buildings

Article

Minimizing Cost Overrun in Rail Projects through 5D-BIM: A Conceptual Governance Framework

Osama A. I. Hussain [1], Robert C. Moehler [2,*], Stuart D. C. Walsh [1] and Dominic D. Ahiaga-Dagbui [3]

1 Department of Civil Engineering, Faculty of Engineering, Monash University, Melbourne, VIC 3800, Australia; osama.hussain@monash.edu (O.A.I.H.); stuart.walsh@monash.edu (S.D.C.W.)
2 Department of Infrastructure Engineering, Faculty of Engineering and Information Technology, The University of Melbourne, Melbourne, VIC 3010, Australia
3 School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia; dominic.ahiagadagbui@deakin.edu.au
* Correspondence: robert.moehler@unimelb.edu.au

Abstract: Integration of 5D Building Information Modeling (BIM) into large rail projects has the potential to significantly enhance cost management and control. Nevertheless, 5D-BIM implementation has encountered difficulties stemming from technical, functional, and governance-related factors. This paper builds a conceptual framework to support financial decision making, enhances project management, and promotes efficient project delivery. The framework encompasses a set of interrelated elements that include project governance, BIM policies and standards, digital platforms, BIM LOD, cost-estimation classification, and continuous improvement. The proposed framework acknowledges the significance of project governance in guiding and organizing the implementation of 5D-BIM. Additionally, BIM policies and standards ensure the adherence to quality standards for the produced BIM models. Digital platforms serve as the basis for multiple users to generate, access, share, and exchange project information. BIM LOD promotes collaboration and coordination among all project stakeholders. Cost-estimation classification aligns the estimation process with the development of project scope and financial decision making. Continuous improvement plays a vital role in optimizing processes, enhancing efficiency, and achieving higher-quality outcomes. Moreover, it fosters stakeholder satisfaction, improves project performance, and nurtures a conducive environment for innovation and learning. The study analyzes the framework utilization in Victorian rail projects and identifies key implementation challenges. The main technical hurdles encountered were the lack of current horizontal infrastructure standards for data exchange and the lack of compatibility with current cost-management standards. Increased project complexity and the absence of clear project governance strategies and processes also posed organizational challenges. A further validation of the framework in real-world rail projects was recommended to achieve the implementation goals.

Keywords: project governance; 5D-BIM; megaprojects; cost overrun; rail projects; conceptual framework

check for updates

Citation: Hussain, O.A.I.; Moehler, R.C.; Walsh, S.D.C.; Ahiaga-Dagbui, D.D. Minimizing Cost Overrun in Rail Projects through 5D-BIM: A Conceptual Governance Framework. *Buildings* **2024**, *14*, 478. https://doi.org/10.3390/buildings14020478

Academic Editors: Zhen Liu and Mohamed Osmani

Received: 29 December 2023
Revised: 29 January 2024
Accepted: 2 February 2024
Published: 8 February 2024

1. Introduction

Navigating mega rail projects requires an in-depth understanding of their expansive and complex nature [1]. Successful project delivery is not just about managing a multitude of complex activities within strict timeframes and budgets [2]. It also involves an extensive array of stakeholders and communication dynamics [3]; as a result, coordination and collaboration among various stakeholders play a vital role [4]. The success of mega rail projects hinges on the robustness of project governance. Poor project governance in megaprojects can lead to delays, scope creep, and inadequate resource allocation, all of which contribute to a snowball effect on costs and eventually lead to a budget blowout and cost overrun [5]. While debate continues among academics on the cost overrun definition and its causes, magnitude, and reference point of measurement, they all agree on the detrimental consequences of this phenomenon [5–11]. The governance of megaprojects is a complex and dynamic field, that requires a multidisciplinary approach and collaborative efforts across sectors and borders. Effective Building Information Modeling (BIM) is regarded as vital to the success of these projects [12]. BIM implementation heavily relies on policies and standards to ensure consistency, interoperability, and quality [13]. However, the gap between the rapidly evolving technological landscape and the slower pace of policy and standard development poses significant challenges. It creates a scenario where the full potential of technological advancements cannot be realized due to regulatory limitations or a lack of guidance [14]. To effectively connect the realms of BIM and construction management, it is important to adopt a flexible approach to policy and standard development that is consistently updated. A collaborative effort between technologists, practitioners, and policymakers is thus essential to establish practical and realistic standards that can effectively utilize the latest technological advancements.

The state of Victoria, Australia, is embarking on its most ambitious rail endeavor to ensure that these projects adhere to both global standards and local regulations by adopting a 5D-BIM framework [15]. This framework incorporates successful strategies employed by other major rail projects worldwide, while also remaining adaptable to the unique policy context of the region.

This paper presents a conceptual governance framework for implementing 5D-BIM to support financial decision making and enhanced project management and to promote efficient project delivery of railway projects. The study builds upon an earlier systematic literature review (SLR) on the role of 5D-BIM in minimizing cost overruns in rail projects [1]. The SLR aggregated 4342 publications and analyzed 1888 papers to identify and discuss cost overruns in rail projects and 5D-BIM applications and trends over the last 23 years [1], and identified key clusters influencing the success of 5D-BIM implementation.

Motivated by the clusters identified in the SLR, the present framework introduces a process of continuous improvement, with the goal of providing a flexible and adaptive environment for 5D-BIM adoption.

This research begins by examining 5D-BIM across various global contexts. Following this global overview, the study methodically narrows its focus to the state of Victoria. This shift from a broad, international perspective to a more concentrated regional analysis allows for the creation of a 5D-BIM framework that is not only informed by global best practices but is also meticulously customized to the specific needs and challenges unique to Victoria. The transition from a wide-ranging analysis to a focused, region-specific application forms the core of the research methodology. This approach ensures that the framework is both globally informed and locally applicable.

The framework looks into 5D-BIM in the context of governing projects, and it provides a comprehensive approach to incorporating 5D-BIM into railway projects while following the Victorian Digital Asset Strategy. To demonstrate the practical implications of this conceptual framework, a case was conducted in Victoria. The study included a thorough investigation of the delivery mechanisms used in mega rail projects in Victoria, as well as an analysis of government-verified documents such as policies, standards, and guidelines. We then identified various conceptual framework elements in the context of Victoria and carefully examined how these elements integrate. The framework's versatility in adapting to different global contexts makes it an invaluable resource. The framework was formulated from previous 5D-BIM implementation experiences and a thorough examination of literature and policies. It delineates crucial aspects of BIM implementation in rail projects, emphasizing governance and adherence to policies and standards in both the international and Victorian/Australian spheres.

The first section of this paper discusses the significance of project governance in the context of mega rail projects and explores the potential contributions of 5D-BIM to effective project management and successful project delivery. The next two sections present a theoretical background and a literature review essential for further comprehension of the research. Next, a contextual background to the current study is provided, as well as the approach for developing the 5D-BIM framework, after which the 5D-BIM framework is described, detailing its different elements and elaborating on the structure and dynamics of the framework. Finally, the Victorian perspective of the 5D-BIM framework is presented, followed by a discussion of the results and conclusions.

2. Background and Theoretical Foundations

This section overviews the key theoretical concepts necessary for a thorough understanding of the study.

2.1. Management Frameworks

Effective project management in public sector megaprojects relies heavily on governance frameworks [16]. These frameworks serve as a vital tool in ensuring transparency, accountability, and compliance with legal and ethical standards [17]. Examples of such frameworks include corporate governance [18], IT governance [19], and BIM governance [20]. They help guide the decision-making process, establish authority and accountability structures, and prioritize regulatory compliance, ethical standards, stakeholder engagement, and strategic decision making. Governance frameworks are designed to optimize resources, streamline processes, and achieve project objectives in megaprojects [21]. They are a highly effective communication tool for involving stakeholders [22].

The rise in digital technology has significantly impacted megaprojects' governance and delivery strategies. Many government agencies and organizations are undergoing a digital transformation and integrating technology into all aspects of their operations. This shift has given rise to the integration of BIM and digital tools into their frameworks [23]. This has led to improvement in the delivery experience of these projects [24]. Governance frameworks that incorporate digital technologies tend to have a flatter and more agile structure, facilitating faster decision making and a greater adaptability to changing market conditions or technological advancements [25]. Incorporating BIM and digital technologies enables decentralized and data-driven decision making through the Common Data Environment (CDE). The Norwegian Quality Assurance Scheme serves as an example. This framework involves a two-stage external quality-assurance process, which is applied before key decision points, as shown in Figure 1.

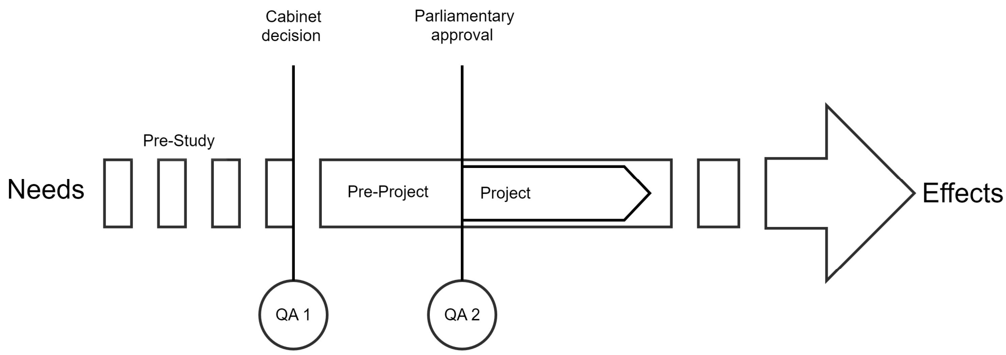


Figure 1. The Norwegian scheme for the quality assurance of major public investments (the QA scheme) [17]. Copyright 2012 by SAGE Publications. Reprinted with permission.

The Norwegian Quality Assurance Scheme offers key advantages for megaproject governance, including a thorough evaluation of project viability, risks, and benefits and ensuring informed decision making. It also emphasizes stakeholder involvement for balanced perspectives and prioritizes early risk identification and management. However, there are challenges such as the ability to adapt to rapid technological and economic changes and managing the complexities and interdependencies of megaprojects. This highlights the need for continuous adaptation and improvement to maintain its effectiveness in a dynamic megaproject environment [17].

Mandates for BIM compliance are often accompanied by supportive measures to facilitate the industry's transition. These measures may include financial and technical assistance. For example, in anticipation of the 2016 BIM mandate, the UK government partnered with industry organizations to offer technical support. This support included initiatives to enhance the skills and capabilities of clients and supply-chain actors, develop standards, and establish knowledge-sharing platforms and BIM-based governance frameworks [26]. An example of a governance framework based on BIM and CDE is the UK BIM Framework, which represents a comprehensive approach to BIM implementation and information management in megaprojects. The framework aligns with the guidelines of The Construction Playbook [27], which sets out key policies and guidance for the assessment, procurement, and delivery of public-works projects and programs in the UK. It emphasizes the transformation of approaches to both the delivery and operation of assets and is particularly focused on guiding organizations toward the successful implementation of BIM information-management practices [20].

The UK BIM Framework requires precise information to support strategic objectives and ensure the security and relevance of the information. It also emphasizes the importance of timely and accurate information for effective decision making. Additionally, a value-based approach to tendering is emphasized, which involves considering both cost and quality, often requiring a BIM execution plan and assessing the capability of involved organizations [20].

Collaborative working is a crucial aspect of the framework. It encourages investments in processes, IT infrastructure, and procedures that promote collaborative efforts [28]. This, in turn, ensures that the information produced is consistent, and that the specified methods are effective before being put into production. The delivery and acceptance of information are crucial stages in the framework, requiring thorough verification against established requirements, standards, and production methods. The primary framework standards are the International Organization for Standardization—Information management using BIM (ISO 19650 series) [29], which provide essential guidance on managing, delivering, and verifying information, ensuring consistency and compliance across projects [20]. An important implicit aspect of the UK BIM Framework is the Common Data Environment (CDE).

2.2. Project Governance

Project governance is crucial for successful project delivery and benefits realization [30]. However, the literature on it remains fragmented, lacking consensus on its definition and elements [31]. Governance involves monitoring and controlling transactions between parties, ensuring efficient value sharing [32]. In the context of a project, governance is multifaceted, involving the parent organization, contractors, suppliers, and project dynamics [33]. A well-defined regulatory framework is essential for successful project governance, ensuring quality, adherence to objectives, effective management of issues, and rigorous evaluation of key documents [34]. Project governance involves aligning project objectives with organizational strategies to benefit stakeholders [33].

As project management has evolved into its own distinct field, governance schools of thought have emerged to analyze the purpose of projects and identify suitable governing mechanisms [35]. There are two main schools of thought on governance in the academic literature. The first school examines governance from the standpoint of the organization at a macro level, while the second school takes a more granular approach and looks at governance from a sub-organizational level [36].

Corporate governance is the responsibility of directors and is the system used to direct and control a corporation [37]. It is led by professional bodies and institutions such as the Australian Institute of Company Directors, the Institute of Directors in Southern Africa, and the Organization for Economic Co-operation and Development.

Project management standards define change as a variation within project boundaries [38]. However, every project functions as an agent of change. Senior management must ensure adequate support for projects to achieve outcomes aligned with organizational objectives [39]. Project governance involves principles, structures, and procedures to manage projects effectively. Projects are subject to oversight by their owners [40]. It is imperative to highlight the inherent conflict between the development or exercise of project governance and the provision of supporting projects to achieve their objectives [36]. This tension arises because one of the primary functions of governance is to establish accountability [41,42]. To address this conflict and manage the risk exposure of individual projects, Turner and Keegan [43] suggest introducing two key roles into organizational governance: the broker and the steward. Central to their proposal is the "single truth" concept, emphasizing a unified information source within an organization to guide decision making across various teams. The broker role focuses on managing external relationships, ensuring alignment between external demands and internal capabilities. Conversely, the steward role focuses on internal coordination, aligning team actions with the organization's policies. Together, these roles create a balance, fostering consistent policy implementation and informed decision making based on a shared understanding of facts [44].

Project-governance challenges often stem from a lack of transparency, which can create a breeding ground for mismanagement, inefficiencies, and even corruption. The absence of transparency can fuel skepticism and mistrust between the government and the public and ultimately undermine the project's credibility and the stakeholders' integrity [45]. In mega rail projects, the sheer magnitude of these projects often amplifies the risks and consequences associated with the absence of transparency [46].

Achieving transparency in project management can be riddled with obstacles, creating a need for robust strategies to combat these challenges [47]. The main challenges in ensuring transparency in project governance include the following:

- Strategic misrepresentation, political pressures, and the influence of vested interests that manipulate the flow of information and suppress unfavorable project cost and progress data to serve specific political agendas [48,49].
- Excessive bureaucracy and complexity of decision-making structures and processes. This includes the presence of hierarchical power dynamics within government agencies, which can impede the free flow of information [50].
- Absence of data-management systems and using outdated or incompatible technology platforms to track and monitor project progress [51].
- Poor stakeholder engagement and inadequate communication of project goals, strategies, and performance to the right stakeholders, which can create an environment conducive to political maneuvering and corruption [52].

Integrating technology-driven solutions such as data analytics and digital platforms can enhance transparency and facilitate the real-time monitoring of project progress. These tools enable stakeholders to access accurate and up-to-date information, promoting accountability and informed decision making throughout the project lifecycle [53].

2.3. Five-Dimensional Building Information Modeling (5D-BIM)

Originally developed for vertical construction projects like buildings [54], BIM is now finding its way into horizontal assets such as roads and railways [55]. This global trend toward increasing BIM implementation in the development and management of horizontal assets is bringing about a multitude of benefits that enhance efficiency, sustainability, and overall project outcomes [56]. The benefits of BIM in horizontal projects like roads and rail include improved accuracy, cost savings, sustainability, and data-driven decision making [57]. 5D-BIM, in particular, provides continuous benefits throughout the project lifecycle in terms of cost estimation, cost budgeting, cost control, quantity take-off, and lifecycle cost analysis [1].

Li and Cao [58] define BIM as a digital representation of an engineering project's entity and functional characteristics. BIM, in essence, is much more than just software; it is a set of data sources and software tools that support various disciplines and build a multidimensional environment [59]. It is a collaborative approach for storing, sharing, exchanging, and managing multidisciplinary information across the full building-project lifecycle, including the planning, design, construction, operation, maintenance, and demolition [60,61].

The foundation of the BIM concept lies in the creation of a centralized model that consolidates all information related to the building. The term "nD" in BIM refers to any views linked to the virtual building model [62]. The 4D links the construction activities represented in time schedules with 3D models to generate a real-time graphical simulation of construction progress versus time. Furthermore, linking "cost" to the BIM model generates the 5D model, which enables the instant generation of cost budgets and financial representations of the model versus time [63]. The different BIM dimensions are shown in Table A1 in the Appendix A.

A typical 5D-BIM model in the rail industry is a comprehensive digital representation of a railway infrastructure project, including the physical and functional characteristics of the railway system. It includes the following detailed elements, tailored to the specific needs and complexities of rail projects [64–66]:

- Railway geometry: Detailed geometric information about tracks, alignments, gradients, turnouts, and crossings, as well as the relationships and clearances between these elements.
- Rail-specific components: This includes the design and specification of rails, sleepers (ties), ballast, signaling equipment, electrification systems (like catenaries or third rails), and communication systems.
- Stations and facilities: Detailed models of station buildings, platforms, canopies, ticketing areas, and other passenger-related facilities.
- Structural elements: Bridges, tunnels, retaining walls, culverts, and other structural components that support the rail infrastructure.
- Interoperability and systems integration: This pertains to integrating various subsystems within the railway infrastructure, such as signaling systems, train control systems, and power supply systems.
- Material specifications and libraries: Provides data on material specifications and access to libraries of products and standard elements commonly used in the rail industry, aiding in the design, specification, and procurement processes.
- Product libraries: Manufacturer-specific components that are used within the railway industry, such as specific types of rail or signaling equipment.
- Standard libraries: Commonly used elements and symbols within the rail industry, often adhering to national and international rail standards.
- Quantities and shared properties: Data for material quantities, length of tracks, number of components, and other quantifiable aspects of the railway, which are vital for cost estimation and procurement.
- Non-geometric data: Information such as maintenance schedules for track and equipment, operation manuals for signaling systems, and warranty information for installed components.
- Analytical models: These models are used for various types of analysis, including the structural analysis of bridges and tunnels, the dynamic analysis of tracks under loading from trains, and capacity analysis for signaling systems.
- Environmental and contextual data: Information about the terrain, surrounding environment, and interface with existing infrastructure, which are crucial for planning, and environmental impact assessments.
- Construction sequencing (4D): Integration of the construction schedule to visualize the construction process over time, optimize the sequence of works, and reduce conflicts during the construction phase.
- Cost estimation (5D): Embedding-cost information for budgeting, cost management, and financial tracking throughout the lifecycle of the railway project.

3. Literature Review

3.1. Previous Studies

Previous studies have endeavored to establish a 5D-BIM framework to manage costs, but they have certain limitations [67]. These studies fail to consider project governance, BIM policies, and stakeholder involvement [68].

For example, Boton et al. [68] conducted an extensive systematic literature review of 5D-BIM, analyzing eighteen different software packages and web solutions. This analysis focused on five key areas of cost-management practices. Based on this study, they developed a 5D-BIM framework, aimed at facilitating informed decision making about the most effective 5D-BIM solutions across different stages of a project's lifecycle. Moses et al. [67] conducted interviews with 21 participants from UK-wide construction organizations and consequently developed a 5D-BIM conceptual framework to facilitate costing in contractor-led projects. Lu et al. [69] developed a framework for accurate cash flow analysis by considering various payment patterns, thereby enhancing cash-flow analysis and aiding contractors in making financial decisions. Ranjbar et al. [70] extends this by incorporating risk analysis into cash-flow management, acknowledging the uncertainties inherent in construction projects.

While these frameworks offer significant advantages at the project level, their implementation could be limited in the case of megaprojects, which are often delivered as a portfolio/program with various types of packages. In addition, these studies exhibit certain limitations, notably overlooking the influence of project governance and BIM policies on the efficacy of 5D-BIM solutions and implementation.

This limitation supports the need for a conceptual framework that can be used by different stakeholders to support financial decision making and enhance project management and delivery. This study, grounded in a thorough systematic literature review on the use of 5D-BIM for minimizing cost overruns in mega rail projects [1], acknowledges the unique challenges and organizational complexities of mega rail projects; it also has a more overarching goal and highlights the importance of a holistic governance framework that encompasses not just financial and risk management but also broader project governance and stakeholder management, ensuring the integrated implementation of 5D-BIM throughout the project lifecycle.

3.2. Critical Analysis of 5D-BIM Implementation in Various Geopolitical Contexts

Different regions have varying approaches to the implementation of Building Information Modeling (BIM) policies. The differences in policy adoption can be explained by the policy diffusion theory, which suggests that a government's decision to adopt a policy is influenced by the decisions of other governments [71]. Peters et al. (2012) [72] expand on this idea by introducing policy-induced innovation, which emphasizes how policy mechanisms can act as incentives for innovation. Filippopoulos and Fotopoulos (2022) [73] contribute to this discussion by highlighting the importance of factors such as regional economic development and openness in determining policy effectiveness.

Building Information Modeling (BIM) is being implemented at different speeds around the world, with countries taking varied approaches. While the US [74] and the UK [75] have made progress with both market-driven and government-mandated methods, China and Australia [76] are still developing their BIM frameworks [77,78]. Singapore [79] has a clear strategy centered around Integrated Digital Delivery (IDD), while Japan's unique design–build system has made BIM adoption slower [80,81]. Germany has created a plan with phases for BIM implementation, including standards, pilot projects, and new project applications [13]. Each country's approach to BIM implementation is shaped by its specific regulatory landscape. To advance BIM globally, it is important to harmonize these diverse approaches, set international standards, and address obstacles. Table A2 in the Appendix A offers a summarized comparison of the various policies and standards for BIM from multiple countries.

Figure 2 presents a worldwide map displaying mega rail projects across the globe that employ BIM throughout their project lifecycle. The comparison of these projects in terms of their BIM maturity reveals a diverse landscape of technological integration and standards. This overview highlights a global trend toward more sophisticated BIM practices. However, the degree of implementation and standardization varies significantly depending on the regional policy context and project-specific factors. A detailed comparison of mega rail projects employing BIM is included in Table A3 in the Appendix A.

Figure 2. Map of mega rail projects employing BIM.

We will analyze the experiences of the UK and India in delivering mega rail projects using BIM, including implementation challenges and benefits. The primary objective of this study is to identify and assess the challenges and success factors associated with BIM implementation in these two contrasting contexts.

3.2.1. Mega Rail Project Governance and Delivery in the United Kingdom (UK)

Rail project delivery and governance in the UK are interpreted as complex and multi-faceted systems/structures involving multiple government agencies and stakeholders. This system/structure is designed to ensure the efficient and effective planning, execution, and oversight of rail infrastructure development, maintenance, and operations [82].

The governance of mega rail projects within the UK is inevitably influenced by the prevailing political context. The UK's political environment is characterized by a parliamentary democracy, where the government's policies, decisions, and actions significantly impact the delivery of various projects [83]. Political shifts, changes in leadership, policy reforms, and governmental priorities can all have profound implications for project governance as well [84]. Although the United Kingdom is widely recognized for its relatively transparent government system, it is not immune to the risks of corruption [85]. The complex nature of mega rail projects often makes them susceptible to political maneuvering, with stakeholders frequently seeking to align project outcomes with their political agendas, regional interests, or electoral considerations. To mitigate this issue and enhance transparency, the government relies on governance frameworks supported by various mechanisms, including the Freedom of Information Act, public consultations providing independent expertise, and parliamentary scrutiny, which aim to ensure that decision-making processes are accessible and accountable to the public.

The UK government has recently launched a roadmap as an umbrella for the governance of infrastructure projects [86]. Beneath this general framework, the rail-project governance formerly adhered to the Guide to Railway Investment Projects (GRIP), subsequently replaced by the Project Acceleration in a Controlled Environment (PACE) [87], which was developed as part of the Programme and Portfolio Management (P3M) framework policy. Figure 3 shows the mega rail projects governance system in the UK.

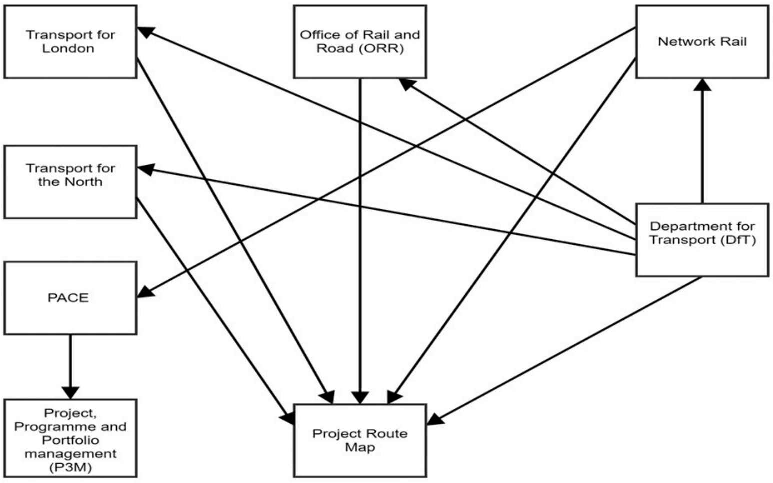


Figure 3. Maga rail governance system/structure in the UK.

The cost estimation and control for mega rail projects is guided by the cost estimating guidance from the Infrastructure and Project Authority [88]. Moreover, the adoption of ISO 19650 Building Information Modeling (BIM), which succeeded BS 1192, serves as the principal reference for BIM integration and information flow within the rail sector [29], collectively forming the foundational framework for 5D-BIM implementation throughout the lifecycle of mega rail projects.

Crossrail [89], as one of the flagship mega rail projects, has significantly reaped the benefits of BIM implementation, serving as a trailblazer and paving the way for subsequent rail projects, like High Speed Two (HS2) [90].

The 5D-BIM system used in Crossrail comprised a Common Data Environment (CDE), a 3D model and a set of different software and tools such as Oracle Primavera (P6) [91] for schedule management. The system was also utilized to generate design drawings in the Industry Foundation Class format (IFC) for fabricating and manufacturing different components of the rail track [89].

Aside from the improved estimation, cost management, and control, the implementation of 5D-BIM in the Crossrail project had many benefits and challenges [92], including substantial direct saving of £70 million in expenses related to additional software and supporting staff, as well as an £8 million savings in risk contingency at Farringdon station.

3.2.2. Mega Rail Project Governance and Delivery in India

The Indian railway network is one of the largest in the world [93]. In the Indian context, the delivery and management of mega rail projects involves a complex interplay of administrative, regulatory, and policy frameworks [94]. At the center is the Ministry of Railways (MoR), which serves as the primary governing body responsible for the development and operation of the nation's railway network. The MoR manages various zones and divisions, each responsible for the administration and management of a specific geographic area [95]. Figure 4 shows the rail project governance in India.

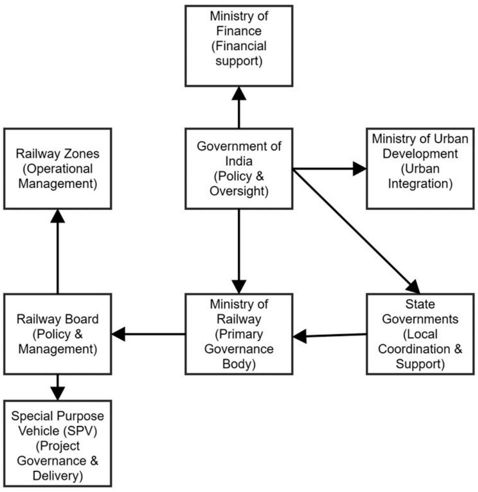


Figure 4. Rail project governance in India.

In 2012, the Indian government expanded the eligibility criteria for the metro rail system to include cities with populations exceeding 2 million. This policy change paved the way for Nagpur City to initiate its metro rail project (Maha-metro) [96], which was one of the first mega rail projects to adopt 5D-BIM in India.

To enhance project management and ensure efficient project delivery, Maha-metro created a Digital Project Strategy Management platform tailored for the Owner Support Office (OSO). This platform incorporates the Enterprise Resource Planning system (ERP), a BIM solution, and cost data, forming a cohesive 5D-BIM ecosystem to streamline project cost management and control [96].

The digital platform incorporates three key systems: Oracle Primavera (P6) [91], SAP [97], and the Bentley software (Project Wise and Asset Wise software) [98]. The results of this integrated system were presented through SAP-BI dashboards. The RIBiTWO software -SE [99] facilitated the seamless integration of data from various sources, including the 3D model, scheduling information from P6, and cost data from SAP. This integration enabled enhanced schedule management (4D) and more effective cost management, control, and analysis (5D) [96].

The Nagpur Metro project has greatly benefited from BIM implementation throughout its lifecycle. During the design phase, BIM has ensured clear scope identification, maintained design consistency, facilitated clash detection and resolution, and automated quality-assurance checks. In the site-planning phase, BIM enhanced site visualization, streamlined logistic management, and optimized schedule management, ultimately reducing the overall project timeline. Throughout the construction stage, BIM played a critical role in project control, status reporting, and the tracking of contract variations and claims. Finally, BIM enabled a seamless project handover, with project data transitioning to the integrated asset management system, ensuring ongoing operational efficiency [96].

3.2.3. Lessons Learned from Case Studies in the UK and India

Introducing 5D-BIM in both the Crossrail and Nagpur Metro projects presented unique challenges, but both projects have substantially benefited from its implementation. Employing 5D-BIM proved to be a thoughtful/successful governance strategy [89,96].

The key successful implementation factors included adhering to the latest BIM policies, standards and mandates [96], developing a robust Common Data Environment (CDE) integrated with the right BIM software and tools [89,96], and the development of a discipline-specific Level of Development (LOD), which were important for ensuring that client requirements were fully understood and to ensure a common understanding among different stakeholders [89]. The team and management's commitment to continuous improvement played a crucial role in achieving success and enhancing the implementation experience. In conclusion, the analyses revealed that even though the political environments in the UK and India differ, certain principles in 5D-BIM have broad applicability.

Table 1 below compares the different elements of the BIM adoption framework employed in Crossrail and the Nagpur Metro Rail Project.

Table 1. BIM adoption framework elements comparison.

Dimension	CDE	Governance	5D-BIM Software and Tools	BIM LOD	Cost Management and Control Standards	BIM Polices and Standards	Digital Platforms
Crossrail	ProjectWise—based on BS 1192	Governance for Railway Investment Projects (GRIP)	Contruent (PRISM)	AEC (UK) BIM protocol	Cost Estimating Guidance—Infrastructure and Project Authority	BS 1192 [100]	SAP–Axiom–SharePoint
Nagpur Metro Rail Project	ProjectWise + AssetWise CDE (eB)	Hybrid model—State Administrative + SPV	RIBiTWO + Primavera P6	BS PAS 1199	Indian Railways—Estimation guideline	BS 1192:2007+A2:2016	SAP-ERP

3.3. D-BIM Implementation Challenges/Barriers

Mega rail projects are typically managed as programs comprising various packages that are executed at different times and in different geographical locations, often by different contractors [101]. This complexity leads to the use of a wide array of software packages across the project. The diversity of software used by each entity poses a significant challenge. High levels of collaboration and data sharing are crucial for successful project delivery, requiring a strong focus on harmonization and software compatibility. Additionally, the field of BIM faces a skills gap, complicating the effective implementation and integration of these technologies [102].

BIM challenges in mega rail projects fall into three categories: Governance (People) addresses leadership and skills gaps; Governance (Policy) focuses on quality control and legal aspects; and Communication Processes and Workflow emphasize effective coordination protocols. Technology involves data security, software selection, and hardware management. The rapid advancement of technology compared with policy updates poses significant challenges in compliance and the alignment of BIM practices with current capabilities. Table 2 shows the key 5D-BIM implementation challenges/barriers, along with their associated fields and categories.

Table 2. D-BIM implementation challenges and barriers.

Category	BIM Field	5D-BIM Key Implementation Challenges/Barriers	Reference
Governance	People	Lack of leadership and commitment from the project team.	[103,104]
		Ambiguity in project roles and responsibilities	[103,104]
		Lack of training and skill gaps	[103–106]
		Resistance to change	[103–106]
	Policy	Challenges with quality control	[78,103]
		Legal challenges in data ownership and sharing	[78,103,104,107]
		Need for success measurement and KPIs	[103,104]
		Risk-management issues	[103]
Policy and standards	Policy	Lack of consistency	[78,103,104,107]
		Uncertainty in compliance with industry and government requirements	[78,103,104]
Communication, processes, and workflow	People	Need for communication protocols	[78,103–106]
	Technology	Data security and privacy risks	[103,104]
Tools and software	Technology	Selecting the right software	[78,103–105,107]
		Data-management challenges	[103,104]
Integration and compatibility	Technology	Difficulties in data migration and integration	[103,104]
		Hardware requirements and cost	[103,106,107]

4. Contextual Background and Research Method

This study, which is an integral part of broader research on minimizing cost overrun in rail projects through 5D-BIM, analyzes the literature on successful governance frameworks, concentrating on megaprojects in the rail industry. It compares the policies and standards from various international governance frameworks and analyzes and conceptualizes dimensions to the context of Victoria, Australia, as a practical conceptual framework. After analyzing the findings from the literature review, the study conducts a detailed policy and document analysis to explore the various governance dimensions involved in the implementation of 5D-BIM, as well as the factors contributing to challenges and successes, with a focus on notable rail projects like Crossrail [108,109] and Nagpur Metro Rail [96].

To develop the 5D-BIM conceptual framework, the initial stage involved a detailed analysis of the SLR results to construct a concept map that identifies the elements of the 5D-BIM framework and illustrates the processes both within and among these elements. Following this, we thoroughly examined, analyzed, and categorized the 5D-BIM implementation challenges and barriers. Finally, we proceeded to investigate the diverse 5D-BIM policies on a global scale and assess their application in real-world projects, extracting valuable lessons from these case studies.

Figure 5 presents the keyword cluster map for the 5D-BIM framework development, using Leximancer as a powerful text-analysis tool. The map helps to dissect and understand the functionality of each cluster element and their relation within the system.

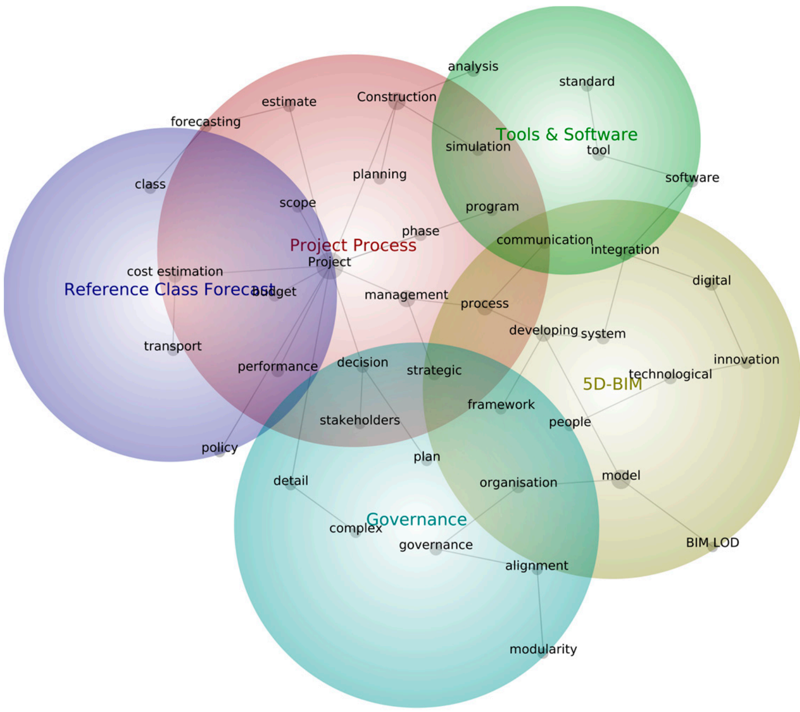
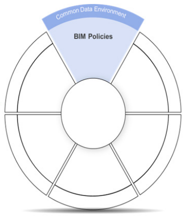
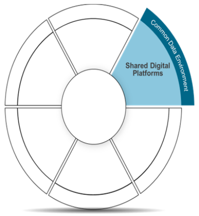
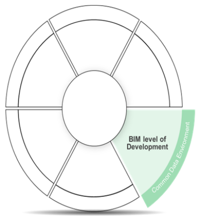
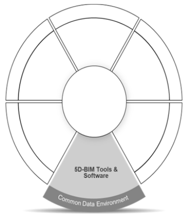
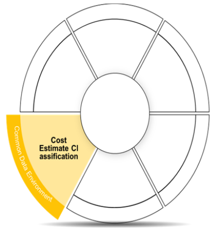
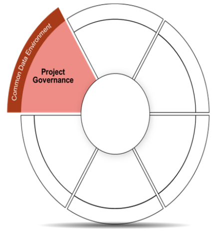
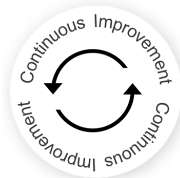
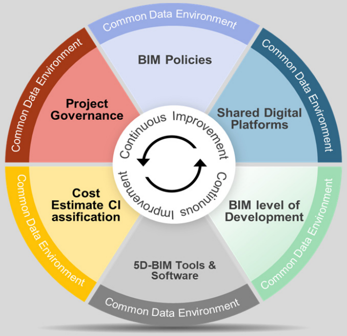


Figure 5. The concept-keyword cluster map for the 5D-BIM framework.

5. The 5D-BIM Conceptual Framework

The distinct elements/categories discussed in the preceding sections set the stage for a deeper understanding of the anatomy, construction logic, and dynamics of a conceptual framework. Table 3 below presents the 5D-BIM conceptual framework and provides a brief overview of its various elements, their definitions, associated benefits, and relevant references.

Table 3. D-BIM conceptual framework.

References	• [13,26,110]	• [111,112]	• [113,114]	• [115,116]	• [117,118]	• [31,33,36,119,120]	• [121,122]
Key Benefits	• BIM policy documents provide clear guidelines that assist organisations in achieving consistent input/output and reducing confusion and a ambiguity [13,26]	• Multiple users can use digital platforms to create, access, share, or exchange information, goods, or services [123,124]. • Digital platforms enable interoperability and transactions in a secure, confidential, and discrete manner, eliminating the need for users from different parties to have simultaneous access to each other [125].	• BIM LOD allows models to become more accurate. It enables teams, including owners, to precisely specify the level of detail required from a BIM model and gain clarity on the scope of the final BIM deliverable [126,127].	• Using the right BIM software is a critical success factor for BIM implementation because it can significantly minimize the costs, time, and risks.	• Cost-estimation classification aligns the estimating process with project-scope development and financial decision-making processes [116]. • Reference-class forecasting removes optimism bias and strategic misrepresentation in projects [128,129]. • Reference-class forecasting generates more accurate forecasts by comparing the project to a statistical distribution of similar historical projects [130].	• Project governance enables the organization in aligning the project objectives with its organizational strategy, achieving project goals, and monitoring performance. It also describes the methods for achieving such goals [131]. • Project governance articulates decision-making processes and specifies criteria for validating the impact on the project. It provides a platform where problems may be discussed and resolved in a timely manner. Project governance serves as means to collect information and report to all stakeholders [132].	• Continuous improvement ensures the efficiency of project processes; it helps to find better ways of accomplishing a task. At the organizational level, it helps in achieving responsiveness, flexibility, and rapid adaptation to change [133].
Definition	• BIM policy is a set of interconnected decisions or plans of action taken by the governments(political group). BIM policy describes the overall objectives, goals, and vision, as well as the strategic measures to achieve these [134,135].	• Digital platforms are extensible technical codebase artefacts. Platform ecosystems typically include third-party modules that supplement this codebase [124].	• LOD is the degree to which the element's geometry and related information have evolved through the BIM development process [136,137].	• BIM software and tools are computer programs that are used to create and manage BIM digital models, which include procedures, rules, and supporting documentation. These tools can range from simple 3D modeling software to sophisticated platforms that facilitate collaboration, data exchange, and decision making throughout the asset lifecycle [138,139].	• Cost-estimation classification is the categorization of cost estimates based on their degree of accuracy, reliability, and completeness. The most common classification systems are the Order of Magnitude (conceptual), Budget, and definitive [116].	• Project governance is defined as a collection of management systems, rules, protocols, relationships, and structures that provide the framework within which decisions for project development and delivery are made in order to realize the desired business or strategic goal [131].	• Continuous improvement is a culture of ongoing improvement that aims to eliminate waste within the whole project or an organization's systems and processes [140].
Framework Element							
	 **5D-BIM Framework** The 5D-BIM framework provides a mechanism for project management/governance/delivery. Continuous improvement lies at the heart of the framework to ensure the integration and efficiency of processes underlying the framework.						

The following subsections succinctly outline the 5D-BIM framework elements and its dynamics.

5.1. Project Governance

In the 5D-BIM framework, project governance serves as the backbone, providing structure and direction for implementing 5D-BIM to achieve project goals while also upholding relevant policies, standards, and regulations. In turn, 5D-BIM supports project governance by acting as a centralized, coordinated, and integrated information source, facilitating informed financial decisions, progress tracking, and risk management throughout the project's lifecycle.

5.2. BIM Policies and Standards

While the role of process and technology is obvious, BIM policies and standards play a crucial role in successful BIM implementation. As the main client of megaprojects, a government's commitment to adopting BIM is pivotal for the construction industry, primarily because this industry is highly fragmented and subject to stringent regulations [13].

Policies and standards offer a roadmap for consistency, ensuring that BIM practices remain uniform within an organization or across various projects. BIM policies and standards bolster quality assurance by outlining best practices, guaranteeing that BIM models and data are not only accurate but also reliable and perfectly suited for their intended purposes. Furthermore, they help in risk mitigation by identifying potential issues and guiding organizations in avoiding costly errors, delays, or disputes.

5.3. Digital Platforms

Due to the need to improve the performance of infrastructure megaprojects, there has been a shift away from using traditional project-delivery methods to collaborative forms of project delivery [141].

Digital platforms encompassing online systems and applications establish the basis for multiple users to generate, access, distribute, or exchange project information [123,124]. Digital platforms enable interoperability and transactions in a secure, confidential, and discrete manner, eliminating the need for users from different parties to have simultaneous access to each other [125]. Employing digital platforms in megaprojects offers a multitude of inherent benefits and possesses the potential to enhance the decision-making process and project governance [142]. Relative to traditional bespoke or "big one-off" strategies, platforms exhibit the capacity to significantly minimize cost overruns in megaprojects [112].

However, a digital platform does not function in a governance vacuum; it inherently replicates a governance framework that establishes protocols, oversees, and facilitates and regulates interactions between participants as well as the exchange of data and data services [143].

Digital platforms exhibit a multitude of typologies, with no one-size-fits-all solution. Their suitability hinges upon the distinct characteristics of the project. Notable digital platforms in the field include Autodesk Cloud for design management [144], Oracle Primavera Cloud for project management [145], Bluebeam for document management [146], ARES PRISM (Contruent) for project control [147], and Bentley OpenRail for railway design and construction [148].

5.4. BIM LOD

BIM LOD fosters collaboration and coordination among all project stakeholders by establishing a shared understanding of what is required in the BIM models [126,127].

BIM LOD signifies the progression of an element's geometry and its associated information during the BIM model-development journey. The American Institute of Architects (AIA) has established a framework comprising five distinct levels of development: LOD 100, LOD 200, LOD 300, LOD 400, and LOD 500 [149].

LOD 100 (Generic) is limited to a generic representation of the project; it may include general railway alignment, cost per linear meter, etc. LOD 200 (Approximate) is more precise than LOD100 but still uses generic elements to represent the geometry of the project. LOD300 (Specific) represents project geometry, with additional information attached to it. LOD 400 (Installation) contains further details beyond the typical use of an architect or engineer. LOD 500 represents the "as built" status for the project [150]. Figure 6 provides an illustrative example showcasing the five LODs in railway element design [136].

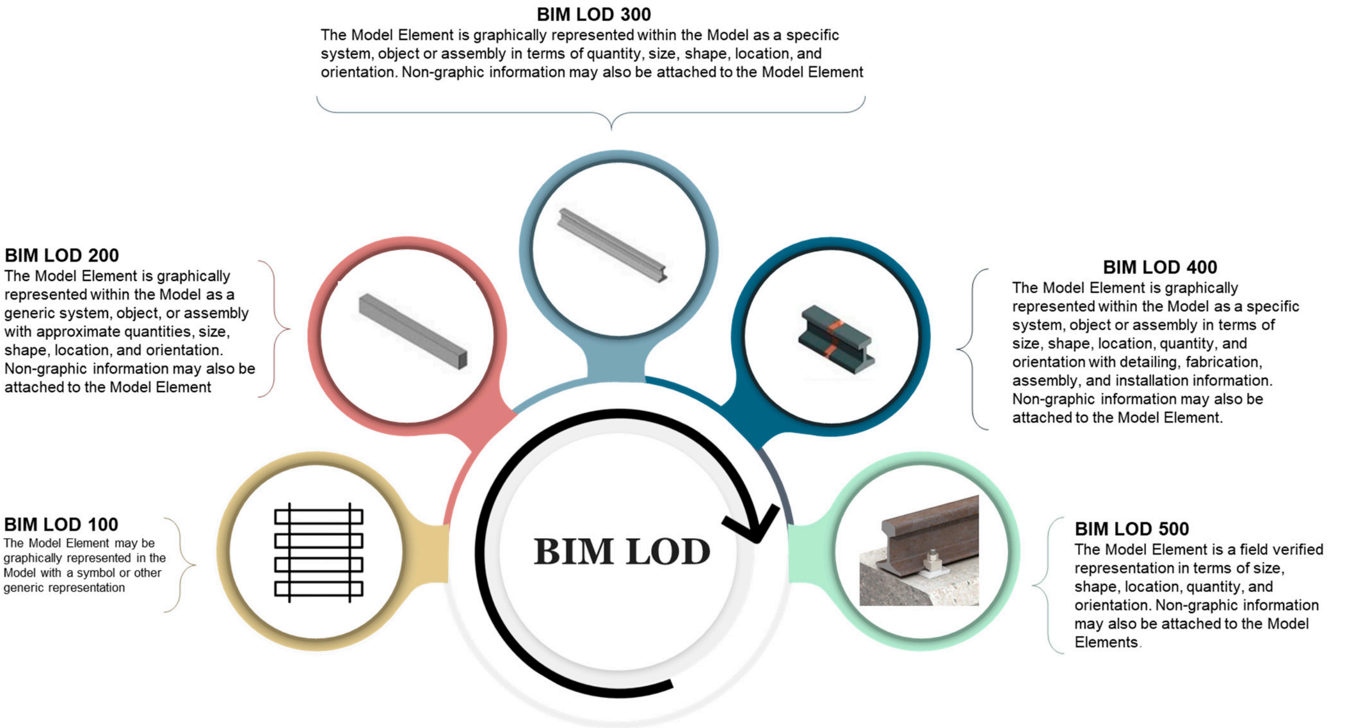


Figure 6. BIM LODs for railway elements.

It is important to distinguish between the level of development and the level of detail; while the level of detail is more concerned with quantity, the level of development represents the degree to which the BIM model was thought through.

5.5. Cost-Estimation Classification

Cost-estimation classification aligns the estimating process with the development of the project scope and financial decision-making processes. It is used to categorize cost estimates based on the maturity level of the project. One of the key functions of project governance is to approve project budgets through different milestones (or gates) in the project lifecycle. The level of maturity of cost estimation is instrumental in obtaining budget approval. Usually, the gate reviews involve assessing the project's progress, risks, and alignment with strategic objectives. Cost-estimation classification provides the metrics to ensure that sound cost data is used to support the project governance and decision-making process at each stage or gate.

5.6. BIM Tools and Software

A variety of software solutions have been developed to facilitate the integration of 5D-BIM into horizontal projects such as roads and railways. However, it is important to note the absence of a universally applicable solution or a "one-size-fits-all" approach. Typically, a combination of software solutions is required for successful implementation. In the course of this study, a comparative analysis was conducted for the popular 5D-BIM software packages. The outcomes of this analysis are documented in Table A4 in the Appendix A. The comparative analysis revealed several key trends in the industry. Increasingly, BIM software products are moving toward cloud-based solutions, reflecting a broader technological shift toward more accessible and collaborative platforms. Additionally, there is a noticeable trend toward flexible pricing models among software providers. This flexibility often includes scaling costs based on project size, type, or the number of users, making 5D-BIM tools more accessible to a wider range of projects and companies. The adoption of these trends can be attributed to advancements in internet and web technologies, which enable more scalable, versatile, and user-friendly software solutions.

5.7. Common Data Environment (CDE)

The Common Data Environment (CDE) is a tool that offers several benefits to project management. The International Organization for Standardization's ISO 19650 sets out the framework for a Common Data Environment (CDE), defining it as an agreed source of project/asset information for the collection, management, and sharing of information containers through a managed process [29]. The central element is the data repository, which is the primary storage space for all data. Additionally, the structure of stored information, crucial for CDE, must be predefined and regularly updated, often as a contractual requirement. The system also involves managing property and access rights to secure the data and to control access [151]. For BIM-based collaboration, it mandates exclusive data exchange through the CDE at specific times, as per the contract. Lastly, it uses planning statuses (work in progress, shared, published, archived) to coordinate cooperation and track the usability of data sets [152]. It promotes collaboration among various project stakeholders, reduces miscommunication and errors, and maintains accountability [153]. The CDE includes robust version control, access control, and documentation of all changes and activities related to the project data. This was demonstrated effectively in a case study by Ye et al. [154], where BIM, CDE, and smart contracts were used for managing claims. It also has predefined storage structures, exclusive data exchange, and planning statuses that track the usability of data sets [155].

However, implementing CDEs is challenging due to a lack of strategy, high costs, inadequate training, and incomplete setup. Better implementation strategies, training, and protocols are needed for efficient CDE utilization [156]. The importance of CDE in managing collaborative work is emphasized, and strategies to overcome barriers in CDE adoption are proposed.

While basic tools/platforms are widely used for team collaboration in projects such as SharePoint, Google Drive, or OneDrive, BIM implementation often requires more sophisticated, advanced platforms such as ProjectWise, Procore, or Aconex (Oracle) [157].The selection process should consider four key aspects: document management, BIM integration, security, and lifecycle functionality [158].

Finally, continuous improvement in mega rail projects is significantly important, as it helps to optimize processes and increase efficiency, resulting in higher quality outcomes, greater stakeholder satisfaction, improved project performance, and the fostering of an environment of innovation and learning [158]. Continuous improvement ensures ongoing adaptation and enhancement to meet evolving requirements and challenges; it plays a pivotal role in identifying bottlenecks, inefficiencies, and areas for enhancement within the interconnected components. It facilitates the streamlining of workflows, promotes synergy between various elements, and enables the integration of feedback and lessons learned into the framework's structure [140].

5.8. Global Adaptability of the 5D-BIM Conceptual Framework

Despite the variations in project governance systems and BIM standards and policies across different countries, the 5D-BIM implementation framework remains adaptable for deployment worldwide. The framework's versatility arises from its robust conceptual basis, allowing it to be tailored to the distinct requirements of diverse national contexts. As illustrated in Table 4, the framework seamlessly integrates with and conforms to the unique structures of the transport and rail project governance and delivery ecosystems in various countries. This compatibility signifies the framework's potential to foster a standardized approach to 5D-BIM implementation while accommodating the specific intricacies of each nation's regulatory and operational landscapes.

Table 4. Alignment of the 5D-BIM implementation framework with global transport and rail project governance and delivery ecosystems.

Key Elements	UK	USA	EU	Victoria (Australia)
Project governance	PACE (Project Acceleration in a Controlled Environment)—replacement of GRIP [87].	Stage–Gate process (differs by state)—California as an example [159]	Europe's Rail Joint Undertaking Governance and Process Handbook [160]	Gateway Review process [161]
Cost-estimation classification	Cost Estimating Guidance–Infrastructure and Project Authority [88].	Cost Estimate Classification System—AACE [162]	ICMS: International Cost Management Standards [163]	Cost Estimate Classification System—AACE [162]
BIM policies and standards	ISO 19650 Building Information Modeling (BIM)-replaced BS 1192 [29].	National BIM Standard-United States® (NBIMS-US™) [164]	ISO 19650 Building Information Modeling (BIM) [29].	Victorian Digital Asset Strategy (VDAS) [165]

6. A Victorian Perspective

In spite of sustained investment by the Australian government in infrastructure development, with a specific focus on rail networks, the present state of infrastructure development in Australia, particularly in the context of rail networks, confronts noteworthy hurdles, particularly concerning accurate cost estimation and robust financial decision-making processes. The implementation of the 5D-BIM framework, along with collaborative procurement methods and sound cost-estimation methods, could help surmount these obstacles and address these challenges [166]. The following section presents an analysis of mega rail project delivery in Victoria.

6.1. Rail Project Governance in Victoria

In Victoria, several entities are entrusted with the delivery and governance of infrastructure rail projects. The pivotal agency in charge of planning, developing, and executing rail infrastructure projects across the state is the Victorian Department of Transport (DoT). Alongside the DoT, there are additional organizations engaged in the oversight of rail infrastructure projects. These include Public Transport Victoria (PTV), Rail Projects Victoria (RPV), the Transport Infrastructure Council (TIC), and Infrastructure Victoria [167].

There are several different processes and mechanisms involved in the governance of Victoria's rail infrastructure projects, including public consultation, environmental assessments, project planning and design, procurement, project management, and operations and maintenance. The precise governance structure for individual projects is contingent upon multiple elements, such as scale, complexity, geographical location, and the spectrum of stakeholders engaged.

In late 2010, the Victorian government introduced the High Value High Risk (HVHR) framework as a strategy to mitigate cost overruns in megaprojects. This framework applies to all public sector investments in infrastructure and information and communications technology. The framework uses different thresholds and assessment forms to classify projects [168].

While all projects covered by the framework undergo the project-assurance process, HVHR are subject to more rigorous scrutiny and mandatory approval processes through the gate review process [168].

The gate review process involves six pivotal decision points (gates) throughout a project's lifecycle: Gate 1 for concept and feasibility; Gate 2 for the business case; Gate 3 for market readiness; Gate 4 for tender decision; Gate 5 for service readiness; and, ultimately, Gate 6 for benefits analysis.

Although the adoption of the HVHR framework has generally enhanced project governance in Victoria, subsequent audits have revealed certain gaps in its implementation. These gaps potentially expose the government to the risk of allocating substantial funds to projects without a clear understanding of the validity or attainability of the projected benefits [169].

6.2. Victorian Digital Asset Strategy (VDAS)

In February 2019, the Victorian Government, jointly with Office of Projects Victoria, announced the release of the Victorian Digital Asset Strategy (VDAS). VDAS aims to ensure that all government projects, including rail projects, adopt and implement digital asset management principles and technologies to elevate asset performance, streamline maintenance processes, and enhance the overall efficiency of project delivery [165,170].

VDAS is structured into three parts: strategic level (Part A), organizational level (Part B), and project level (Part C). Together, these parts offer comprehensive guidance on planning, implementing, managing, and maintaining an efficient digital-asset strategy across the asset lifecycle. The guidelines outline three levels of capabilities and 14 requirements throughout the asset lifecycle to ensure successful implementation. VDAS was developed in collaboration with the industry and is aligned with the international standard ISO 19650. While VDAS is not mandatory, there is an increasing trend of it being adopted in rail projects [171].

6.3. Cost-Estimation Classification

The gate review process serves as a framework for evaluating the progress and quality of a project at different stages, including the accuracy and reliability of the cost estimates. By classifying cost estimation at each gate based on the available project information and level of detail, stakeholders can make informed decisions regarding project continuation, resource allocation, and risk management. It is crucial to conduct regular reviews and validations of cost estimates at each gate to ensure that the project stays on track and remains within the allocated budget.

The AACE International Cost-Estimate Classification System serves as the basis for various estimation tools utilized by the Victorian government [172]. The system consists of five classes, which are as follows: Class 5—Rough Order of Magnitude Estimate (ROM): prepared very early in the project life cycle; Class 4—Preliminary Estimate: prepared during the project-planning phase when the project scope is still being defined and preliminary data is available; Class 3—Detailed Estimate: prepared during the early stages of project development when the project scope is defined to a certain extent; Class 2—Study Estimate: prepared during the preliminary design phase when the project scope is partially defined and conceptual or preliminary engineering designs are available; Class 1—Control Estimate: prepared for the control and monitoring of project costs during project execution.

Classes 5 and 4 of the cost estimation could be applied during gate 1, the concept and feasibility stage. At this stage, the project idea is conceptualized and evaluated, and cost estimation is generally high-level and exploratory, focusing on providing a ROM estimate. This initial estimate helps in determining the feasibility and potential benefits of the project. Cost-estimation classes 3 and 2 are more aligned with business-case development, specifically at gate 2. The Class 1 estimate could be used for tender documents and when the project is market-ready in stage 3.

It is noteworthy that mega rail projects are typically organized as a program of several interconnected projects or packages, each with its own unique characteristics and delivery methods. Due to the diversity and complexity of these packages, it is common for the cost-estimation classification to be applied differently to each one.

6.4. 5D-BIM Software and Tools and the Common Data Environment (CDE)

Key 5D-BIM software and solutions in Victoria include RIB-Cost-X, Bexel Manager, ARES PRISM (now known as Contruent), Cubicost, and PriMus. Regarding the Common Data Environment (CDE), government agencies in Victoria have opted for an array of basic collaboration tools/platforms such as SharePoint, Google Drive, and OneDrive as well as robust solutions like ProjectWise, Procore, and Aconex (Oracle) for projects employing BIM.

The selection of the 5D-BIM software and CDE platform is tailored to the unique requirements and complexity of each project.

7. Discussion

7.1. D-BIM Framework Development

The literature suggests that the challenges and key success factors associated with 5D-BIM implementation can be systematically categorized into five distinct domains: Project Governance, Policies and Standards, Communication Processes and Workflow, Tools and Software, and Integration and Compatibility, as outlined in Table 3. Moreover, Figure 5, the concept map, demonstrates the interconnection between 5D-BIM implementation and five main areas: Tools and Software, Project Processes, Digital Platforms, Governance, and Reference Class Forecasting. Furthermore, the analysis of policies and case studies discussed provided valuable insights and empirical evidence from the industry, highlighting the essential elements for successful 5D-BIM implementation, including sound project governance, the use of appropriate BIM tools and software, adherence to the latest BIM policies and standards, using a reliable Common Data Environment (CDE) for team collaboration, and information exchange. In light of these findings and the significant impact of governance on various complexities within mega rail projects, we have developed a conceptual 5D-BIM framework containing the following elements: project governance, BIM policies and standards, digital platforms, BIM LOD, cost-estimation classification, alongside a Common Data Environment (CDE) as shown in Figure 7 below.

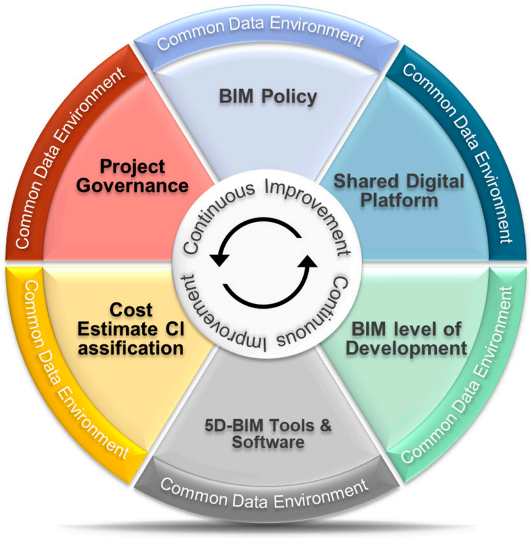


Figure 7. 5D-BIM Framework.

7.2. Implementing 5D-BIM across Various Policy and Governance Frameworks/Structures

The governance of mega rail projects in India and the UK reflects the differences in their political systems, policies, and regulatory environments, which subsequently impact the transparency and management of these projects. Effective project governance is crucial for ensuring transparency, mitigating risks, and preventing corruption. While both countries have made efforts to promote transparency in their respective rail projects, the varying regulatory frameworks, public participation, digital infrastructure, and anti-corruption measures contribute to different levels of transparency.

In the UK, the established regulatory framework and emphasis on public engagement contribute to a relatively higher degree of transparency in mega rail projects. The integration of advanced technologies, such as 5D-BIM, has significantly enhanced project planning, execution, and maintenance. The use of such technologies has streamlined processes, improved decision making, and enabled efficient cost management throughout the lifecycle of these projects. Furthermore, the UK government has established mechanisms like the

Freedom of Information Act, public consultations, and parliamentary scrutiny to ensure accountability and transparency, minimizing the risks of corruption or inefficiencies.

Conversely, in India, the governance of mega rail projects is influenced by a different political and regulatory context. The complexities of the Indian bureaucratic system, along with varying levels of corruption, can pose challenges to maintaining transparency in project governance. However, the Indian government has been increasingly adopting digital infrastructure and technologies such as BIM to improve project management. While these efforts are underway, there is still a need for more robust institutional mechanisms and anti-corruption measures to enhance transparency and accountability in the governance of mega rail projects.

Despite the differences in policies, political systems, and environments between India and the UK, the implementation of 5D-BIM has demonstrated similar requirements and success factors in both countries.

The 5D-BIM framework builds on the key success implementation factors from the two projects, including compliance with the latest BIM policies, standards and mandates [96], developing a robust Common Data Environment (CDE) that is seamlessly integrated with appropriate BIM software and tools [89,96], and development of a discipline-specific Level of Development (LOD) [89].

In addition, the elements of the framework respond to the 5D-BIM implementation challenges: the digital platforms facilitate efficient data sharing and management, addressing data synchronization issues similar to those encountered in the Nagpur project. The Cost Estimation Classification directly addresses cost overrun concerns by providing a more accurate and detailed estimation process, and the Continuous Improvement emphasizes the adaptability of the framework to ensure that it remains relevant as project demands and technologies evolve, addressing the need for continuous adaptation that is seen in both projects.

The use of 5D-BIM has proven instrumental in improving project efficiency, data management, and decision-making processes, leading to enhanced transparency and accountability. The successful integration of 5D-BIM in both countries serves as a testament to the universal benefits of adopting advanced technologies in project governance, irrespective of the political environment. By studying and learning from the experiences of the UK and India, other countries can draw valuable insights and develop best practices to enhance their own project governance frameworks, promote transparency, and mitigate the risks of corruption in mega rail projects.

7.3. Application to the Victorian Mega Rail Program Context

Victoria is undertaking an ambitious rail program with a visionary outlook. The program's estimated budget is around AUD 150 billion. Given the sheer scale and diversity of this large pipeline of infrastructure upgrades, there is a pressing need for enhanced governance efforts. These efforts are essential to foster a more structured project management and delivery environment, ensuring that each project is effectively managed and coordinated within this expansive program. Enhanced governance necessitates a policy change/transformation. Implementing governance frameworks such as the 5D-BIM framework and its integral elements could be the best response to this policy change and a starting point for further learning.

Outlined below are the various framework elements employed in Victoria. In project governance, the predominant tool is the gate review process. VDAS serves as the state's flagship policy for digital engineering and BIM implementation. Moreover, the state employs the AACE estimation classification for cost development. The following discussion provides a concise overview of these elements.

The governance of mega rail projects in Victoria aligns more closely with the UK's approach rather than India's, primarily in terms of its structured approach, regulatory mechanisms, and emphasis on transparent decision-making processes. Similar to the UK's governance framework, Victoria's infrastructure rail projects are overseen by various entities such as the Victorian Department of Transport (DoT), Public Transport Victoria (PTV), and Rail Projects Victoria (RPV). These agencies collaborate to ensure the effective planning, execution, and oversight of rail infrastructure development, mirroring the multi-faceted governance structures seen in the UK's Department for Transport (DfT), Network Rail, and the Office of Rail and Road (ORR).

Furthermore, the implementation of the High Value High Risk (HVHR) framework and gate review process in Victoria, aimed at addressing potential cost overruns in megaprojects, reflects the UK's emphasis on robust governance frameworks, such as the Guide to Railway Investment Projects (GRIP) and Project Acceleration in a Controlled Environment (PACE). Both governance models emphasize the importance of stringent gate review processes and clear decision points throughout the project lifecycle to ensure effective project management and minimize financial risks.

The Crossrail project in the UK stands as a prime example of successful project delivery and governance, showcasing the importance of effective coordination between various government entities, stakeholders, and industry partners. Similarly, the Nagpur Metro Rail Project in India highlights the significance of leveraging advanced technologies and strategic partnerships to ensure efficient project implementation and sustainable urban development. Figure 8 provides a Victorian perspective of the 5D-BIM framework.

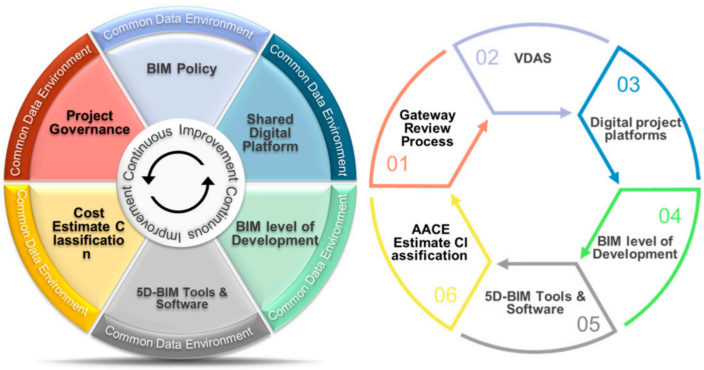


Figure 8. A Victorian perspective of the 5D-BIM framework.

The following subsections outlines key insights gained regarding various aspects of the 5D-BIM Framework:

7.3.1. Common Data Environment (CDE)

CDE is a critical component of the conceptual 5D-BIM framework. The importance of CDE as a centralized data repository lies in ensuring accurate, consistent, and real-time access to project information, thus enhancing transparency, efficiency, and cost management and control [155].

This approach is supported by the literature and proven in practice through successful implementation in mega rail projects like Crossrail and Nagpur Metro Rail. The success of Crossrail, with its hybrid cloud-computing platform combining Microsoft Azure and Bentley's AssetWise software and Nagpur Metro's utilization of iTWO and Bentley Systems' Open Rail CDE, underscore the practical advantages of a CDE. These include enhanced collaboration, process optimization, and improved project [89,96]. For Victoria, adopting a CDE as an integral component of the 5D-BIM framework aligns with the literature and industry best practices, promising improved coordination, efficiency, and cost management in its mega rail projects.

7.3.2. Governance

Incorporating governance into the 5D-BIM framework can facilitate better integration of technology and processes, ensuring that data-driven decisions are made efficiently and effectively.

Crossrail, noted for its vast scale and complex engineering requirements, encountered significant challenges in managing diverse stakeholders and aligning multiple project phases. It implemented a governance framework that prioritized clear communication, accountability, and regular monitoring. This approach was key in ensuring effective decision making and risk management, keeping the project aligned with its goals. The Nagpur Metro, dealing with a wide network of contractors and consultants, adopted transparent operational protocols supported by BIM and efficient communication strategies, emphasizing stakeholder engagement.

For Victoria, incorporating project governance as part of the 5D-BIM conceptual framework can provide a guide for developing governance models that emphasize accountability and stakeholder engagement. This would involve restructuring the current gate review process and setting up clear governance roles, developing transparent communication channels, and implementing robust monitoring and reporting systems.

7.3.3. BIM Policies and Standards

BIM policies and standards are crucial for maintaining consistency and quality in mega rail projects, as evidenced by the Crossrail and Nagpur Metro projects. These standards provide a roadmap for uniform BIM practices, ensuring that models and data are accurate, reliable, and fit for purpose. For instance, Crossrail's adherence to the UK's BIM Level 2 standards ensured collaborative work and data accuracy, crucial for efficiently managing complex infrastructure.

Victoria can benefit significantly from implementing a BIM mandate for mega rail projects similar to the UK's BIM Level 2 standards. Such a mandate would encourage the adoption of advanced digital technologies across the sector, leading to increased efficiency, cost savings, and improved project outcomes. By mandating BIM, Victoria can ensure that all mega rail projects follow a consistent framework for data management and collaboration, leading to better coordinated and more efficient project delivery. Furthermore, a BIM mandate can drive innovation and upskill the workforce in the latest digital construction techniques, positioning Victoria as a leader in modern, efficient, and sustainable infrastructure development.

7.3.4. BIM Level of Development (LOD)

Having a defined LOD as part of the 5D-BIM framework ensures that everyone involved in the project has a shared understanding of the model's precision and content at different stages of the project.

In the Crossrail project, the adoption of specific LOD standards, aligned with the UK's BIM Level 2 requirements, facilitated effective communication and coordination among the diverse teams involved. This approach ensured that the models developed were suitably detailed for various project phases, enhancing overall efficiency and reducing the likelihood of misunderstandings or information gaps.

In practice, the LOD framework does not align strictly with design phases but rather describes completion and deliverables in LOD terms, accommodating the varying progression rates of different building systems.

7.3.5. D-BIM Tools and Software

Both the academic literature and industry experience emphasize the importance of selecting appropriate BIM software for successful project delivery, particularly in complex mega rail projects like Crossrail and Nagpur Metro. The notion of a "one size fits all" software solution is impractical; instead, a combination of specialized software, where each software contributes its unique capabilities, is often required to address various project needs effectively, enhancing the overall project management process.

For mega rail projects in Victoria, adopting a similar strategy of using a mix of BIM software, tailored to the project's specific requirements, can enhance efficiency, collaboration, and project success.

7.3.6. Cost-Estimation Classification

Cost-estimation classification provides a structured approach to estimating costs at various stages of the project, enabling accurate budgeting and cost management and control. Despite implementing 5D-BIM, both the Crossrail and Nagpur Metro projects encountered cost overruns. Better cost-estimation techniques, such as benchmarking and cost-estimation classification, could have provided a more accurate and dynamic financial overview, allowing for the early detection of potential budget deviations and enabling timely corrective actions.

Incorporating cost-estimation classifications in 5D-BIM can significantly benefit mega rail projects in Victoria. It will allow the project team to have a more granular and accurate understanding of the project costs at each stage, leading to better budget management and a reduced risk of cost overruns.

8. Conclusions

This research has developed a conceptual 5D-BIM framework in response to governance challenges in mega rail projects applied in the context of the state of Victoria, Australia. The findings significantly support the development of better adapted 5D-BIM solutions for both academia and industry. It has synchronized project governance and appropriate 5D-BIM solutions to minimize cost overruns in mega rail projects.

The framework is unique in focusing on mega rail projects, drawn from a comprehensive review and analysis of the literature and policies and standards in various geographical areas, each with its unique policy and governance ecosystem. Therefore, it aligns with state-of-the-art research development and the 5D-BIM consideration of best practices.

As discussed in this study, governments must adapt to the increasing complexities and challenges of mega rail projects. Such adaptation necessitates redefining the current governance frameworks and systems. It is recommended that the Victorian government adopt a strategic approach to 5D-BIM implementation. This approach should focus on establishing robust governance frameworks, investing in essential digital infrastructure, and fostering a culture of transparency, collaboration, and innovation within the rail sector. The 5D-BIM framework has the potential to provide significant value in mitigating cost overruns in the Victorian government state-wide mega rail projects.

The 5D-BIM conceptual framework is introduced as a foundational template to be empirically tested in future research. Potential directions for further research involve assessing the framework's practicality in real-life mega rail projects to evaluate, validate, and rigorously scrutinize the elements and dynamics of the framework, with the aim of establishing its universal applicability in different governance ecosystems.

Author Contributions: Conceptualization and methodology, all authors; software and visualization, O.A.I.H.; project administration, writing—original draft preparation, funding acquisition, investigation, validation, resources, data curation, and formal analysis, O.A.I.H. and R.C.M.; writing—review and editing, all authors; supervision, R.C.M., S.D.C.W. and D.D.A.-D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by a Monash University Graduate Scholarship No. 31854893.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The below abbreviations are used in this paper:

BIM	Building Information Modeling
5D-BIM	Five-Dimensional Building Information Modeling
VDAS	Victorian Digital Asset Strategy
CDE	Common Data Environment
BIM LOD	BIM Level of Development
SLR	Systematic Literature Review
QA	Quality Assurance
ISO	International Organization for Standardization
IDD	Integrated Digital Delivery
CAD	Computer-Aided Design
EVM	Earned-Value Management
DfT	Department for Transport
ORR	Office of Rail and Road
GRIP	Guide to Railway Investment Projects
PACE	Project Acceleration in a Controlled Environment
P3M	Programme and Portfolio management
HS2	High-Speed Two
IFC	Industry Foundation Class format
Maha-metro	Maharashtra Metro Rail Corporation Limited
OSO	Owner Support Office
ERP	Enterprise Resource Planning system
DoT	Department of Transport
PTV	Public Transport Victoria
RPV	Rail Projects Victoria
TIC	Transport Infrastructure Council
HVHR	High Value High Risk

Appendix A

Table A1. BIM dimensions.

BIM Dimension	Descriptions	Characteristics	Popular Software/Solutions
3D	3D-BIM is the foundational level; it represents the geometry dimensions.	3D building data and information, field layout and civil data, reinforcement and structure analysis, existing model data.	AutoCAD, Revit, Bentley MicroStation, ArchiCAD, Allplan, and Tekla.
4D	4D-BIM adds the element of time to the 3D model.	Project schedule and phasing, just-in-time schedule, installation schedule, payment visual approval, last planner schedule, critical point.	Synchro PRO, Navisworks, Trimble Vico Office, Fuzor, Asta Power Project, and C3D interactive.
5D	5D-BIM extends the capabilities of the model by incorporating cost estimation and quantity take-off data.	Conceptual cost planning, quantity extraction to cost estimation, trade verification, value engineering, prefabrication.	RIB CostX, Bexel Manager, PriMus, Cubicost, and Contruent (Ares prism).
6D	6D-BIM focuses on sustainability and environmental aspects.	Energy analysis, green-building element, green-building certification tracking, green-building point tracking.	Autodesk BIM 360 Ops, FM: Systems, and EcoDomus.
7D	7D-BIM integrates the facility management and operation and maintenance data into the model.	Building life cycles, BIM as built data, BIM cost operation and maintenance, BIM digital lend-lease planning.	IBM TRIRIGA, ARCHIBUS, IBM Maximo, and FM: Systems.

Table A2. A comparison of various BIM policies and standards from different countries.

Country	BIM Policy	Approach	Challenges/Support	References
China	Outline of Development of Construction Industry Informatisation (2016–2020) Railway BIM Data Standard [173]	Strong government involvement.	Policy development lags behind practical application	[14,174]
USA	National BIM Standard—United States® (NBIMS-US™) [164]	Market-driven, less government enforcement.	Barriers to BIM adoption include size and scale of the project, high training and migration costs, general resistance and reluctance, and the computer-aided design (CAD) vs. BIM debate	[75,175]

Table A2. *Cont.*

Country	BIM Policy	Approach	Challenges/Support	References
UK	Government Construction Strategy (2016–2020) [176]	Government-mandated BIM in public projects.	Setting standards and protocols for collaborative work	[175,177]
Singapore	Singapore BIM Guide [79]	Government-led with strategic technology adoption.	Training, standards development, and incentives	[80,178]
Japan	Guidelines for BIM Standard Workflows (MLIT, 2020) [179]; Vision for the Future and Roadmap to BIM [180]	Combination of government initiative and private sector involvement.	Challenges include difficulty in immediate promotion according to international standards, lack of mandatory BIM use, and reliance on government-led projects	[80,81]
Germany	German BIM Implementation Strategy for Federal Buildings [181]	Emphasis on standardization and industry-driven initiatives.	National BIM standards and guidelines focused on interoperability	[182,183]
Australia	National BIM Guide [76]	Market-driven with some government influence.	Barriers in small and medium-sized Eenterprises (SMEs) include ROI concerns and resource limitations	[77,78]

Table A3. Comparison of mega rail projects employing BIM.

Project	Location	BIM Standards and Policy	BIM Maturity Level
California High-Speed Rail	USA	NBIMS-US	Advanced: Full collaboration with a shared model, real-time data sharing, and highly integrated processes.
Maryland Purple Line			
HS2	United Kingdom	BS 1192/ISO 19650	
Crossrail		BS 1192	
Riyadh Metro	Saudi Arabia	Emerging BIM adoption, no standardized framework or BIM policy	Moderate: Greater collaboration, shared data through common formats, and more advanced BIM software.
Qatar Rail	Qatar		
Etihad Rail	United Arab Emirates		
MTR Northern Link	Hong Kong	HKIBIM [184]; advanced BIM adoption	
Rail Baltica	Baltic States (EU)	Varies by country; moving toward ISO 19650	
Stuttgart–Ulm	Germany	ISO 19650; moderate BIM adoption	
City Rail Link	New Zealand	NZ BIM Handbook [185]; moderate BIM adoption	
Melbourne Airport Rail	Australia	NATSPEC BIM Guide; moderate to advanced BIM adoption	
Suburban Rail Loop			
Sydney Metro			
Nagpur Metro Rail Project	India	BS 1192:2007+A2:2016; emerging BIM adoption	
Metro Istanbul	Turkey	Emerging BIM adoption; no standardized framework	Developing: Isolated or early-stage BIM usage, limited collaboration, basic BIM tools.

Table A4. Popular 5D-BIM software packages.

Software/Solution	Competitive Advantage	Key Features	Training Availability	Additional Notes	Cost (Approx.)	References
RIB- Cost-X	Cost-X excels at enabling users to conduct thorough quantity take-offs and cost estimations directly from the BIM model. This functionality automates the generation of quantities and cost data based on the elements within the BIM model, while also facilitating comprehensive cost analysis and reporting.	Construction estimating, take-off, BIM file support	Online, self-paced, day sessions, private training	Integrates with Microsoft Excel	Flexible pricing based on project type/size/no. of users.	[68,186,187]
Bexel Manager	Bexel Manager stands out for having advanced visualization tools that integrate with the 3D model to represent cost data in intuitive charts, graphs, and dashboards, helping stakeholders to understand complex cost information more easily.	3D, 4D, 5D, 6D BIM uses, digital construction management	Online, trainer-led, self-paced	Advanced open BIM technologies	Varies, 985 AUD/user/year for Bexel Manager Teamworks; 250+ users.	[188–190]

Table A4. *Cont.*

Software/Solution	Competitive Advantage	Key Features	Training Availability	Additional Notes	Cost (Approx.)	References
ARES PRISM (rebranded as Contruent)	ARES PRISM is highly regarded for supporting Earned-Value Management (EVM), allowing for better project control, and also for its high scalability and customizability.	Integrated cost and scheduling, project management	Instructor-led and online, fundamental to advanced	Executive dashboards	Flexible pricing based on project type/size/no. of users.	[191]
Cubicost	Cubicost is known for its strong integration capabilities with various BIM platforms, allowing users to leverage 3D models for accurate quantity take-off and cost estimation.	BIM for quantity surveying, 5D-BIM cost management	Workshops, online courses, interactive sessions	Supports different modeling and estimation modules; TAS, TRB, TBQ, TME modules	Not specified	[192,193]
PriMus	PriMus is often praised for its user-friendly interface, making it accessible and intuitive for both seasoned professionals and those new to cost-estimation software. It seamlessly integrates with various price books and databases, enabling users to access up-to-date pricing information for materials and resources.	Drag-and-drop interface, integrates with CAD	Online resources and support	Manages quantity surveying, cost estimating, BOQ	Starts at 31.57 AUD/month	[191,194]

References

1. Hussain, O.A.I.; Moehler, R.C.; Walsh, S.D.C.; Ahiaga-Dagbui, D.D. Minimizing Cost Overrun in Rail Projects through 5D-BIM: A Systematic Literature Review. *Infrastructures* **2023**, *8*, 93. [CrossRef]
2. Capka, J.R. Megaprojects: Managing a Public Journey. *Public Roads* **2004**, *68*, 1.
3. Ahmad, S.; Algeo, C.; Foster, S.; Sohal, A.; Prajogo, D.; Moehler, R. Review of the key challenges in major infrastructure construction projects: How do project managers 'skill-up'? In Proceedings of the Annual Conference of the European Academy of Management 2019, Lisbon, Portugal, 26–28 June 2019; European Academy of Management (EURAM): Brussels, Belgium, 2019; pp. 1–39.
4. Erkul, M.; Yitmen, I.; Celik, T. Dynamics of stakeholder engagement in mega transport infrastructure projects. *Int. J. Manag. Proj. Bus.* **2020**, *13*, 1465–1495. [CrossRef]
5. Flyvbjerg, B.; Ansar, A.; Budzier, A.; Buhl, S.; Cantarelli, C.; Garbuio, M.; Glenting, C.; Holm, M.S.; Lovallo, D.; Lunn, D.; et al. Five things you should know about cost overrun. *Transp. Res. Part A Policy Pract.* **2018**, *118*, 174–190. [CrossRef]
6. Love, P.E.; Smith, J.; Simpson, I.; Regan, M.; Olatunji, O. Understanding the landscape of overruns in transport infrastructure projects. *Environ. Plan. B Plan. Des.* **2015**, *42*, 490–509. [CrossRef]
7. Cavalieri, M.; Cristaudo, R.; Guccio, C. Tales on the dark side of the transport infrastructure provision: A systematic literature review of the determinants of cost overruns. *Transp. Rev.* **2019**, *39*, 774–794. [CrossRef]
8. Ahiaga-Dagbui, D.D.; Love, P.E.D.; Smith, S.D.; Ackermann, F. Toward a Systemic View to Cost Overrun Causation in Infrastructure Projects: A Review and Implications for Research. *Proj. Manag. J.* **2017**, *48*, 88–98. [CrossRef]
9. Balali, A.; Moehler, R.C.; Valipour, A. Ranking cost overrun factors in the mega hospital construction projects using Delphi-SWARA method: An Iranian case study. *Int. J. Constr. Manag.* **2020**, *22*, 2577–2585. [CrossRef]
10. Love, P.E.D.; Sing, C.-P.; Carey, B.; Kim, J.T. Estimating Construction Contingency: Accommodating the Potential for Cost Overruns in Road Construction Projects. *J. Infrastruct. Syst.* **2015**, *21*, 04014035. [CrossRef]
11. Love, P.E.; Ahiaga-Dagbui, D.D. Debunking fake news in a post-truth era: The plausible untruths of cost underestimation in transport infrastructure projects. *Transp. Res. Part A Policy Pract.* **2018**, *113*, 357–368. [CrossRef]
12. Musawir, A.U.; Abd-Karim, S.B.; Mohd-Danuri, M.S. Project governance and its role in enabling organizational strategy implementation: A systematic literature review. *Int. J. Proj. Manag.* **2020**, *38*, 1–16. [CrossRef]
13. Lee, G.; Borrmann, A. BIM policy and management. *Constr. Manag. Econ.* **2020**, *38*, 413–419. [CrossRef]
14. Xie, M.; Qiu, Y.; Liang, Y.; Zhou, Y.; Liu, Z.; Zhang, G. Policies, applications, barriers and future trends of building information modeling technology for building sustainability and informatization in China. *Energy Rep.* **2022**, *8*, 7107–7126. [CrossRef]
15. As-Saber, S.N.; Härtel, C.E.J.; As-Saber, S.; Campus, C. Geopolitics and governance: In search of a framework. In Proceedings of the Asia-Pacific Schools and Institutes of Public Administration (NAPSIPAG) Conference, Sydney, NSW, Australia, 4–5 December 2006.
16. Klakegg, O.J.; Williams, T.; Magnussen, O.M.; Glasspool, H. Governance Frameworks for Public Project Development and Estimation. *Proj. Manag. J.* **2008**, *39*, S27–S42. [CrossRef]
17. Shiferaw, A.T.; Klakegg, O.J. Linking policies to projects: The key to identifying the right public investment projects. *Proj. Manag. J.* **2012**, *43*, 14–26. [CrossRef]

18. Gillan, S.L. Recent developments in corporate governance: An overview. *J. Corp. Financ.* **2006**, *12*, 381–402. [CrossRef]
19. Mangalaraj, G.; Singh, A.; Taneja, A. IT Governance Frameworks and COBIT-A Literature Review. In Proceedings of the 20th Americas Conference on Information Systems, AMCIS 2014, Savannah, GE, USA, 7–9 August 2014.
20. UK Government. UK BIM Framework. 2023. Available online: https://www.ukbimframework.org/ (accessed on 29 November 2023).
21. Burton, R.M.; Obel, B. The science of organizational design: Fit between structure and coordination. *J. Organ. Des.* **2018**, *7*, 1–13. [CrossRef]
22. Derakhshan, R.; Turner, R.; Mancini, M. Project governance and stakeholders: A literature review. *Int. J. Proj. Manag.* **2019**, *37*, 98–116. [CrossRef]
23. Papadakis, E.; Tsironis, L. Towards a hybrid project management framework: A systematic literature review on traditional, agile and hybrid techniques. *J. Mod. Proj. Manag.* **2020**, *8*, 124–139.
24. Georgiadou, M.C. An overview of benefits and challenges of building information modelling (BIM) adoption in UK residential projects. *Constr. Innov.* **2019**, *19*, 298–320. [CrossRef]
25. Grundler, A.; Westner, M. Scaling Agile Frameworks vs. Traditional Project Portfolio Management: Comparison and Analysis. In Proceedings of the International Conferences on Internet Technologies & Society (ITS 2019), Hong Kong, China, 8–10 February 2019; pp. 51–62.
26. Oti-Sarpong, K.; Leiringer, R.; Zhang, S. A critical examination of BIM policy mandates: Implications and responses. In *Construction Research Congress 2020: Computer Applications*; American Society of Civil Engineers: Reston, VA, USA, 2020; pp. 763–772.
27. UK Government. The Construction Playbook. In Constuction. Playbook. 2023. Available online: https://www.gov.uk/government/publications/the-construction-playbook (accessed on 29 November 2023).
28. Godager, B.; Mohn, K.; Merschbrock, C.; Klakegg, O.J.; Huang, L. Towards an improved framework for enterprise BIM: The role of ISO 19650. *J. Inf. Technol. Constr.* **2022**, *27*, 1075–1103. [CrossRef]
29. *ISO 19650-1:2018*; Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM)—Information Management Using Building Information Modelling—Part 1: Concepts and principles. ISO: Geneva, Switzerland, 2018.
30. Sanderson, J. Risk, uncertainty and governance in megaprojects: A critical discussion of alternative explanations. *Int. J. Proj. Manag.* **2012**, *30*, 432–443. [CrossRef]
31. Ahola, T.; Ruuska, I.; Artto, K.; Kujala, J. What is project governance and what are its origins? *Int. J. Proj. Manag.* **2014**, *32*, 1321–1332. [CrossRef]
32. Williamson, O.E. Transaction-cost economics: The governance of contractual relations. *J. Law Econ.* **1979**, *22*, 233–261. [CrossRef]
33. Turner, R.; Müller, R. The governance of organizational project management. In *Cambridge Handbook of Organizational Project Management*; Cambridge University Press: Cambridge, UK, 2017; pp. 75–91.
34. Samset, K.; Volden, G.H. Major projects up front: Analysis and decision-rationality and chance. In Proceedings of the 11th IRNOP Conference, Oslo, Norway, 17–18 June 2013.
35. Söderlund, J. Pluralism in Project Management: Navigating the Crossroads of Specialization and Fragmentation. *Int. J. Manag. Rev.* **2011**, *13*, 153–176. [CrossRef]
36. Too, E.G.; Weaver, P. The management of project management: A conceptual framework for project governance. *Int. J. Proj. Manag.* **2014**, *32*, 1382–1394. [CrossRef]
37. Code, C. *The Financial Aspects of Corporate Governance*; The Committee on the Financial Aspects of Corporate Governance and Gee and Co., Ltd.: London, UK, 1992; Available online: https://www.ecgi.global/sites/default/files/codes/documents/cadbury.pdf (accessed on 17 January 2024).
38. Gareis, R. Changes of organizations by projects. *Int. J. Proj. Manag.* **2010**, *28*, 314–327. [CrossRef]
39. Muller, R. *Project Governance*; Routledge: London, UK, 2017. [CrossRef]
40. Jonny Klakegg, O. Pursuing relevance and sustainability: Improvement strategies for major public projects. *Int. J. Manag. Proj. Bus.* **2009**, *2*, 499–518. [CrossRef]
41. Knodel, T. Preparing the organizational 'soil' for measurable and sustainable change: Business value management and project governance. *J. Chang. Manag.* **2004**, *4*, 45–62. [CrossRef]
42. Ross, J.W.; Weill, P. Six IT decisions your IT people shouldn't make. *Harv. Bus. Rev.* **2002**, *80*, 84–95. [PubMed]
43. Turner, J.R.; Keegan, A. Mechanisms of governance in the project-based organization: Roles of the broker and steward. *Eur. Manag. J.* **2001**, *19*, 254–267. [CrossRef]
44. Blomquist, T.; Müller, R. Practices, Roles, and Responsibilities of Middle Managers in Program and Portfolio Management. *Proj. Manag. J.* **2006**, *37*, 52–66. [CrossRef]
45. Bruzelius, N.; Flyvbjerg, B.; Rothengatter, W. Big decisions, big risks. Improving accountability in mega projects. *Transp. Policy* **2002**, *9*, 143–154. [CrossRef]
46. Flyvbjerg, B. What you should know about megaprojects and why: An overview. *Proj. Manag. J.* **2014**, *45*, 6–19. [CrossRef]
47. Nielsen, K.R. Governance of the Megaproject. In *Advice from Those Who've Been There, Done That*; American Society of Civil Engineers: Reston, VA, USA, 2013; p. 5.

48. Flyvbjerg, B.; Holm, M.S.; Buhl, S. Underestimating costs in public works projects: Error or lie? *J. Am. Plan. Assoc.* **2002**, *68*, 279–295. [CrossRef]
49. Locatelli, G.; Mariani, G.; Sainati, T.; Greco, M. Corruption in public projects and megaprojects: There is an elephant in the room! *Int. J. Proj. Manag.* **2017**, *35*, 252–268. [CrossRef]
50. Van Marrewijk, A.; Clegg, S.R.; Pitsis, T.S.; Veenswijk, M. Managing public–private megaprojects: Paradoxes, complexity, and project design. *Int. J. Proj. Manag.* **2008**, *26*, 591–600. [CrossRef]
51. He, Q.; Tian, Z.; Wang, T. Performance measurement methods in megaprojects: An analytical review. *Int. J. Proj. Manag.* **2022**, *40*, 634–645. [CrossRef]
52. Mok, K.Y.; Shen, G.Q.; Yang, J. Stakeholder management studies in mega construction projects: A review and future directions. *Int. J. Proj. Manag.* **2015**, *33*, 446–457. [CrossRef]
53. Kumar, K.; Simpson, G. Phronesis as a Paradigm for ICT-enabled Transparency: The Case of the Nicaragua Canal Megaproject. In Proceedings of the Twenty-First Americas Conference on Information Systems, Fajardo, Puerto Rico, 13–15 August 2015.
54. Wierzbicki, M.; De Silva, C.W.; Krug, D.H. BIM–history and trends. In Proceedings of the 11th International Conference on Construction Applications of Virtual Reality, Bauhaus-Universität, Weimar, Germany, 3–4 November 2011; pp. 3–4.
55. Bensalah, M.; Elouadi, A.; Mharzi, H. Integrating Bim in Railway Projects: Review & Perspectives for Morocco & Mena. *Int. J. Recent Sci. Res.* **2018**, *9*, 23398–23403. [CrossRef]
56. Smith, P. BIM implementation–global strategies. *Procedia Eng.* **2014**, *85*, 482–492. [CrossRef]
57. Suchocki, M. The Bim-For-Rail Opportunity. In *Building Information Modelling*; Garrigos, A.G., Mahdjoubi, L., Brebbia, C.A., Eds.; WIT Press: Billerica, MA, USA, 2017; pp. 37–44.
58. Li, Y.-W.; Cao, K. Establishment and application of intelligent city building information model based on BP neural network model. *Comput. Commun.* **2020**, *153*, 382–389. [CrossRef]
59. Tang, L.; Chen, C.; Tang, S.; Wu, Z.; Trofimova, P. Building Information Modeling and Building Performance Optimization. *Encycl. Sustain. Technol.* **2017**, *2017*, 311–320. [CrossRef]
60. Sacks, R.; Eastman, C.; Lee, G.; Teicholz, P. *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers*; John Wiley and Sons: Hoboken, NJ, USA, 2018.
61. Eadie, R.; Browne, M.; Odeyinka, H.; McKeown, C.; McNiff, S. BIM implementation throughout the UK construction project lifecycle: An analysis. *Autom. Constr.* **2013**, *36*, 145–151. [CrossRef]
62. Wildenauer, A.A. Critical assessment of the existing definitions of BIM dimensions on the example of Switzerland. *Terminology* **2020**, *23*, 24.
63. Smith, P. BIM and the 5D Project Cost Manager. *Procedia Soc. Behav. Sci.* **2014**, *119*, 475–484. [CrossRef]
64. Pyrgidis, C.N. *Railway Transportation Systems: Design, Construction and Operation*, 2nd ed.; CRC Press: Boca Raton, FL, USA, 2022.
65. Alqatawna, A.; Sánchez-Cambronero, S.; Gallego, I.; Rivas, A. BIM-centered high-speed railway line design for full infrastructure lifecycle. *Autom. Constr.* **2023**, *156*, 105114. [CrossRef]
66. Bensalah, M.; Elouadi, A.; Mharzi, H. *Railway Information Modeling RIM*; Wiley: Hoboken, NJ, USA, 2019.
67. Moses, T.; Heesom, D.; Oloke, D. Implementing 5D BIM on construction projects: Contractor perspectives from the UK construction sector. *J. Eng. Des. Technol.* **2020**, *18*, 1867–1888. [CrossRef]
68. Vigneault, M.A.; Boton, C.; Chong, H.Y.; Cooper-Cooke, B. An Innovative Framework of 5D BIM Solutions for Construction Cost Management: A Systematic Review. *Arch. Comput. Methods Eng.* **2020**, *27*, 1013–1030. [CrossRef]
69. Lu, Q.; Won, J.; Cheng, J.C.P. A financial decision making framework for construction projects based on 5D Building Information Modeling (BIM). *Int. J. Proj. Manag.* **2016**, *34*, 3–21. [CrossRef]
70. Ranjbar, A.A.; Ansari, R.; Taherkhani, R.; Hosseini, M.R. Developing a novel cash flow risk analysis framework for construction projects based on 5D BIM. *J. Build. Eng.* **2021**, *44*, 103341. [CrossRef]
71. Graham, E.R.; Shipan, C.R.; Volden, C. The Diffusion of Policy Diffusion Research in Political Science. *Br. J. Polit. Sci.* **2013**, *43*, 673–701. [CrossRef]
72. Peters, M.; Schneider, M.; Griesshaber, T.; Hoffmann, V.H. The impact of technology-push and demand-pull policies on technical change—Does the locus of policies matter? *Res. Policy* **2012**, *41*, 1296–1308. [CrossRef]
73. Filippopoulos, N.; Fotopoulos, G. Innovation in economically developed and lagging European regions: A configurational analysis. *Res. Policy* **2022**, *51*, 104424. [CrossRef]
74. GSA, B. *Guide for Spatial Program Validation—GSA BIM Guide Series 02*; US General Service Administration: Washington, DC, USA, 2007.
75. Edirisinghe, R.; London, K. Comparative analysis of international and national level BIM standardization efforts and BIM adoption. In Proceedings of the 32nd CIB W78 Conference, Eindhoven, The Netherlands, 27–29 October 2015; pp. 27–29.
76. National BIM Guide. In NATSPEC. 2022. Available online: https://bim.natspec.org/documents/natspec-national-bim-guide (accessed on 17 January 2024).
77. Hosseini, M.; Banihashemi, S.; Chileshe, N.; Namzadi, M.O.; Udaeja, C.; Rameezdeen, R.; McCuen, T. BIM adoption within Australian Small and Medium-sized Enterprises (SMEs): An innovation diffusion model. *Constr. Econ. Build.* **2016**, *16*, 71–86. [CrossRef]
78. Aibinu, A.; Venkatesh, S. Status of BIM adoption and the BIM experience of cost consultants in Australia. *J. Prof. Issues Eng. Educ. Pract.* **2014**, *140*, 4013021. [CrossRef]

79. Singapore BIM Guide. 2013. Available online: https://www.corenet.gov.sg/media/586132/Singapore-BIM-Guide_V2.pdf (accessed on 17 January 2024).
80. Kaneta, T.; Furusaka, S.; Tamura, A.; Deng, N. Overview of BIM implementation in Singapore and Japan. *J. Civ. Eng. Archit.* **2016**, *10*, 1305–1312.
81. Kaneta, T.; Furusaka, S.; Deng, N. Overview and problems of BIM implementation in Japan. *Front. Eng. Manag.* **2017**, *4*, 146–155. [CrossRef]
82. Champion, J. Rail Infrastructure Planning in Wales—A Quick Guide. 2016. Available online: https://research.senedd.wales/media/ho3pynai/english.pdf (accessed on 17 January 2024).
83. Moehler, R.C.; Chan, P.; Greenwood, D. The interorganisational influences on construction skills development in the UK. In Proceedings of the 24th Annual ARCOM Conference, Cardiff, UK, 1–3 September 2008; pp. 23–32.
84. Moran, M. *Politics and Governance in the UK*; Bloomsbury Publishing: London, UK, 2017.
85. Fazekas, M.; Dávid-Barrett, E. Corruption risks in UK public procurement and new anti-corruption tools. *Eur. J. Crim. Policy Res.* **2015**, *23*, 245–267.
86. UK-Project Routemap. 2023. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1080239/Handbook__-_FINAL.pdf (accessed on 17 January 2024).
87. PACE (Project Acceleration in a Controlled Environment). 2023. Available online: https://www.networkrail.co.uk/industry-and-commercial/supply-chain/existing-suppliers/rail-speed/ (accessed on 20 October 2023).
88. Infrastructure and Projects Authority Cost Estimating Guidance. Available online: https://assets.publishing.service.gov.uk/media/6050c9528fa8f55d324b0c84/IPA_Cost_Estimating_Guidance.pdf (accessed on 17 January 2024).
89. Smith, S. Building Information Modelling—Moving Crossrail, UK, forward. *Proc. Inst. Civ. Eng Manag Procure Law* **2014**, *167*, 141–151. [CrossRef]
90. Floros, G.S.; Ruff, P.; Ellul, C. Impact of Information Management During Design & Construction on Downstream Bim-Gis Interoperability for Rail Infrastructure. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*; ISPRS: London, UK, 2020; pp. 61–68.
91. Primavera P6. 2023. Available online: https://www.oracle.com/au/construction-engineering/primavera-p6/ (accessed on 8 September 2023).
92. Crossrail Project: Application of BIM (Building Information Modelling) and Lessons Learned. Available online: https://learninglegacy.crossrail.co.uk/documents/crossrail-project-application-of-bim-building-information-modelling-and-lessons-learned/ (accessed on 17 January 2024).
93. Chakraborty, V.; Dutta, S. Indian railway infrastructure systems: Global comparison, challenges and opportunities. *Proc. Inst. Civ. Eng.-Smart Infrastruct. Constr.* **2022**, *175*, 127–140. [CrossRef]
94. Raghuram, G.; Gangwar, R. *Indian Railways in the Past Twenty Years Issues, Performance and Challenges*; Indian Institute of Management Ahmedabad: Gujarat, India, 2008; Available online: https://www.iima.ac.in/sites/default/files/rnpfiles/2008-07-05Raghuram.pdf (accessed on 17 January 2024).
95. Yadava, S.K.S.; Chaudharyb, K.K.; Khatalc, S.K. Issues and Reforms in Indian Railways. *Int. J. Trade Commer.* **2012**, *1*, 106–125.
96. Pakhale, P.D.; Pal, A. Digital project management in infrastructure project: A case study of Nagpur Metro Rail Project. *Asian J. Civ. Eng.* **2020**, *21*, 639–647. [CrossRef]
97. SAP ERP. 2023. Available online: https://www.sap.com/australia/products/erp/what-is-sap-erp.html (accessed on 8 September 2023).
98. Bentley. 2023. Available online: https://www.bentley.com/ (accessed on 17 January 2024).
99. RIB. 2023. Available online: https://www.rib-software.com/en/home (accessed on 8 September 2023).
100. BS 1192:2007+A2:2016. Available online: https://knowledge.bsigroup.com/products/collaborative-production-of-architectural-engineering-and-construction-information-code-of-practice?version=standard (accessed on 8 November 2023).
101. Nag, B.; Singh, J.; Tiwari, V. Choosing the appropriate project management structure, project financing, land acquisition and contractual process for Indian railway mega-projects: A case study of the Dedicated Freight Corridor project. *J. Proj. Progr. Portf. Manag.* **2012**, *3*, 39–54. [CrossRef]
102. Gaur, S.; Tawalare, A. Investigating the role of BIM in stakeholder management: Evidence from a metro-rail project. *J. Manag. Eng.* **2022**, *38*, 05021013. [CrossRef]
103. Ariono, B.; Wasesa, M.; Dhewanto, W. The Drivers, Barriers, and Enablers of Building Information Modeling (BIM) Innovation in Developing Countries: Insights from Systematic Literature Review and Comparative Analysis. *Buildings* **2022**, *12*, 1912. [CrossRef]
104. Faisal Shehzad, H.M.; Binti Ibrahim, R.; Yusof, A.F.; Mohamed Khaidzir, K.A.; Shawkat, S.; Ahmad, S. Recent developments of BIM adoption based on categorization, identification and factors: A systematic literature review. *Int. J. Constr. Manag.* **2022**, *22*, 3001–3013. [CrossRef]
105. Mayouf, M.; Gerges, M.; Cox, S. 5D BIM: An investigation into the integration of quantity surveyors within the BIM process. *J. Eng. Des. Technol.* **2019**, *17*, 537–553. [CrossRef]
106. Btoush, M.; Haron, A.T. Understanding BIM adoption in the AEC industry: The case of Jordan. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *271*, 12044. [CrossRef]

107. Ghaffarianhoseini, A.; Tookey, J.; Ghaffarianhoseini, A.; Naismith, N.; Azhar, S.; Efimova, O.; Raahemifar, K. Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renew. Sustain. Energy Rev.* **2017**, *75*, 1046–1053. [CrossRef]
108. Dodgson, M.; Gann, D.; MacAulay, S.; Davies, A. Innovation strategy in new transportation systems: The case of Crossrail. *Transp. Res. Part A Policy Pract.* **2015**, *77*, 261–275. [CrossRef]
109. May, I.; Taylor, M.; Irwin, D. Crossrail: A Case Study in BIM. 2017. Available online: https://ethz.ch/content/dam/ethz/special-interest/baug/igt/tunneling-dam/kolloquien/2016/May_Crossrail_BIM_Implementierung_ohne_Risiko.pdf (accessed on 17 January 2024).
110. Lindblad, H.; Guerrero, J.R. Client's role in promoting BIM implementation and innovation in construction. *Constr. Manag. Econ.* **2020**, *38*, 468–482. [CrossRef]
111. Liu, L.; Fan, Q.; Liu, R.; Zhang, G.; Wan, W.; Long, J. How to benefit from digital platform capabilities? Examining the role of knowledge bases and organisational routines updating. *Eur. J. Innov. Manag.* **2022**, *26*, 1394–1420. [CrossRef]
112. Ansar, A.; Flyvbjerg, B. How to solve big problems: Bespoke versus platform strategies. *Oxford Rev. Econ. Policy* **2022**, *38*, 338–368. [CrossRef]
113. Abualdenien, J.; Borrmann, A. Levels of detail, development, definition, and information need: A critical literature review. *J. Inf. Technol. Constr.* **2022**, *27*, 363–392. [CrossRef]
114. Seo, M.B.; Lee, D. Development of Railway Infrastructure BIM Prototype Libraries. *Appl. Sci.* **2020**, *10*, 8118. [CrossRef]
115. Sun, C.; Jiang, S.; Skibniewski, M.J.; Man, Q.; Shen, L. A literature review of the factors limiting the application of BIM in the construction industry. *Technol. Econ. Dev. Econ.* **2017**, *23*, 764–779. [CrossRef]
116. Collao, J.; Lozano-Galant, F.; Lozano-Galant, J.A.; Turmo, J. BIM Visual Programming Tools Applications in Infrastructure Projects: A State-of-the-Art Review. *Appl. Sci.* **2021**, *11*, 8343. [CrossRef]
117. Batselier, J.; Vanhoucke, M. Practical application and empirical evaluation of reference class forecasting for project management. *Proj. Manag. J.* **2016**, *47*, 36–51. [CrossRef]
118. Themsen, T.N. The processes of public megaproject cost estimation: The inaccuracy of reference class forecasting. *Financ. Acc. Manag.* **2019**, *35*, 337–352. [CrossRef]
119. Garland, R. *Project Governance: A Practical Guide to Effective Project Decision Making*, 1st ed.; Kogan Page Publishers: London, UK, 2009.
120. Ul Musawir, A.; Serra, C.E.M.; Zwikael, O.; Ali, I. Project governance, benefit management, and project success: Towards a framework for supporting organizational strategy implementation. *Int. J. Proj. Manag.* **2017**, *35*, 1658–1672. [CrossRef]
121. Al Ahbabi, M.; Alshawi, M. BIM for client organisations: A continuous improvement approach. *Constr. Innov.* **2015**, *15*, 402–408. [CrossRef]
122. Singh, J.; Singh, H. Continuous improvement philosophy—Literature review and directions. *Benchmarking Int. J.* **2015**, *22*, 75–119. [CrossRef]
123. Oh, S.; Syn, S.Y. Motivations for sharing information and social support in social media: A comparative analysis of F acebook, T witter, D elicious, Y ou T ube, and F lickr. *J. Assoc. Inf. Sci. Technol.* **2015**, *66*, 2045–2060. [CrossRef]
124. Tiwana, A.; Konsynski, B. Complementarities between organizational IT architecture and governance structure. *Inf. Syst. Res.* **2010**, *21*, 288–304. [CrossRef]
125. Geliskhanov, I. Digital platform: A new economic institution. *Qual. Success J.* **2018**, *19*, 20–26.
126. Alshorafa, R.; Ergen, E. Determining the level of development for BIM implementation in large-scale projects. *Eng. Constr. Archit. Manag.* **2021**, *28*, 397–423. [CrossRef]
127. Grytting, I.; Svalestuen, F.; Lohne, J.; Sommerseth, H.; Augdal, S.; Lædre, O. Use of LoD Decision Plan in BIM-projects. *Procedia Eng.* **2017**, *196*, 407–414. [CrossRef]
128. Flyvbjerg, B. Curbing optimism bias and strategic misrepresentation in planning: Reference class forecasting in practice. *Eur. Plan Stud.* **2008**, *16*, 3–21. [CrossRef]
129. Flyvbjerg, B.; Hon, C.; Fok, W.H. Reference class forecasting for Hong Kong's major roadworks projects. *Civ. Eng.* **2016**, *169*, 17–24. [CrossRef]
130. Servranckx, T.; Vanhoucke, M.; Aouam, T. Practical application of reference class forecasting for cost and time estimations: Identifying the properties of similarity. *Eur. J. Oper. Res.* **2021**, *295*, 1161–1179. [CrossRef]
131. Bekker, M.C.; Steyn, H. Defining 'project governance' for large capital projects. In Proceedings of the AFRICON 2007, Windhoek, South Africa, 26–28 September 2007; pp. 1–13.
132. Shtub, A.; Globerson, S. *Project Management: Processes, Methodologies, and Economics*; Tsinghua University Press Co., Ltd.: Beijing, China, 2006.
133. Kaye, M.; Anderson, R. Continuous improvement: The ten essential criteria. *Int. J. Qual. Reliab. Manag.* **1999**, *16*, 485–509. [CrossRef]
134. Howlett, M.; Cashore, B. Conceptualizing public policy. In *Comparative Policy Studies: Conceptual and Methodological Challenges*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 17–33.
135. Lipsmeier, A.; Kühn, A.; Joppen, R.; Dumitrescu, R. Process for the development of a digital strategy. *Procedia CIRP* **2020**, *88*, 173–178. [CrossRef]

136. bimforum.org. Level of Development Specification. 2023. Available online: https://bimforum.org/resource/lod-level-of-development-lod-specification/ (accessed on 6 February 2023).
137. Latiffi, A.A.; Brahim, J.; Mohd, S.; Fathi, M.S. Building information modeling (BIM): Exploring level of development (LOD) in construction projects. *Appl. Mech. Mater.* **2015**, *773*, 933–937. [CrossRef]
138. ISO. ISO/Information Technology—Vocabulary. 2023. Available online: https://www.iso.org/obp/ui/#iso:std:iso-iec:2382,ed-1:v2:en (accessed on 17 January 2024).
139. Amoaha, E.K.; Nguyenb, T.V. Optimizing the usage of Building Information Model (BIM) interoperability focusing on data not tools. In Proceedings of the International Symposium on Automation and Robotics in Construction, ISARC, Banff, AB, Canada, 21–24 May 2019; IAARC Publications: Oulu, Finland, 2019; pp. 1081–1090.
140. Bhuiyan, N.; Baghel, A. An overview of continuous improvement: From the past to the present. *Manag. Decis.* **2005**, *43*, 761–771. [CrossRef]
141. Koseoglu, O.; Keskin, B.; Ozorhon, B. Challenges and Enablers in BIM-Enabled Digital Transformation in Mega Projects: The Istanbul New Airport Project Case Study. *Buildings* **2019**, *9*, 115. [CrossRef]
142. Wijayasekera, S.C.; Hussain, S.A.; Paudel, A.; Paudel, B.; Steen, J.; Sadiq, R.; Hewage, K. Data Analytics and Artificial Intelligence in the Complex Environment of Megaprojects: Implications for Practitioners and Project Organizing Theory. *Proj. Manag. J.* **2022**, *53*, 485–500. [CrossRef]
143. Nielsen, R.K.; Ganter, S.A. *The Power of Platforms: Shaping Media and Society*; Oxford University Press: Oxford, UK, 2022.
144. Autodesk. Autodesk. 2023. Available online: https://www.autodesk.com/company/autodesk-platform#:~:text=How-will-Autodesk%E2%80%99s-cloud-based-to-realize-its-full-value (accessed on 27 September 2023).
145. Oracle. Oracle Primavera. 2023. Available online: https://www.oracle.com/au/construction-engineering/primavera-cloud-project-management/service-for-owners-datasheet/ (accessed on 27 September 2023).
146. Bluebeam. 2023. Available online: https://www.bluebeam.com/au/ (accessed on 27 September 2023).
147. ARES PRISM. 2023. Available online: https://www.contruent.com/resources/blog/ares-prism-rebrands-to-contruent-with-launch-of-innovative-capital-project-management-software-solution/ (accessed on 27 September 2023).
148. Bentley, S. OenRail. 2023. Available online: https://www.bentley.com/software/openrail-conceptstation/ (accessed on 27 September 2023).
149. The American Institute of Architects (AIA). G202-2013 Project BIM Protocol. 2013. Available online: https://www.aiacontracts.org/contract-documents/19016-project-bim-protocol (accessed on 18 September 2021).
150. Gigante-Barrera, A.; Dindar, S.; Kaewunruen, S.; Ruikar, D. LOD BIM Element specification for Railway Turnout Systems Risk Mitigation using the Information Delivery Manual. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *245*, 042022. [CrossRef]
151. Bucher, D.; Hall, D. Common Data Environment within the AEC Ecosystem: Moving collaborative platforms beyond the open versus closed dichotomy. In *EG-ICE 2020 Proceedings: Workshop on Intelligent Computing in Engineering*; Universitätsverlag der TU Berlin: Berlin, Germany, 2020; pp. 491–500.
152. Özkan, S.; Seyis, S. Identification of common data environment functions during construction phase of BIM-based projects. In Proceedings of the Conference CIB W78-LDAC 2021, Luxembourg, 11–15 October 2021.
153. Radl, J.; Kaiser, J. Benefits of implementation of common data environment (CDE) into construction projects. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *471*, 22021. [CrossRef]
154. Ye, X.; Zeng, N.; Liu, Y.; König, M. Smart Contract-Enabled Construction Claim Management in BIM and CDE-Enhanced Data Environment. In Proceedings of the International Conference on Construction Logistics, Equipment, and Robotics, Munich, Germany, 9–11 October 2023; Springer: Berlin/Heidelberg, Germany, 2023; pp. 40–47.
155. Preidel, C.; Borrmann, A.; Mattern, H.; König, M.; Schapke, S.E. Common data environment. In *Building Information Modeling*; Springer: Cham, Switzerland, 2018; pp. 279–291.
156. Ahmed, İ.A.; Pehlevan, E.E. Investigation of Effectiveness of Common Data Environments (CDEs) Utilized in Metro Projects. In Proceedings of the International Symposium of the International Federation for Structural Concrete, Istanbul, Turkey, 5–7 June 2023; Springer: Cham, Switzerland, 2023; pp. 1601–1610.
157. Jaskula, K.; Papadonikolaki, E.; Rovas, D. Comparison of current common data environment tools in the construction industry. In Proceedings of the European Conference on Computing in Construction (EC3), Computing in Construction, Crete, Greece, 10–12 July 2023.
158. Mudholkar, V.V. Six-Sigma: Delivering Quality to Mega Transportation Projects. In *Transportation and Development Innovative Best Practices*; ASCE: Reston, VA, USA, 2008; pp. 284–289. [CrossRef]
159. California, H. Speed Rail Authority. 2023. Available online: https://hsr.ca.gov/about/high-speed-rail-business-plans/2020-business-plan/chapter-6/ (accessed on 20 October 2023).
160. EU-Rail Governance and Process Handbook. 2022. Available online: https://rail-research.europa.eu/wp-content/uploads/2022/10/EU-Rail-Governance-and-Process-Handbook.pdf (accessed on 20 October 2023).
161. Department of Treasury and Finance Victoria. Gateway Review Process. 2023. Available online: https://www.dtf.vic.gov.au/infrastructure-investment/gateway-review-process (accessed on 20 October 2023).
162. American Association of Cost Engineers. Cost Estimate Classification Systems. 2023. Available online: https://library.aacei.org/pgd01/pgd01.shtml#TableofContents (accessed on 20 October 2023).

163. International Cost Management Standard Coalition. International Cost Management Standards; ICMS: 2023. Available online: https://icms-coalition.org/ (accessed on 20 October 2023).
164. NBIMS-US. The National BIM Standard-United States. 2023. Available online: https://www.nationalbimstandard.org/ (accessed on 20 October 2023).
165. Office of Projects Victoria. VDAS. 2019. Available online: http://www.opv.vic.gov.au/Victorian-Chief-Engineer/Victorian-Digital-Asset-Strategy/VDAS-Resources/Frequently-asked-questions/FAQs-Digital-engineering (accessed on 2 November 2020).
166. Love, P.E.; Zhou, J.; Edwards, D.J.; Irani, Z.; Sing, C.-P. Off the rails: The cost performance of infrastructure rail projects. *Transp. Res. Part A Policy Pract.* **2017**, *99*, 14–29. [CrossRef]
167. Department of Infrastructure, Transport RD and C. Infrastructure Investment Response to COVID-19. 2020. Available online: https://investment.infrastructure.gov.au/infrastructure_investment/infrastructure_investment_response_covid-19/ (accessed on 2 November 2020).
168. Department of Treasury and Finance-Victoria. High Value High Risk (HVHR) Framework. 2023. Available online: https://www.audit.vic.gov.au/report/high-value-high-risk-2016-17-delivering-hvhr-projects?section= (accessed on 27 August 2023).
169. VAGO. *High Value High Risk 2016–17: Delivering HVHR Projects*; Victorian Auditor-General's Office: Melbourne, VIC, Australia, 2016. Available online: https://www.audit.vic.gov.au/sites/default/files/20161026-HVHR.pdf (accessed on 17 January 2024).
170. Office of Projects Victoria. *Victorian Digital Asset Strategy*; Office of Projects Victoria: Melbourne, VIC, Australia, 2019. Available online: https://www.vic.gov.au/victorian-digital-asset-strategy (accessed on 20 October 2023).
171. Chen, Y.; Jupp, J. Exploring the Nexus between Digital Engineering and Systems Engineering and the Role of Information Management Standards. In Proceedings of the Australasian Universities Building Education Association Conference, Sydney, NSW, Australia, 23–25 November 2022.
172. Australian Government, Department of Infrastructure, Transport, Regional Development C and the A. *Guidance Note 3A—Probabilistic Contingency Estimation*; Australian Government, Department of Infrastructure, Transport, Regional Development C and the A: Canberra, ACT, Australia, 2023. Available online: https://investment.infrastructure.gov.au/sites/default/files/documents/guidance-note-3A-probabilistic-cost-estimation-v2.pdf (accessed on 20 October 2023).
173. Railway BIM Data Standard. Available online: https://www.buildingsmart.org/wp-content/uploads/2017/09/bSI-SPEC-Rail.pdf (accessed on 17 January 2024).
174. Rui, W.; Liu, B.; Wang, M.; Zhang, Y.; Liu, A. Review and prospect of BIM policy in China. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2017; Volume 245, p. 22021.
175. Cheng, J.C.P.; Lu, Q. A review of the efforts and roles of the public sector for BIM adoption worldwide. *J. Inf. Technol. Constr. (ITcon)* **2015**, *20*, 442–478.
176. United Kingdom Government. Government Construction Strategy (2016–2020). Available online: https://assets.publishing.service.gov.uk/media/5a80ac49ed915d74e622fca7/Government_Construction_Strategy_2016-20.pdf (accessed on 17 January 2024).
177. Thompson, W.R. The UK BIM Revolution. Bachelor's Thesis, California Polytechnic State University, San Luis Obispo, CA, USA, 2017. Available online: https://shorturl.at/gsuA2 (accessed on 17 January 2024).
178. Liu, B.; Wang, M.; Zhang, Y.; Liu, R.; Wang, A. Review and prospect of BIM policy in China. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *245*, 22021. [CrossRef]
179. Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Guidelines for BIM Standard Workflows (MLIT, 2020). Available online: https://www.mlit.go.jp/tec/tec_fr_000079.html (accessed on 17 January 2024).
180. Vision for the Future and Roadmap to BIM. Available online: https://www.mlit.go.jp/jutakukentiku/content/001351970.pdf (accessed on 17 January 2024).
181. German BIM Implementation Strategy for Federal Buildings. Available online: https://www.bimdeutschland.de/fileadmin/media/Downloads/Download-Liste/Hochbau/Masterplan_BIM_Bau.pdf (accessed on 17 January 2024).
182. Schumacher, R.; Theißen, S.; Höper, J.; Drzymalla, J.; Lambertz, M.; Hollberg, A.; Forth, K.; Wimmer, R.; Bahlau, S.; Meins-Becker, A.; et al. Analysis of current practice and future potentials of LCA in a BIM-based design process in Germany. *E3S Web Conf.* **2022**, *349*, 10004. [CrossRef]
183. Borrmann, A.; Hochmuth, M.; König, M.; Liebich, T.; Singer, D. Germany's governmental BIM initiative–Assessing the performance of the BIM pilot projects. In Proceedings of the 16th International Conference on Computing in Civil and Building Engineering, Osaka, Japan, 6–8 July 2016; pp. 871–878.
184. HKBIM. The Hong Kong Institute of Building Information Modelling—BIM Standards. Available online: https://www.bim.cic.hk/en/resources/publications_detail/8 (accessed on 17 January 2024).
185. The NZ BIM Handbook. Available online: https://www.biminnz.co.nz/nz-bim-handbook (accessed on 17 January 2024).
186. Mesároš, P.; Smetanková, J.; Mandičák, T. The fifth dimension of BIM–implementation survey. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *222*, 12003. [CrossRef]
187. Lim, M.Y. The Impact of Using Measurement Software in the Quantity Surveying Consultancy. Ph.D. Thesis, University Tunku Abdul Rahman, Kampar, Malaysia, 2020.
188. Abdulfattah, B.S.; Abdelsalam, H.A.; Abdelsalam, M.; Bolpagni, M.; Thurairajah, N.; Perez, L.F.; Butt, T.E. Predicting implications of design changes in BIM-based construction projects through machine learning. *Autom. Constr.* **2023**, *155*, 105057. [CrossRef]

189. Garg, A.; Alothman, A.; Vilventhan, A. Integration of Building Information Modelling and Facility Management for Metro Rail Project: A Case Study. In *Building Construction and Technology*; Springer: Berlin/Heidelberg, Germany, 2023; pp. 113–126.
190. Lenart, S.; Janjić, V.; Jovanović, U.; Vezočnik, R. Real-time monitoring and analyses of sensory data integrated into the BIM platform. In Proceedings of the 6th International Conference on Road and Rail Infrastructure, VI, Pula, Croatia, 20–22 May 2020; University of Zagreb: Zagreb, Croatia, 2021; pp. 20–21.
191. El Khatib, M.; Khadim, S.B.; Al Ketbi, W.; Al Kuwaiti, N.H.; El Khatib, A. Digital Transformation and Disruptive Technologies: Effect of Blockchain on Managing Construction Projects. In Proceedings of the 2022 International Conference on Cyber Resilience (ICCR), Dubai, United Arab Emirates, 6–7 October 2022; pp. 1–9.
192. Fariq, N.; Ismail, S.; Ab Rani, N.I. Effective 5D Bim Requirements for Risk Mitigation during Pre-Contract Stage. *J. Surv. Constr. Prop.* **2022**, *13*, 12–19. [CrossRef]
193. Tan, Y.Y. Exploring Application of E-Tendering in Malaysian Construction Industry during COVID-19 Pandemic. Bachelor's Thesis, University Tunku Abdul Rahman, Kampar, Malaysia, 2022.
194. Akinshipe, O.; Aigbavboa, C.; Oke, A.; Sekati, M. Transforming Quantity Surveying Firms in South Africa Through Digitalisation. In Proceedings of the AHFE 2021 Virtual Conferences on Human Factors, Business Management and Society, and Advances in Human Factors in Management and Leadership, Online, 25–29 July 2021; Springer: Berlin/Heidelberg, Germany, 2021; pp. 255–265.