2 are shown in Table 4.

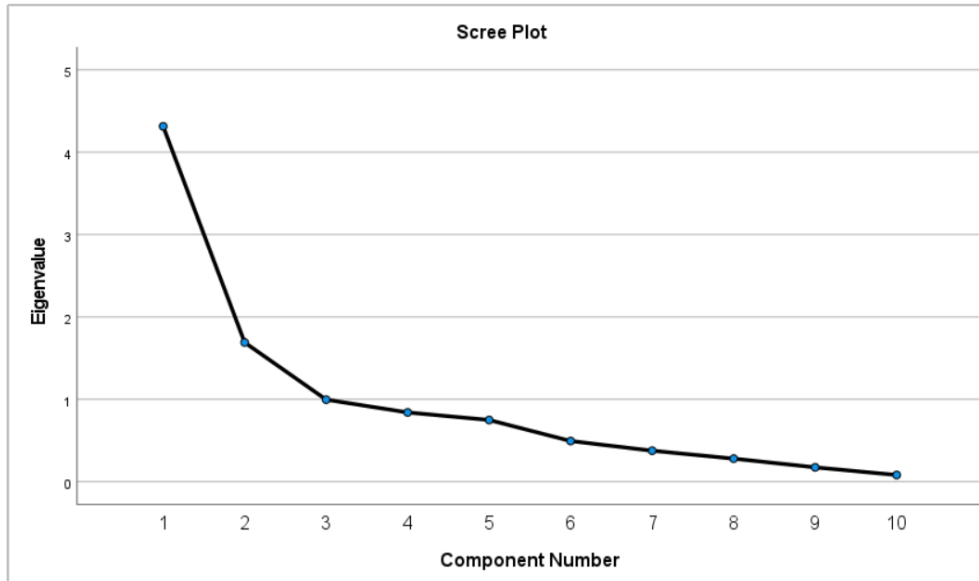


Fig. 4 : Scree plot for the challenges of EPCC contract in ECRL project

4.5 Component Score of Coefficient Matrix

Table 4 Component score of coefficient matrix

No.	Challenges	Component	
		1	2
1.	Design changes	0.782	0.345
2.	Government changes	0.761	-0.468
3.	Cost Overruns	0.825	-0.441
4.	Land Acquisition	0.695	0.386
5.	Interdependence of Stakeholders	0.445	0.432
6.	Communication barrier	0.699	0.352
7.	Project Management Complexity	-0.095	0.227
8.	Regulatory Compliance	0.807	-0.492
9.	Technical Specifications and Integration	-0.264	0.496
10.	Timeline Delays	0.737	0.397

Table 4 shows two component scores of coefficient matrix that extracted from the SPSS software. Each challenge has a particular component score for component 1 and 2. The most critical challenges for every component would be the maximum value of coefficient matrix that closer to 1. Whereas, other challenges with of coefficient matrix that not close to 1 are having lesser influence comparing with the critical challenges.

According to the total variance of initial eigenvalue in Table 4, 2 principal components where the eigenvalue greater than 1 is chosen from total of 10 principal components. In the analysis of coefficients matrix for principal component 1, the most critical challenges are cost overruns, regulatory compliance and design changes.

Besides, for the principal component two, the most critical challenges were contributed by technical specifications and integration, interdependence of stakeholders and timeline delays.

Table 5 Summaries of Principal Component Analysis findings

No.	Challenges	Component	
		1	2
1.	Design changes	0.782	-
2.	Government changes	-	-
3.	Cost Overruns	0.825	-
4.	Land Acquisition	-	-
5.	Interdependence of Stakeholders	-	0.432
6.	Communication barrier	-	-
7.	Project Management Complexity	-	-
8.	Regulatory Compliance	0.807	-
9.	Technical Specifications and Integration	-	0.496
10.	Timeline Delays	-	0.397

Table 5 presents the results of Principal Component Analysis (PCA) using SPSS software, identifying the critical challenges of the EPCC contract as follows: (1) design changes, (2) cost overruns, (3) interdependence of stakeholders, (4) regulatory compliance, (5) technical specifications and integration, and (6) timeline delays. These six challenges can be used for further analysis of the EPCC contract issues in the ECRL project. Based on the PCA results, suggestions or potential solutions can be proposed for the effective implementation of EPCC contracts in Malaysia's large-scale construction industry.

4.6 Determination of potential solutions for challenges of Engineering, Procurement, Construction and Commissioning (EPCC) contract in East Coast Rail Link (ECRL) project.

Based on the Principal Component Analysis (PCA), critical challenges of EPCC contract in East Coast Rail Link (ECRL) can be obtained and it can be used for further analysis. The results show that there are total of 6 critical challenges which are design changes, cost overruns, interdependence of stakeholders, regulatory compliance, technical specifications and integration and timeline delays. Hence, potential solutions can be determined based on literature review, best practices analysis from similar large-scale infrastructure projects worldwide and acquire verification of the potential solution from the experienced project manager to improve the implementation of Engineering, Procurement, Construction and Commissioning (EPCC) contract in East Coast Rail Link (ECRL).

- Design Changes

To address design changes in EPCC contracts, early and continuous stakeholder involvement, the use of Building Information Modeling (BIM), and robust change management processes are essential. Engaging stakeholders early and regularly ensures alignment with project requirements, reducing revisions, delays, and cost overruns. BIM improves visualization and coordination, identifying potential issues before construction begins and reducing design errors and change orders. Establishing clear procedures for evaluating, approving, and documenting design changes helps manage their impact on project costs and timelines, mitigating risks and maintaining control over project parameters (Olander et al., 2005).

- **Cost Overruns**

To effectively manage cost overruns in EPCC contracts, strategies include detailed cost estimation and budgeting during the planning phase, incorporating contingencies for unforeseen expenses. Value engineering techniques optimize project costs without sacrificing quality by evaluating design and construction alternatives. Regular financial monitoring tracks expenditures against budgets, enabling prompt corrective actions to maintain cost control and achieve project financial objectives. These strategies are crucial for mitigating risks and ensuring project success within budgetary constraints (Eastman et al., 2011)

- **Interdependence of Stakeholders**

Implementing Integrated Project Delivery (IPD) in EPCC contracts enhances collaboration among stakeholders by aligning their interests from project inception to completion. IPD fosters transparency, shared risk, and joint decision-making, improving project outcomes and reducing conflicts, according to the American Institute of Architects (AIA). Clear communication channels are crucial, ensuring stakeholders are informed about progress, changes, and decisions, minimizing misunderstandings and delays. Effective communication management, as advocated by the Project Management Institute (PMI), enhances stakeholder engagement and project success. Additionally, developing a stakeholder management plan identifies roles, manages expectations, and mitigates conflicts, crucial for achieving project objectives and fostering positive relationships, as highlighted by Freeman (1984) (Freeman et al., 1984).

- **Regulatory Compliance**

Engaging early with regulatory authorities is essential in EPCC contracts to understand compliance needs and secure permits, minimizing delays and aligning with legal standards (Ramus and Sutter et al., 2013). Implementing a compliance monitoring system ensures ongoing adherence to regulations through audits and inspections, vital for detecting and correcting issues promptly, per the International Organization for Standardization (ISO). Training project teams on regulations and compliance fosters a culture of adherence, crucial for maintaining compliance standards and adapting to regulatory changes (Sampaio et al., 2009).

- **Technical Specifications and Integration**

Utilizing standardized technical specifications and construction methods in EPCC contracts ensures consistency and quality control, reducing variability and enhancing communication among stakeholders, as highlighted by Love et al. (2010). Developing a comprehensive systems integration plan is crucial for coordinating technical components and testing procedures, facilitating seamless project execution and alignment with overall objectives (Shenhar and Dvir et al., 2007). Engaging technical experts in reviewing and validating plans enhances feasibility and quality, addressing complex challenges early and ensuring realistic technical specifications (Turner and Müller et al., 2005).

- **Timeline Delays**

Detailed scheduling and planning are crucial for managing timeline delays effectively in EPCC contracts. The importance of creating comprehensive project schedules that include all activities, milestones, and dependencies using tools like Microsoft Project or Primavera. These tools enable project managers to monitor progress, anticipate challenges, and allocate resources efficiently to keep the project on track (Lock et al., 2020). The Critical Path Analysis, identifies the sequence of critical activities that determine the project's minimum duration. By mapping out dependencies and focusing on optimizing these critical paths, project managers can prioritize tasks and allocate resources effectively to prevent delays (Kerzner et al., 2017)

Contingency planning is essential for addressing unforeseen issues that may impact the project timeline. PMI (2017) underscores the need for establishing backup plans and resources, such as extra time for high-risk activities or alternative suppliers, to maintain project momentum and mitigate disruptions (PMI et al., 2017).

4.7 Comparative analysis for sustainability performance of EPCC contracts with Design-Build and Design-Bid-Build

The sustainability performance of Engineering, Procurement, Construction, and Commissioning (EPCC) contracts is assessed through comparison with alternative project delivery methods like Design-Build (DB) and Design-Bid-Build (DBB), focusing on economic, environmental, and social dimensions (Yu et al., 2017)

Economically, EPCC contracts offer integrated project management, aiming to control costs and adhere to budgets despite higher initial expenses. In contrast, DB contracts prioritize faster delivery and early cost estimates, potentially leading to higher initial bids due to uncertainties, while DBB contracts leverage competitive bidding but may encounter longer timelines and cost escalations.

Environmentally, EPCC contracts facilitate early adoption of environmental standards and green practices across project phases, whereas DB contracts emphasize sustainable practices through collaborative efforts, contingent on team commitment. DBB contracts allow owners to enforce environmental standards upfront but may lack integration during construction.

Socially, EPCC contracts manage health, safety, and community engagement throughout the project lifecycle, fostering local economic benefits, albeit requiring diligent management against cost and schedule pressures. DB contracts can address social sustainability if prioritized, yet with reduced owner control over design specifics, whereas DBB contracts provide early social sustainability mandates but may lack cohesion during construction, potentially compromising social impacts.

A SWOT analysis highlights EPCC contracts' strengths in integrated management and cost control, alongside challenges like higher initial costs and management complexity. Opportunities include comprehensive planning and innovation, while threats include management inefficiencies and subcontractor conflicts.

5. Conclusion

The challenges in Engineering, Procurement, Construction, and Commissioning (EPCC) for the East Coast Rail Link (ECRL) project were identified through a literature review and a structured questionnaire involving stakeholders. Ten critical challenges, including design changes, cost overruns, and regulatory compliance, were pinpointed through Principal Component Analysis (PCA). The proposed solutions address these challenges by emphasizing early stakeholder involvement, robust change management, detailed cost estimation, Integrated Project Delivery (IPD), standardized technical methods, and regulatory engagement.

In evaluating EPCC contracts against Design-Build (DB) and Design-Bid-Build (DBB) methods, a comprehensive analysis across economic, environmental, and social dimensions reveals EPCC's strengths in integrated project management and sustainability practices. Despite higher initial costs, EPCC contracts promise economic savings, while DB focuses on speed and DBB on competitive pricing. Environmentally, EPCC starts with green practices but requires strict oversight, whereas DB promotes early collaboration and DBB allows owner-driven standards. Socially, EPCC excels in safety and community engagement management but needs careful oversight, contrasting DB's potential for social sustainability and DBB's control with potential integration challenges. A SWOT analysis highlights EPCC's management strengths and identifies opportunities for innovation, yet acknowledges challenges in cost and complexity, urging stakeholders towards more efficient and sustainable infrastructure approaches.

Acknowledgement

The authors sincerely thank MRL Sdn. Bhd. for their invaluable cooperation and for providing essential information for this research study. They also express their profound gratitude to Universiti Tun Hussein Onn Malaysia for their unwavering support in facilitating this research work.

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