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Mapping the Nexus of 5D BIM and Big Data in Project Cost Management: A Systematic Review

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ABSTRACT

Success in construction projects fundamentally depends on exceptional project management, with project cost management (PCM) being one of the key components. However, PCM often faces constraints such as outdated data and data inaccuracies throughout the project's lifecycle, which consequently undermine its reliability. Recently, 5D Building Information Modelling (BIM) is gaining attention as an innovative work process that could facilitate PCM enhancement. Despite the potential of 5D BIM to address the PCM issues, it is found that technology struggles with certain PCM data complexities; thus, suggesting that big data analytics (BDA) might be beneficial if used concurrently with 5D BIM in providing solutions. Nevertheless, the linkage between 5D BIM components and big data (BD) attributes remains scantily mapped. Therefore, a systematic mapping between these domains is necessary as a forerunner to manifest their relationship. In order to address this gap, this research employs a systematic literature mapping method with the aim to illustrate the associations and the potential synergies between 5D BIM and BD attributes. The findings suggest that there is a distinct theoretical connection between them, highlighting the need for further exploration and investigation for practical implementation. This research serves as a milestone in understanding the interplay between 5D BIM and BD attributes, paving the way for more effective integration in the current industry practices.

Key words: *project cost management, 5D BIM, big data attributes, systematic mapping.*

1.0 INTRODUCTION

Project cost management (PCM) has always been a crucial part in a construction project management (George; & Vallance, 1987; Memon et al., 2010; Unegbu et al., 2023). Its vitality is depictive by the fact that Project Management Institute (PMI) includes PCM among the ten fundamental knowledge areas in project management (Peter, 2023). As such, key components like the cost management plan, cost estimation, budgeting and cost control must be managed effectively to ensure that projects are completed within the agreed budget (Lewis, 2016; Unegbu et al., 2023). However, the conventional approaches are often hindered by various limitations such as the lack of real-time data updates, complexities in integrating information from diverse sources, and susceptibility to errors due to manual inputs (Lu et al., 2018; Parsamehr et al., 2023). As construction projects become increasingly complex and dynamic, there is a growing demand to modernize and enhance conventional PCM practices and improve data management, thus leading to the need for technological advancements (Parsamehr et al., 2023). Therefore, digitalization of PCM is regarded as a crucial step towards addressing data management issues in construction projects.

Although, the construction sector was previously identified as the second least digitized industry in 2015, there has been a significant progress in this sector from 2020 to 2022, as reported by McKinsey (Jose et al., 2023). This significant construction digitalization can be considered ameliorating through policies where there have been around 142 national digitalization policies implemented between 2017 and 2022 (Zhang et al., 2023). In Malaysia, the Construction 4.0 Strategic Plan (2021-2025) was developed to respond to the rapid advancements of the Fourth Industrial Revolution, identifying twelve emerging technologies (CIDB, 2020) as shown in Figure 1.

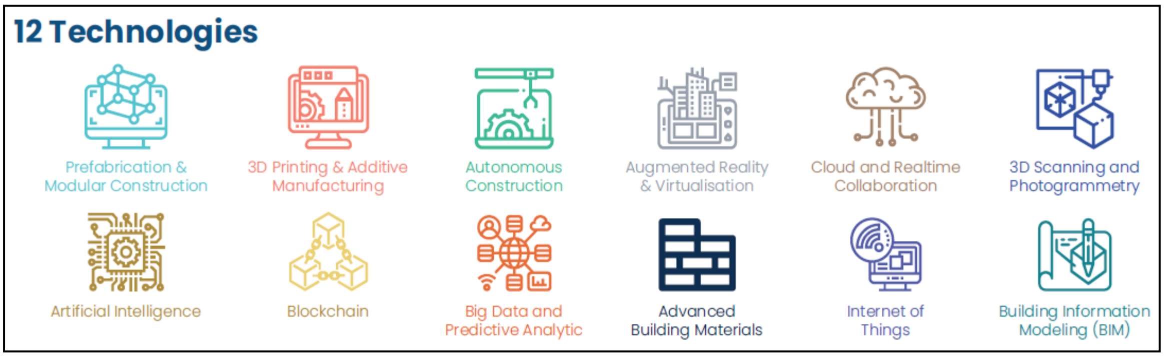

Figure 1. Emerging Technologies in Construction Sector (CIDB, 2020)

Among these technologies, BIM (Building Information Modeling) and big data analytics (BDA) have the ability to address data management issues and are regarded as digital strategies and modern working methods to refine the needs of the digital age (Chen, 2022; Kaufmann et al., 2018; Moreno et al., 2019; Smith, 2016). It has also been reported in KPMG's 2023 Global Construction Survey that BIM and advanced data analytics are among the top three technologies with the potential to deliver the greatest return of investment (ROI) with 49% and 36% of the respondents voted for them respectively (Armstrong et al., 2023). Hence, in the context of PCM, the integration of 5D BIM software and BDA can bring greater ROI and improvements within the sector.

Although the integration between both technologies seems noteworthy, the processes within 5D BIM in PCM should fulfil principally attributes of big data which are Volume, Velocity, Variety and Veracity to be concurred as big data and reflects the need to leverage BDA (Bilal et al., 2019; Min et al., 2014). Despite various literature emphasizing the prospects of BIM data and BDA in the context of facility management, construction waste management, energy management and others (Bilal, Oyedele, Akinade, et al., 2016; Demirdogen et al., 2023; Fang et al., 2024; Shen & Pan, 2023), few scholars still concurs that BIM data is not large enough to be recognized as big data (Anunson, 2018; Correa, 2015; Wilkinson, 2019). Therefore, it sets in motion the disagreement among scholars and thus, to be resolved by investigating this potential concept through the research.

The integration of 5D BIM and BDA is no longer an evolutionary idea but an operational necessity in PCM. As digital twins and predictive analytics become increasingly embedded in project delivery work flows, BIM usage in the absence of advanced analytics limits its usefulness in real-time decision-making and cost projection by leveraging large-scale and heterogeneous datasets. For example, predictive cost modelling using historical project data and real-time procurement feeds is possible only with the computational power of BDA tools like Hadoop, Spark, and Python-based analytics platforms (Bilal et al., 2019; Lu et al., 2018) Without this integration, the cost-planning features of 5D BIM still remain reactive rather than proactive by undermining its potential for continuous cost intelligence. Therefore, understanding the theoretical associations between 5D BIM and BDA is crucial in formulating future research direction and prospects of industrial applications. This paper aims to illustrate the outcome of a systematic mapping analysis conducted to map both 5D BIM in the context of PCM components and big data characteristics. It delineates two objectives: (1) to explore relevant literature related to 5D BIM and big data characteristics, and (2) to identify shared connection between 5D BIM and big data characteristics. Therefore, this research has been carried out through an in-depth literature review.

2.0 5D BIM AND BIG DATA ATTRIBUTES IN PROJECT COST MANAGEMENT

2.1 Project Cost Management (PCM) in Construction Sector

The construction sector has always been recognized for its contribution towards development of socio-economic and economic growth (Abdullah, 2004; Lopes & Banaitienė, 2024; Morledge et al., 2006). It has been reported in the Malaysia Economic Outlook 2024 that construction is expected to be the fastest developing industry in 2024 where the gross domestic product (GDP) growth is 6.8% in comparison to other sectors as shown in Table 1 (MOF, 2023; Star, 2024).

Table 1. GDP Development in Various Sectors (MOF, 2023)

	2022[10]		2023[11]		2024[12]	
POPULATION[2] (million)	32.7		33.4		33.7	
DOMESTIC PRODUCTION	RM million	change (%)	RM million	change (%)	RM million	change (%)
Gross Domestic Product (constant 2015 prices)	1,510,939	8.7	1,569,247	~ 4.0[17]	1,645,078	4.0 – 5.0
Agriculture	99,073	0.1	99,620	0.6	100,770	1.2
Mining and quarrying	96,199	2.6	95,448	-0.8	98,030	2.7
Manufacturing	364,131	8.1	369,359	1.4	384,727	4.2
Construction	53,441	5.0	56,824	6.3	60,688	6.8
Services	881,310	10.9	930,125	5.5	981,990	5.6
Import duties	16,785	7.3	17,868	6.5	18,873	5.6

Since the construction sector has vital roles in the national economy, continuous improvement has been made in construction project management as it has major impact on the sector's performance (CIDB, 2017; Hatema et al., 2022; Htoo et al., 2023; Rodrigo et al., 2024). According to Project Management Institute (PMI), there are 10 knowledge areas which are common in most of the projects (Sotille, 2016). Among various knowledge areas in project management, PCM is very essential since the project cost performance can lead to cost overrun which is the construction global issue where in 2022 alone, there were more than 10 Billion USD cost overrun from 12,206 of construction projects, hence it demands an attention (Htoo et al., 2023; Tembo et al., 2024).

Project cost management is a discipline in construction that involves planning, monitoring, and controlling the financial aspects of a construction project (Unegbu et al., 2023). PCM is essential as it assesses the feasibility of a project. During the initial stage, feasibility studies are conducted to ensure whether the project is viable to be completed within the available funds (Heralova, 2017). Additionally, it establishes a baseline for project costs and aids in forecasting both expenses and revenue, hence enabling construction projects to avoid losses and prevent over-budgeting (Venkataraman & Pinto, 2023). Furthermore, PCM also helps in identifying cost reduction opportunities by comparing estimated costs with actual cost while analyzing variances to determine potential corrective actions (Pheng, 2018). In the industry, financial constraints are common, and cost overruns can lead to substantial repercussions (Leu et al., 2023; Paydar et al., 2023). Therefore, proficient cost management becomes indispensable for ensuring that projects are not only completed on schedule and within budget but also meet the anticipated quality standards (Hassan & Al-Kindy, 2023).

As PCM is essential due to various reasons, it encompasses a range of activities to ensure financial resources are effectively allocated throughout the project lifecycle. In the conventional approach, cost management typically revolves around the creation of detailed cost estimates during the project planning phase, followed by the allocation of budgets for various project components (Antoniou et al., 2023). Throughout the lifecycle, costs are monitored and compared to the established budget, with adjustments made as needed to ensure that the project remains financially on track (Williams, 2023). Nevertheless, conventional methods often rely heavily on historical data and expert judgment to generate cost estimates and manage expenses (Alshammari, 2022). Concurrently, it involves the manual inputs of data in spreadsheets, manual reporting and the identification of potential cost overruns by the project team (Bettemir & Yücel, 2023; Ciotta et al., 2021). Based on the above activities, the data within the PCM are generated diverse forms as in Table 2 which are reflecting the complications in handling the data in the conventional practices (Jadid, 2013; Olawumi et al., 2017).

Table 2. Data forms & Its Example (Jadid, 2013; Olawumi et al., 2017)

Forms	Examples of Data
Structured	Bills of Quantities & Unit rates
Semi-structured	Vendor quotes & Cost plan
Unstructured	Meeting notes, site footage & scanned document

Despite the use of software such as Microsoft Excel, the documentation is still being printed out and stored as physical files in cabinets, which causes accessibility issues (Rathnayaka et al., 2024). Moreover, some consultant firms are still using outdated operating systems, which impedes their ability to upgrade from legacy systems. For example, some companies retain the use of Windows 7 and 8.1 and have not migrated to Windows 10; hence, they can only use Buildsoft legacy estimating software such as Global and Offsider and cannot upgrade to 2016 versions (Hook, 2016). Consequently, they may have limited flexibility to adapt to changes or unforeseen circumstances during the project's execution (Kerzner, 2022). On top of that, ineffective PCM practices due to fragmented data flows can lead to scope creep, procurement delays, and resource underutilisation. For example, inconsistency of subcontractors billing against actual work progress is common in conventional PCM which may lead to conflicts and payment delays that directly impact the cashflows (Alzara et al., 2023; Kerzner, 2022). All these limitations highlight that, despite being an essential discipline, further refinement is needed within PCM. Therefore, there is a pressing need for a paradigm shift towards adopting modern cost management tools and technologies, where 5D BIM software and BDA are viewed as potential platforms to address these issues.

2.2 5D BIM in PCM

In general, 5D BIM is an advanced construction and project management methodology that extends the capabilities of conventional 3D BIM models by incorporating time and cost dimensions (Kun et al., 2023). This integration of time and cost dimensions enables project teams to visualize how design changes, scheduling adjustments, and resource allocations affect both project costs and timelines. This capability facilitates more informed decision-making, enhances project efficiency, and improves cost control (Fariq, 2022; Glodon, 2021). Thus, it optimizes project outcomes by considering not only what a building will look like but also when it will be built and how much it will cost. This can be further comprehended through the 5D BIM software diversified functions which include accelerated quantity take-off, cost estimation, intelligent revision management and integrated cloud collaboration.

Accelerated quantity takeoff represents the power of technology and automation to expedite the conventionally time-consuming process of quantifying and measuring materials for a construction project (Fahmilia & Isvara, 2023). The key advantage of accelerated quantity takeoff lies in its ability to significantly reduce the time and effort invested in the estimation process (Al-Musawi & Naimi, 2023; Sing et al., 2022). Construction professionals can swiftly and systematically analyze project specifications, blueprints, and relevant documentation; extracting pertinent information with unprecedented speed. Additionally, the use of accelerated quantity takeoff contributes to enhanced collaboration among project stakeholders, as the digital outputs provide clear and standardized documentation that can be easily shared and understood across diverse teams (Gaur & Tawalare, 2022).

Besides, in the context of cost estimation, the detailed 3D model created in the BIM environment serves as a rich repository of information, allowing Quantity Surveyors (QS) to conduct accurate and precise assessments of materials, labor costs, and equipment requirements (Pezeshki & Ivari, 2018). This advanced approach minimizes reliance on manual take-off processes, which have historically prone to errors, and introduces a new level of efficiency in the estimation process (Mayouf et al., 2019). The cost estimation process after the take-off can be illustrated in Figure 2 (Abanda et al., 2017)

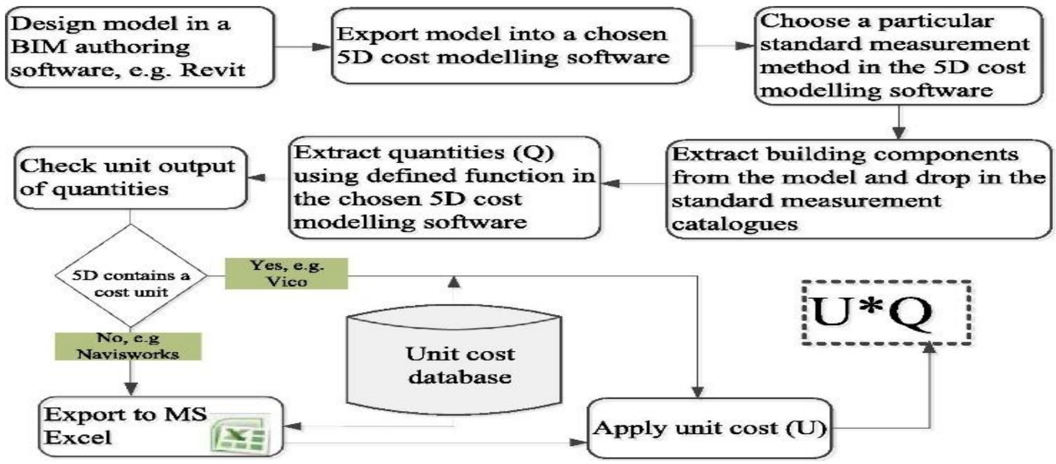

Figure 2. Cost Estimating Process in BIM Software (Abanda et al., 2017)

Meanwhile, 5D BIM software also has the capacity to seamlessly integrate design alterations and schedule adjustments, automatically updating the associated cost estimate (Glodon, 2021). This dynamic responsiveness to changes ensures that the cost estimate remains reflective of the project's current state, mitigating the risks associated with outdated information (Dan et al., 2023). In addition to its ability to accommodate changes, 5D BIM excels in generating comprehensive reports and analyses that offer valuable insights into the cumulative impact of all revisions on the project's budget and schedule (Alzara et al., 2023). These reports provide project teams with a detailed understanding of how each modification influences the overall project parameters, empowering them to make data-driven decisions.

On top of that, Integrated cloud collaboration represents a paradigm shift in construction project management, driven by the transformative capabilities of cloud-based platforms. This approach serves as a central hub for project data, encompassing 3D models, schedules (4D), and cost information (5D); thereby, fostering real-time collaboration among diverse stakeholders (Glodon, 2021). The cloud-based integration surpasses geographical constraints by enabling project teams to access, share, and update critical project data from any location (Smith, 2016). This flexibility not only enhances communication among team members but also expedites change management processes, promoting a more agile project environment.

Despite the various capabilities of 5D BIM software, there are several challenges encountered in the implementation of this technology in the PCM area. One of the most prominent issues is inaccurate and inappropriate data allocation where cost managers often receive incomplete or poorly structured models from designers, requiring them to manually review and rectify these models before proceeding with cost-related tasks (Lu et al., 2018; Stanley & Thurnell, 2014). This review process can cause significant project delays, coordination issues, and rework, ultimately compromising the reliability of the 5D BIM model for PCM purposes (Smith, 2016). Moreover, interoperability issues between BIM software and cost management platforms further intensify these challenges. Hence, the implementation of openBIM standards like Industry Foundation Classes (IFC) and using Application Programming Interfaces (APIs) to integrate BIM with Enterprise Resource Planning (ERP) systems can minimize data loss (Arayici et al., 2023; Eastman et al., 2011) which still needs to be prevented. Additionally, delays caused by the multiple design revisions or change orders needs to be addressed through real-time impact which are still lacking in current 5D BIM implementation.

Another challenge is the sheer volume of data where MRT BIM Level 2 project generated 2.3 terabytes of data (Azman, 2018). This directly indicates that the 5D BIM platform is incapacitated for long-term data management as the data continues to grow throughout the lifecycle of the project (Varunkumar, 2023). The software also faces issues in the context of storing multi-structured data, where 5D BIM is only capable to store structured data (Demirdogen et al., 2023; Hurwitz, 2013; Jeong, 2018; Motawa, 2017). However, PCM consists of all types of data structures, which include historical data, assumption lists, resource requirements, and financial health information. Unlike structured data, which are organized and easily searchable, these types of data are often unstructured and less organized (EcoSys, 2023). For instance, the platform has limitations in fully leveraging data such as industry benchmark, sensor data and project's historical data, where it could produce remarkable outputs in cost estimation (Parsamehr et al., 2023).

This shift prompts the need for new analytical platforms and methodologies to unlock the full potential of the integrated data. Failing to embrace these innovations could lead to underutilization of valuable insights latent within the combined datasets, as the conventional methods become obsolete in the face of the intricate and multifaceted nature of contemporary BIM data (Correa, 2015; Schober, 2016). Hence, there is a pressing need for the construction industry to adopt advanced data analytics platforms to effectively navigate and extract meaningful intelligence from this amalgamated data landscape. Thus, scholars emphasize the compatibility of BDA in handling BIM in PCM (Bilal, Oyedele, Qadir, et al., 2016; Hosey, 2018; Lu et al., 2018).

2.3 5D BIM and its Fulfilment of Big Data Attributes in PCM

The constraints faced in the traditional methods of processing, storing and analysing data, compels the era of big data, particularly in the context of 5D BIM platform (Boton et al., 2015; Lu et al., 2018). The notion of big data needs to be understood clearly; therefore, the term 'data' must be defined first. Data consists of unprocessed numbers, text and symbols that require storage and processing tools to become valuable to users (Cambridge, 2017). On the other hand, big data refers to the inability of traditional methods to store, process and analyse data due to its vast generation of data in the database (Huang, 2021; Olsson & Bull-Berg, 2015). The distinction between data and big data can be further clarified through the following Table 3.

Table 3. Data and Big Data (Kune et al., 2016; Pendyala, 2018)

Property	Data	Big Data
Amount of data	Segregation as historical & operational data where filtration will be done on historical data for rapid database queries.	Enormous data creation from various sources that can be replicated in larger storage devices.
Pace	Transaction is low at a time.	Transaction at fast pace due to several sources.
Format	Structured & semi-structured data generally.	Multi-structured data.
Reliability	Accuracy & applicability of data.	

Table 3 illustrates the conventional way of reflecting main attributes of data and big data which are Volume (amount of data), Velocity (pace), Veracity (reliability) and Variety (format) (Pendyala, 2018; Yousry, 2018). In the context of PCM, volume refers to the abundance of cost data generated throughout the project lifecycle, such as estimates, claims, and expenditure records (Bilal et al., 2019; Marzouk & Enaba, 2019).

Meanwhile, velocity can be referred as the speed at which data from real-time sources like sensors, equipment logs, and progress updates must be processed to support timely cost decisions (Rao et al., 2022). Besides, variety indicates the heterogeneity of PCM data formats which includes structured, semi-structured and unstructured data (Kamm et al., 2023; Motawa, 2017). Finally, veracity addresses the accuracy of the data, which is often compromised by human input errors, inconsistent updates, or conflicting sources (Pendyala, 2018). These outlined characteristics are essential indicators since 5D BIM data can only be considered as big data when the datasets fulfil these characteristics (Bilal et al., 2019; Min et al., 2014). Otherwise, various abilities of BDA cannot be fully leveraged in providing data-driven insights (Farghaly, 2019; Lynch, 2018; Marzouk & Enaba, 2019). Despite the 4 Vs of big data offer the foundational framework, there is a need to comprehend in the context of PCM. As the relationship between 5D BIM and big data attributes is not well-defined, this paper provides a systematic mapping to establish their theoretical connection.

3.0 SYSTEMATIC LITERATURE MAPPING ANALYSIS PROCESS

The research involved a comprehensive review of numerous secondary sources from recent 5 years. Hundreds of documents related to 5D BIM and big data were meticulously examined and analyzed through various prominent online databases, e-books, and journals. The systematic mapping process was carried out by connecting two different domains, which are 5D BIM in PCM that consists of cost management plan (CMP), cost estimation, budgeting and cost control while another one is Vs of big data that are volume, velocity, variety and veracity. Despite the Vs of big data often referred to the 3 Vs which are volume, variety and velocity (Bilal et al., 2019), this mapping includes veracity as 4^{th} V of big data attributes as the PCM is often tangled with the issues of accuracy. Hence, this research explores 4 Vs of big data.

Several methods were employed in the review process, including scanning, second-level reading comprehension, and relevant data extraction (Aritonang et al., 2019; Boland et al., 2017). As this research needs to align with the objectives, the studies which are addressing both 5D BIM in PCM and at least one of the 4Vs of big data attributes were being included. Concurrently, research prior to 2020 were excluded to ensure this research in line with the contemporary studies made. Furthermore, inaccessible full text papers were excluded to align with appropriate systematic reviews (Boland et al., 2017). Throughout the process, there were only 37 of sources that reflected the relationship between 5D BIM and big data characteristics, with some showing direct and indirect manifestation. Subsequently, the synthesis of the review outcomes was exhibited through a table of associations between 5D BIM and big data characteristics. Thus, the research method employed demonstrates a systematic approach used to achieve the research aim as previously outlined. The Figure 3 depicts in-depth review process.

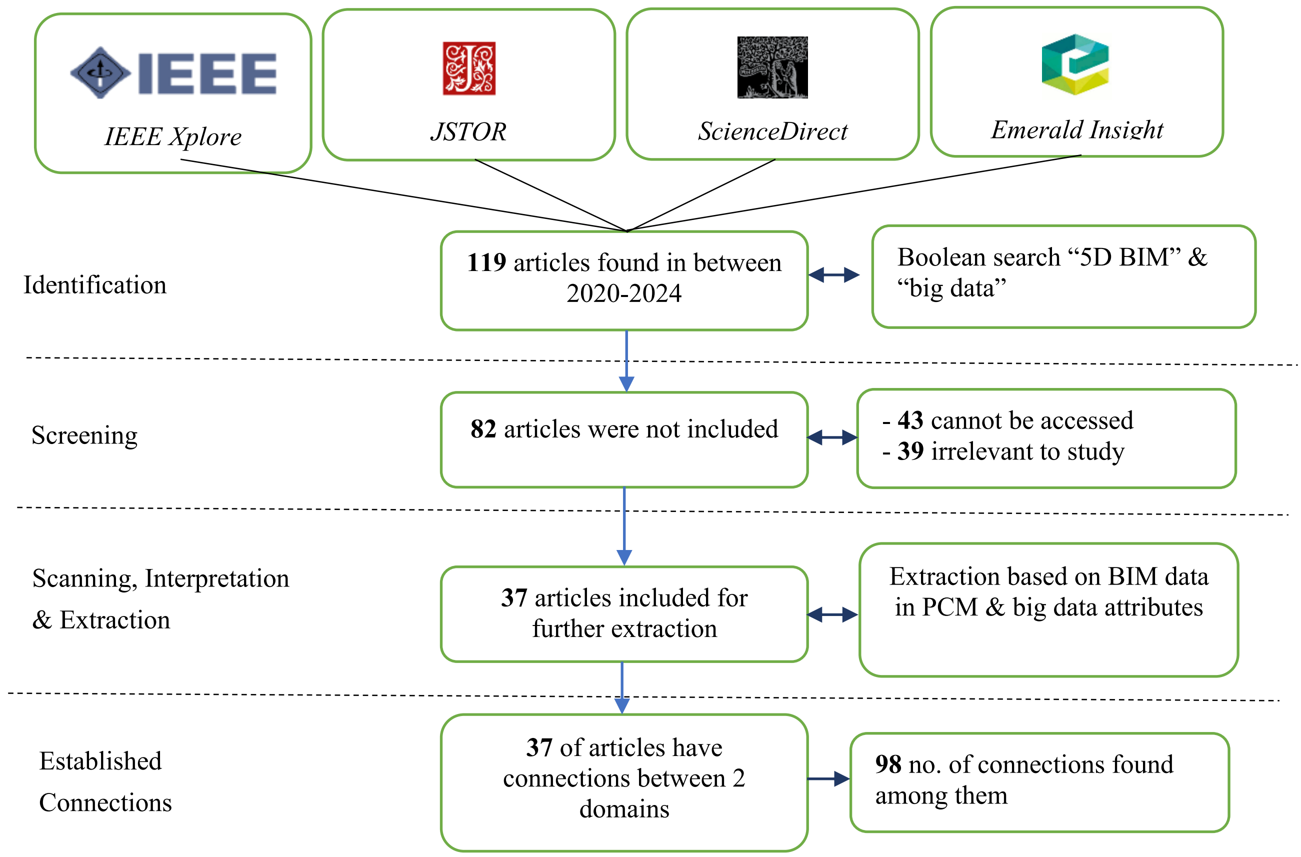

Figure 3. Process of In-depth Review.

4.0 SYSTEMATIC MAPPING OUTCOMES

Table 4. Mapping of 5D BIM in PCM and Big Data Attributes

BD Attributes / 5D BIM in PCM	**Volume**	**Velocity**	**Variety**	**Veracity**
CMP			Boje et al. (2020); Gusmao Brissi et al. (2022); Sena and Fabricio (2023); Wang and Lu (2022)	Abioye et al. (2021); Arayici et al. (2023); Babalola et al. (2021); Bello et al. (2021); Boje et al. (2020); Haruna et al. (2021); Liu et al. (2022); Moses et al. (2020); Sena and Fabricio (2023)
Cost Estimation	Bello et al. (2021); Boje et al. (2020); Ding et al. (2022); Haruna et al. (2021); Moses et al. (2020); Stride et al. (2020)		Al-Saeed et al. (2020); Arayici et al. (2023); Boje et al. (2020); Elghaish et al. (2020); Girginkaya Akdag and Maqsood (2020); Gusmao Brissi et al. (2022); Haruna et al.	Abioye et al. (2021); Al-Saeed et al. (2020); Arayici et al. (2023); Boje et al. (2020); Datta et al. (2023); El Hajj et al. (2023); Elghaish et al. (2020); Famakin et al. (2022); Koo and O'Connor (2022); Likita

			(2021); Moses et al. (2020); Regona et al. (2022); Singh et al. (2023)	et al. (2024); Liu et al. (2022); Moses et al. (2020); Regona et al. (2022); Sena and Fabricio (2023); Stride et al. (2020); Tan et al. (2023); Van Tam et al. (2023)
Budgeting	Abioye et al. (2021); Assafi et al. (2022); Datta et al. (2023); Kamunda et al. (2021); Moshtaghian and Noorzai (2023)	Abioye et al. (2021); Assafi et al. (2022); Babalola et al. (2021); Brandín and Abrishami (2021); Moses et al. (2020)	Datta et al. (2023); Girginkaya Akdag and Maqsood (2020); Gusmao Brissi et al. (2022); Regona et al. (2022); Singh et al. (2023)	Abioye et al. (2021); Babalola et al. (2021); Cevikcan and Kose (2021); Elghaish et al. (2020); Haruna et al. (2021); Moses et al. (2020); Moshtaghian and Noorzai (2023); Sena and Fabricio (2023)
Cost Control	Abioye et al. (2021); Boje et al. (2020); Rankohi et al. (2023)	Abioye et al. (2021); Banerjee and Nayaka (2022); Bello et al. (2021); Boje et al. (2020); Brandín and Abrishami (2021); Chen et al. (2022); Ding et al. (2022); Elghaish and Abrishami (2021); Elghaish et al. (2021); Mahamood and Fathi (2022); Meng et al. (2020); Rankohi et al. (2023); Regona et al. (2022)	Abioye et al. (2021); Banerjee and Nayaka (2022); Boje et al. (2020); Chen et al. (2022); Ding et al. (2022); Elghaish et al. (2021); Gusmao Brissi et al. (2022)	Abioye et al. (2021); Arayici et al. (2023); Bello et al. (2021); Boje et al. (2020); Elghaish and Abrishami (2021); Mahamood and Fathi (2022)

Based on Table 4, the systematic mapping analysis illustrates a significant relationship between 5D BIM in PCM and big data characteristics. Firstly, despite not having any relationship with Velocity of big data, it has been found that cost estimation in 5D BIM software has the most associations, with 33 connections. This is probably due to the fact that cost managers primarily use 5D BIM software for estimation activity rather than the other three remaining activities (Monteiro & Martins, 2013; Valinejadshoubi et al., 2024). On top of that, the strong associations with Variety and Veracity highlights the challenges of handling multi-structure data while ensuring accuracy during quantity take-off and cost rates application (Elghaish et al., 2020). In contrast, the least relatable is cost management plan (CMP), with only 13 connections, where Veracity is the predominant relationship. This is consistent with major studies that indicate CMP is mainly concerned on the accuracy of data (PMI, 2013; Vigneault et al., 2020). Meanwhile, there are 23 interrelationships found between budgeting in 5D BIM and the 4Vs of big data. These relationships span all the big data characteristics, as their significant real-time data involvement during the budgeting process (Inzerillo et al., 2024; Sabri, 2024). This can be further supported by the increasing role of real-time updates in regard to material pricing or procurement process which are rarely emphasized in the conventional usage of BIM (Alzara et al., 2023). Finally, cost control appears to be the second-highest number of associations, with 29 connections to big data characteristics. This is consistent with the involvement of multi-structured data where comprehensive data is required for real-time monitoring, anomaly detection and predictive analytics which are complex to be handled by BIM models (Alzara et al., 2023; Sabri, 2024; Vigneault et al., 2020).

In the context of big data, Veracity is found to be most related characteristics across all the components, with approximately 40 linkages. It is undeniable that accurately defined data are needed in the 5D BIM software for precise quantification and estimation, hence, project cost can be controlled within the established baseline and minimizing conflicts throughout the construction stage (Bilal, Oyedele, Qadir, et al., 2016; Farghaly, 2019; Lu et al., 2018). Next, the second-most related attribute is Variety, which has 26 connections overall. 5D BIM projects are often intertwined with multi-structure of data such as audio, video, text, and relational database which illuminates the linkage with the Variety of big data (Kamm et al., 2023; Kent, 2020). Conversely, the least associated big data attribute is Velocity, which is only related to budgeting and cost control. This may be due to the generation of sensor data and real-time data feeds during the monitoring and controlling phases through project management software, RFIDs, equipment and machinery sensors and others (Bilal, Oyedele, Qadir, et al., 2016; Rao et al., 2022). Therefore, the systematic mapping hypothetically suggests that there are connotations between 5D BIM in PCM and big data characteristics in accordance to the analysis of the relevant secondary sources. These outcomes are significant as they provide a foundation for future research aimed at determining the extent of data creation versus the capabilities of 5D BIM software in the real-world practice.

5.0 CONCLUSION

Although there is very limited research available in relation on 5D BIM and big data, this paper has successfully identified the linkages between 5D BIM in PCM and big data characteristics through a systematic mapping of existing studies from the past 5 years. The findings indicate that 5D BIM in PCM has connections with big data attributes, even though only budgeting and cost control fulfil all the 4-Vs of big data. Despite these associations being established theoretically, they represent a crucial first step in addressing the previously unclear interrelationship between these domains. Thus, these associations are significant as they provide a foundation for future research particularly on integrating 5D BIM and big data analytics in PCM. Based on this foundation. the correlation between 5D BIM and big data analytics will be explored in the real-life practices in Malaysian construction industry.

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7.0 AUTHOR CONTRIBUTIONS

Faris Hyder Ali is a PhD candidate who works on this research work, and Siti Nora Haryati Abdullah Habib is the supervisor for the PhD candidate.

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