INFOGAIN PUBLICATION

International Journal of Advanced Engineering, Management and Science (IJAEMS)
Peer-Reviewed Journal
ISSN: 2454-1311 | Vol-10, Issue-5; Jul-Aug, 2024
Journal Home Page: https://ijaems.com/
DOI: https://dx.doi.org/10.22161/ijaems.105.10

A Political, Sustainable, and Management Building Information Modelling (BIM) Key Performance Indicators (KPIs) for Public-Private Partnership (PPP) Projects

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Received: 15 May 2024; Received in revised form: 25 Jun 2024; Accepted: 07 Jul 2024; Available online: 12 Jul 2024

Abstract— *Public-Private Partnership (PPP) is a partnership between the public and private sectors to deliver a project or service generally provided by the public sector. many studies suggests that Building information modelling can help in making better decisions throughout the project. However, despite the number of studies on BIM for PPP, there is still no consensus on a standardized comprehensive performance evaluation. The study presents a review based on in-depth review of 26 articles to find KPIs for the purpose of evaluating the impact of adopting Building Information Modeling (BIM) in Public-Private Partnership (PPP) projects. It is hoped that this research will establish a standardized the performance evaluation of such complex projects to overcome to fully understand the benefits and overcome challenges. The KPIs afterward is subcategorized into (Internal/External) and (Technical/Non-Technical) Indicators. The results of this study clarify Key performance indicators (KPIs) to evaluate the Public-Private Partnership (PPP) projects for the main purpose of measuring the impact of adopting the new technology BIM on the overall status of these projects, and to overcome the challenges of merely evaluating the projects based on time and cost used in the current traditional performance management. KPIs are divided into Management (cost, time, quality), Sustainable (manpower, machine, material) and finally political KPIs.*

Keywords— ***Building Information Modeling (BIM), Public-Private Partnerships (PPP), Key Performance Indicators (KPIs), Political, Management, Sustainability, Performance Management.***

I. INTRODUCTION

Public-Private Partnership (PPP) projects are gaining momentum worldwide. Typically, PPP is characterised by complexity, long-term construction, operation and maintenance periods (Liang & Wang, 2019). PPP projects deal with multiple stakeholders in various contract duration, which uncovers working and information integration risks (Habib et al., 2020). Public infrastructure projects operate based on Public-Private partnership PPP, where this procurement method often ensures value for money. However, other issues arise, such as cost and schedule overruns (Love et al., 2015). Accurate performance evaluation needs to be improved in many Public-Private Partnership (PPP) projects (Xu et al., 2020). Effective performance measurement/evaluation is critical to the successful delivery of PPP projects, as the traditional post-evaluation focuses only on budget and schedule and disregards other elements that make a project successful (Love et al., 2015).

Building information modelling (BIM) is seen as a mechanism for improving collaboration and integration in public-private partnerships (PPPs) (Habib et al., 2020). BIM adoption increases the quality and efficiency of AEC (Architecture, Engineering and Construction) projects (Ma et al., 2019). Using BIM effectively for PPP performance evaluation for projects is quite challenging (Xu et al., 2020). BIM execution framework for PPP performance management helps to guide stakeholders and improve work efficiency (Yuan et al., 2020). BIM can also provide a digital representation of the physical and functional

characteristics of the projects throughout the whole project life cycle (Love et al., 2015) However, BIM can introduce users to additional risk because information sharing increases (Habib et al., 2020).

In public-private partnership (PPP) projects, effective performance management (PM) is critical to achieving value for money (VFM) (Yuan et al., 2020). Numerous urban rail transit PPP projects face cost overruns, schedule deviations, and poor quality. The lack of good project performance is a critical issue to be solved (Wang et al., 2021). BIM can also combine Web and Cloud technology and help in performance monitoring and performance-based payments (Yuan et al., 2020). There needs to be more research on the sustainability aspects of the performance assessment of buildings (Olawumi & Chan, 2021). Accurate performance evaluation needs to be improved in many Public-Private Partnership (PPP) projects (Xu et al., 2020).

II. RESEARCH METHODS AND DATA COLLECTION

This study uses quantitative and qualitative research methods to analyse and categorize academic publications to perceive political, sustainable, and management Key Performance Indicators (KPIs) to measure the impact of adopting Building Information Modelling (BIM) in Public-Private Partnership (PPP) projects. The study consists of seven steps, as shown in Figure.1.

Step 1: To locate Key Performance Indicators (KPIs) for Public-Private Partnership projects to eventually evaluate BIM-based projects. A wide range of publications was analysed using different keyword-based combinations (BIM, building information modelling, PPP, public-private partnership, assessment, evaluation, sustainability, management, political, key performance indicators, KPI, benefits, measuring, and impact).

Step 2: Explore academic publications based on the previous keyword search and extract Key Performance Indicators (KPIs) for PPP.

Step 3: The selected KPIs are then sorted based on their recurrence in the selected previous publications to find the KPIs studied the most in the literature.

Step 4: Sort the selected KPIs that recurred in more than one publication (a single KPI found in more than one publication) and eliminate the KPIs found only once.

Step 5: After determining PPP projects' KPIs, each is assigned Political, Sustainable (manpower, machine, material), and Management (time, cost, quality) triangle constraints.

Step 6: From a different perspective, the KPIs also were categorised into Technical/Non-Technical and External/Internal performance indicator

Step 7: Sorted and categorized data is then summarized into readable and comprehensive tables. The resulting tables will be used to evaluate the impact of adopting BIM in PPP projects.

Twenty-six publications are yielded to extract thirty-three Key Performance Indicators (KPIs) to evaluate adopting Building Information Modelling (BIM) in Public-Private Partnership (PPP) projects. Management KPIs are the most frequent method of evaluating any project. Management KPIs and what are also called project management constraints are divided into time, cost, and quality. Sustainable constraints are divided into manpower, machine, and material KPIs.

1. Building Information Modelling in Public-Private Partnership Projects

Performance assessment and evaluation if done effectively are crucial to successfully implement Public-Private Partnership (PPP) Projects (Love et al., 2015; Xu et al., 2020). The traditional ex-post evaluation of projects, on the other hand, is only concerned with the budget and the predetermined timeline. However, BIM can trigger collaboration and improve integration due to the digital representation of physical functional project features, and can help making educated decision throughout the projects (Love et al., 2015). Therefore, Life-cycle conceptual framework of performance management can contribute to resilience construction (Liu et al., 2019). Other researchers, on the other hand, investigated the impact and relationship between contractual flexibility and BIM-enabled PPP project performance, particularly during construction. The findings show that both content and executing flexibility have a significant positive impact on the performance of BIM-enabled PPP projects during the construction phase (Xu et al., 2022). And accurate and efficient performance evaluation of PPP projects through the use of the IFC extension and the enhanced matter-element method (Xu et al., 2020). Other studies adopted a different strategy, integrating empirical and experimental research, beginning with semi-structured interviews and progressing to the development of a BIM Based Performance Management System (BPMS) by connecting it with Web and Cloud technologies (Yuan et al., 2020).

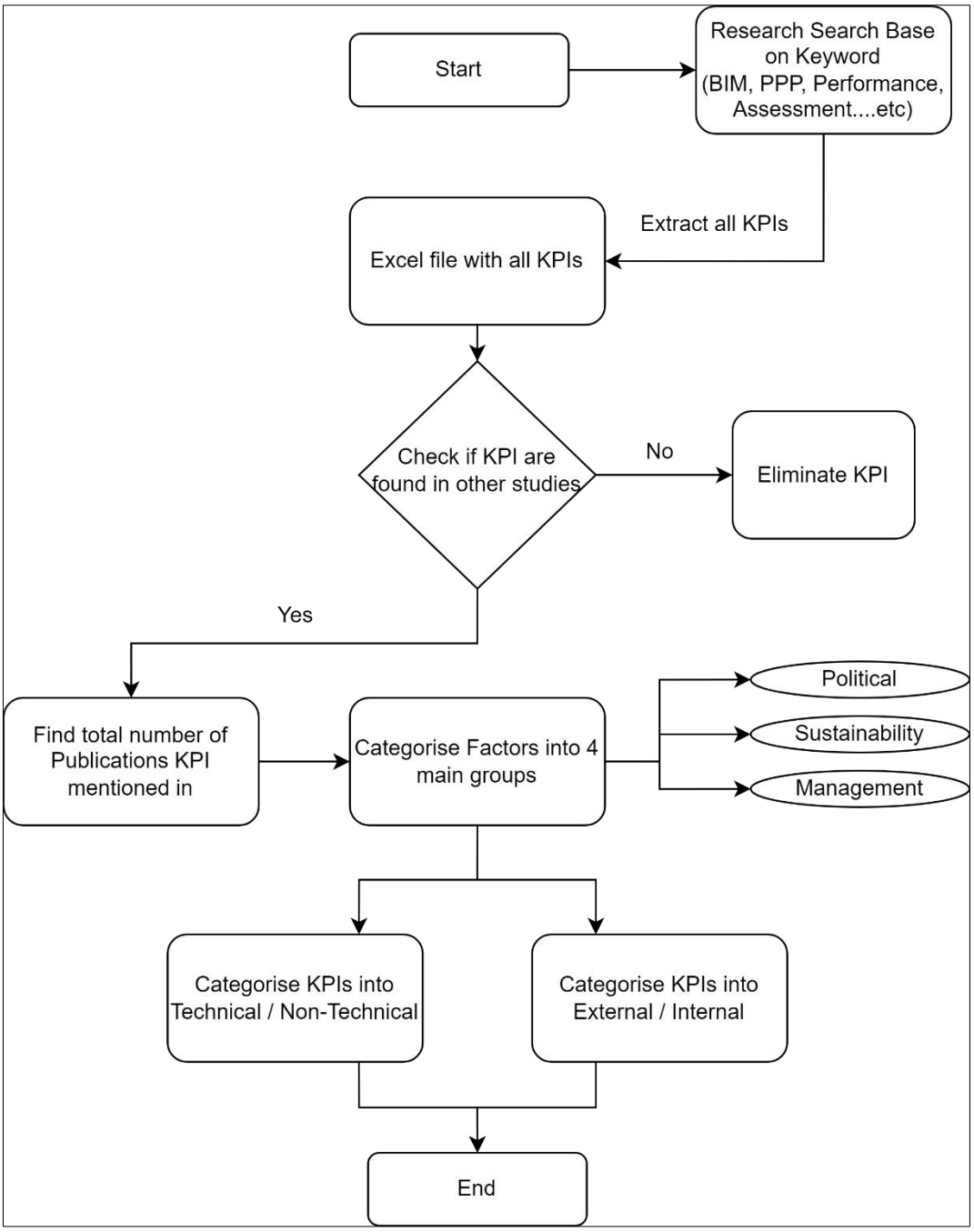

Fig.1. Flow diagram of selection of BIM KPIs for PPP performance evaluation.

Cost performance of infrastructure rail projects were found in two different studies, where BIM shows the ability to help in visualisation which assist in defining the public requirements for the best LRT route for the LRT (Love, Ahiaga-Dagbui, et al., 2017) as well as helps increase the cost certainty throughout the project construction phase (Love, Zhou, et al., 2017). Researchers used different levels of contextual factors to measure the multidimensionality of behavioural responses to BIM adoption in construction projects (Cao et al., 2021). effective stakeholder dynamics and stakeholder engagement or empowerment positively plays an important role in BIM implementation and project performance (Zhang et al., 2022). BIM may have reduced expenses, Scope changes, failure to adjust to risk and uncertainty, ineffective project management and governance on a hospital project performance (Love & Ika, 2022). Nevertheless, exploring the BIM cloud-Based and information exchange to evaluate the performance of Public-private partnership PPP projects' throughout the building life cycle (Redmond et al., 2012). Nevertheless, anticipating the risk of completion of PPP projects using Big Data analysis is the main goal of another study, which

include oracle finance, BIM models, and finally Primavera (Owolabi et al., 2018).

2. Performance Evaluation for PPPs

a. Political and Legal Key Performance Indicators

Public-private partnership projects are generally considered one of the most complex procurement methods that take longer to execute than traditional ones (Xu et al., 2022). Objective and comprehensive performance evaluation for Public-private partnership projects is often missing. However, efficiently evaluating the performance of PPP projects adopting Building Information Modelling (BIM) is quite harder (Xu et al., 2020). Many studies have tried to develop BIM models for a specific segment in PPP Projects, such as improving the Value for Money (VfM) by supporting the decision-making process (Ren & Li, 2017), studying and mitigating the impact of risks associated with BIM adoption in PPP (Habib et al., 2020), and exploring the impact of contractual flexibility on project performance in PPP (Xu et al., 2022).

Table 1: Political Key Performance Indicators (KPIs)

Category / Indicator		Publication
Political – Legal	Risk of Adverse changes in law, policy or regulations	(Cheng et al., 2020; Doloi, 2012; Du et al., 2018; Habib et al., 2020; Ke et al., 2010; Ren & Li, 2017)
	Organization structure	(Doloi, 2012; Ke et al., 2010)
	Risk of Force majeure	(Hoeft et al., 2021; Li et al., 2020)

The public-private partnership (PPP) procurement approach is a relatively new concept developed in the early 1990s as an acceptable and better solution for many municipalities' procurement issues and challenges (Ke et al., 2010). However, the operation phase in PPP projects is normally longer and more complex than traditional procurement methods, which can lead to amplified risks (Doloi, 2012). Building Information Modelling (BIM) is a new integration tool for the public and private sectors to help collaborate and integrate PPP projects (Habib et al., 2020). A comprehensive and holistic evaluation of the impact of adopting Building information modelling (BIM) in Public-private partnership (PPP) projects is essential to fully understand whether it is justifiable to adopt BIM in PPP projects. For this purpose, fragmented political and legal performance indicators were collected from the literature as shown in table.1.

Public-private partnerships are project management concepts focusing mainly on value-for-money procurement benefits (Ren & Li, 2017). Investors and financiers show concerns with the capital market, laws, and regulations (Du et al., 2018). Risk of adverse changes in law, policy, or regulations are one of the most issues regarding PPP projects, because it can involve external factors that results in adversely affecting the project performance, such as: change in law and tax regulation changes (Doloi, 2012; Ke et al., 2010). Change of BIM policies was ranked eleventh between twenty three other risk factors related to PPP projects (Habib et al., 2020). On the other hand, a proper organizational structure requires action from both public and private stakeholders (Hoeft et al., 2021) to support project sustainability (Hoeft et al., 2021; Li et al., 2020).

b. Sustainability Key Performance Indicators

Public-private partnership projects are generally considered one of the most complex procurement methods that take longer to execute than traditional ones (Xu et al., 2022). Objective and comprehensive performance evaluation for Public-private partnership projects is often missing. However, efficiently evaluating the performance of PPP projects adopting Building Information Modelling (BIM) is quite harder (Xu et al., 2020). Many studies have tried to develop BIM models for a specific segment in PPP Projects, such as improving the Value for Money (VfM) by supporting the decision-making process (Ren & Li, 2017), studying and mitigating the impact of risks associated with BIM adoption in PPP (Habib et al., 2020), and exploring the impact of contractual flexibility on project performance in PPP (Xu et al., 2022). PPP projects' performance measurements are essential to maintain stakeholders' sustainable interest, ensuring future generations' interest in social, economic, and environmental development (Liang & Wang, 2019).

Table 2: Sustainability Key Performance Indicators (KPIs)

Category / Indicator			Publication
Sustainability	**Manpower**	Experience and knowledge gains	(Chen et al., 2020; Habib et al., 2020; Liang & Wang, 2019; Wang et al., 2021)
		employment opportunities	(Hossain et al., 2018; Li et al., 2020; Wang et al., 2021; Xu et al., 2020)
		Specialized Expertise	(Eadie et al., 2013; Hossain et al., 2018; Porwal & Hewage, 2013)
		Technical Staff Resources	(Cheng et al., 2020; Porwal & Hewage, 2013; Xu et al., 2020)
		Staff training	(Habib et al., 2020; Yuan et al., 2020)
	Machine	Equipment/ Material/ condition and number	(DENG et al., 2017; Ren & Li, 2017; Xu et al., 2020; Yuan et al., 2020)
		effective interface management	(Budayan et al., 2020; Love et al., 2015; Wang et al., 2021)
	Material	Use of construction waste	(Hoeft et al., 2021; Li et al., 2020; Olawumi & Chan, 2021; Ren & Li, 2017; Yuan et al., 2020)
		Equipment/ Material/ condition and number	(DENG et al., 2017; Ren & Li, 2017; Xu et al., 2020; Yuan et al., 2020)
		Use of innovation materials	(Hoeft et al., 2021; Li et al., 2020)

sustainable development and sustainability in construction has become a theme for this time. Sustainability key performance indicators are categorised into three main subcategories, which are manpower, machine, and material or what is known as (3Ms). Each subcategory contains performance indicators that will be later utilised to evaluate the sustainable performance of PPP projects adopting BIM, as shown in table 2. The manpower subcategory contains (experience and knowledge gains, employment opportunities, specialised expertise, technical staff resources, and staff training). Manpower describes the operational and functional labour or people indicators engaged in delivering a product or a service. On the other hand, from a different perspective, materials indicators are (the use of construction waste, the use of innovative materials and the number and condition of materials). The materials subcategory deals with components and consumables to satisfy the construction deliverables. Furthermore, the machine subcategory deals with project facilities, systems, and equipment. The materials indicators are (equipment number /condition and effective interface management).

c. Management Key Performance Indicators

Measuring the expected and actual business success of projects focuses on project management constraints which are time, cost, and quality (PMBOM 7th). Public-Private partnership PPP projects are generally a more complex and more extended type of project (Xu et al., 2022). Plenty of projects are experiencing remarkable schedule and cost overruns during construction (Love et al., 2015). Public-Private Partnership (PPP) Projects are highly complex, significant investments with long-term relationships among many stakeholders, leading to a high risk of project mis-performance (Liang & Wang, 2019). BIM adoption is still challenging and requires changing the existing work practice. Public procurements need a different collaborative BIM approach, where the owner needs procedural and legal frameworks (Porwal & Hewage, 2013).

Table 3: Management Key Performance Indicators (KPIs)

Category / Indicator			Publication
Management	Time	on-time or earlier project completion	(Chan et al., 2019; Cheng et al., 2020; Liang & Jia, 2018; Xu et al., 2020)
		Completion/Time Delay	(Doloi, 2012; Ren, 2019; Ren & Li, 2017)
		schedule variance	(Chen et al., 2020; Xu et al., 2020)
	cost	Investment life cycle Cost and return	(Budayan et al., 2020; Chan et al., 2019; Eadie et al., 2013; Habib et al., 2020; Hoeft et al., 2021; Hossain et al., 2018; Liang & Wang, 2019; Love et al., 2015; Porwal & Hewage, 2013; Ren, 2019; Wang et al., 2021; Xu et al., 2020) (Cheng et al., 2020; DENG et al., 2017; Du et al., 2018; Li et al., 2020; Liang & Jia, 2018)
		Construction Cost overrun	(Du et al., 2018; Ren & Li, 2017)
		Cost management	(Chen et al., 2020; Liang & Wang, 2019)
		cost variance	(Chen et al., 2020; Xu et al., 2020)
	Quality	contract management and control	(Budayan et al., 2020; Cheng et al., 2020; Hossain et al., 2018; Love et al., 2015; Porwal & Hewage, 2013; Ren & Li, 2017; Wang et al., 2021; Xu et al., 2020)
		Relationship quality within the project team	(Budayan et al., 2020; Chen et al., 2020; Cheng et al., 2020; Hossain et al., 2018; Xu et al., 2022; Yuan et al., 2020)
		Effectiveness of facility management	(Budayan et al., 2020; DENG et al., 2017; Li et al., 2020; Love et al., 2015; Ren, 2019; Wang et al., 2021)
		quality and innovation public service	(Hossain et al., 2018; Liang & Jia, 2018; Liang & Wang, 2019; Ma et al., 2019; Wang et al., 2021)
		Design Quality and innovation	(Budayan et al., 2020; Doloi, 2012; Love et al., 2015; Ren & Li, 2017)
		Technical specifications	(DENG et al., 2017; Doloi, 2012; Liang & Wang, 2019; Porwal & Hewage, 2013)
		Life-cycle evaluation and monitoring	(Hossain et al., 2018; Ren, 2019; Ren & Li, 2017; Yuan et al., 2020)
		qualification rate (Qualified unit/inspection unit) * 100%	(Chen et al., 2020; Hoeft et al., 2021; Li et al., 2020; Xu et al., 2020)
		constructability and maintainability analysis	(Budayan et al., 2020; Doloi, 2012; Du et al., 2018; Ren & Li, 2017)
		The third-party assessment results	(Wang et al., 2021; Yuan et al., 2020)
		Change in scope	(Cheng et al., 2020; Doloi, 2012)
		periodic performance reports	(Cheng et al., 2020; Yuan et al., 2020)
		reduce the rework	(Chan et al., 2019; Yuan et al., 2020)
		continuous improvement	(Hoeft et al., 2021; Li et al., 2020)

Project management key performance indicators are the most commonly utilized to evaluate projects. Management KPIs are divided based on the project management constraints (cost, time, and quality) (PMBOM 7th). Each subcategory or management constraint contains several KPIs that will be later used to evaluate the performance of PPP projects that adopt BIM, as shown in table 3. Fourteen quality constraints are gathered from the literature. However, the most frequent KPIs in the quality subcategory are (contract management and control, relationship quality with the project team, effectiveness of quality management, and quality and innovation of public services). On the other hand, for time KPIs, we found that (on-time or earlier project completion, time delays, and schedule variance) are the essential KPIs to evaluate projects. However, the KPIs are most used to assess the cost of PPP projects (Investment life cycle cost and return, construction cost overrun, cost management, and cost variance).

III. RESULTS AND DISCUSSION

This study investigates the Political, sustainable, and management Key Performance Indicators (KPIs) to evaluate the Public-Private Partnership PPP Projects, with the main goal of evaluate the impact of adopting Building Information Modelling (BIM). The results of the literature analysis reveal thirty-three Key Performance Indicators (KPIs) to evaluate the Public-Private partnership (PPP) projects, and were divided into three main categories: Political, Sustainable, and Management. Each indicator is also categorized into (Internal/External) and (Technical/Non-Technical) KPIs, where after evaluation each project will perceive the status of performance and understand the strength and weaknesses aspects of each project as shown in Tables 4,5,6.

From the theoretical perspective, this study enriches the performance management of PPP projects, and provide a new comprehensive of performance system to evaluate and assess PPP project from different perspectives. The findings of this research provide a systematic reference for the public and private sectors to broadly evaluate from political, sustainable, and management perspectives. Furthermore, evaluating the impact of adopting BIM will be more accurate due to the comprehensive performance evaluation, on the contrary to the traditional evaluation focusing on time and cost of construction.

Eventually, it is hoped that this paper will clarify the comprehensive performance evaluation of PPP projects and smoothing the evaluation of Building information modelling (BIM) implementation in Public-Private Partnership (PPP) projects. Despite this study's strengths, the method of evaluating BIM adoption using the selected KPIs are not included in this article. However, in the future, evaluating the impact of adopting BIM using the selected indicators will be conducted and analysed. Future research may also consider the different character of different fields, countries, or PPP type, future studies also may focus on one specific area or country to make deep analysis.

Table 4: Political Key Performance Indicators (KPIs)

Category / Indicator		External	Internal	Technical	Non-Technical
Political – Legal	Risk of Adverse changes in law, policy or regulations	✓	-	-	✓
	Organization structure	-	✓	✓	-
	Risk of Force majeure	✓	-	-	✓

Table 5: Management Key Performance Indicators (KPIs)

Category / Indicator			External	Internal	Technical	Non-Technical
Management	**Time**	on-time or earlier project completion	-	✓	✓	-
		Completion/Time Delay	✓	-	-	✓
		schedule variance	-	✓	✓	-
	cost	Investment life cycle Cost and return	✓	-	✓	-
		Construction Cost overrun	✓	-	-	✓
		Cost management	-	✓	✓	-

		cost variance	-	✓	✓	-
	Quality	contract management and control	-	✓	✓	-
		Relationship quality within the project team	-	✓	-	✓
		Effectiveness of facility management	-	✓	✓	-
		quality and innovation public service	-	✓	-	✓
		Design Quality and innovation	-	✓	✓	-
		Technical specifications	-	✓	✓	-
		Life-cycle evaluation and monitoring	-	✓	✓	-
		qualification rate (Qualified unit/inspection unit) * 100%	-	✓	✓	-
		constructability and maintainability analysis	-	✓	✓	-
		The third-party assessment results	✓	-	✓	-
		Change in scope	✓	-	-	✓
		periodic performance reports	-	✓	✓	-
		reduce the rework	-	✓	✓	-
		continuous improvement	-	✓	-	✓

Table 6: Sustainability Key Performance Indicators (KPIs)

Category / Indicator			External	Internal	Technical	Non-Technical
Sustainability	Manpower	Experience and knowledge gains	-	✓	-	✓
		employment opportunities	✓	-	✓	-
		Specialized Expertise	✓	-	✓	-
		Technical Staff Resources	-	✓	✓	-
		Staff training	-	✓	-	✓
	Machine	Equipment/ Material/ condition and number	-	✓	✓	-
		effective interface management	✓	-	-	✓
	Material	Use of construction waste	-	✓	-	✓
		Equipment/ Material/ condition and number	-	✓	✓	-
		Use of innovation materials	✓	-	✓	-

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