PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 22 ISSUE 3 (2024), Page 273 – 287

BIG DATA ANALYTICS (BDA) FRAMEWORK FOR CONSTRUCTION COST ESTIMATION IN MALAYSIA

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Abstract

The construction industry is undergoing significant changes due to the growing volume of data, necessitating the adoption of Big Data Analytics (BDA) for improved project management. Construction projects are inherently uncertain, often resulting in cost overruns. This research focuses on the development of a framework for implementing big data analytics in the estimation of construction costs within the Malaysian construction sector. To achieve this goal, a quantitative research approach was employed, which involved an examination of the industry's awareness of construction cost estimation, comprehension of big data analytics processes in the context of cost estimation, and an exploration of the challenges and potential solutions associated with the integration of BDA. The resultant framework for construction cost estimation via BDA is a dynamic and evolving tool. It is refined iteratively based on insights derived from a questionnaire survey distributed to Consulting Quantity Surveying Practice (CQSP) registered with the Board of Quantity Surveyors Malaysia (BQSM). The BDA framework emerges as a fundamental tool for cost estimators, notably quantity surveyors, facilitating the digital transformation of the cost estimation process and substantively enhancing the precision of contemporary cost estimation methodologies.

Keywords: Big Data, Analytics, Construction Cost Estimation, Cost Overrun, Framework

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INTRODUCTION

The global construction industry plays a pivotal role in shaping the Gross Domestic Product (GDP) and Gross National Product (GNP) of numerous countries worldwide, thus serving as a critical driver of economic growth. Through the fundamental objectives of generating output, creating employment opportunities, and elevating living standards, the construction sector makes substantial contributions to sustainable economies on a global scale (Basaif et al., 2020). However, it is noteworthy that, as emphasized by Michael Burke, Co-Chair of the World Economic Forum Infrastructure and Urban Development Community, the current business models and strategies within the construction industry may not suffice to meet the evolving demands of the future (Buehler et al., 2018). Hence, industry stakeholders are compelled to proactively prepare for disruptions and assume a responsible role in fostering societal progress, stimulating economic development, and upholding environmental stewardship.

The construction industry's impact extends far beyond economic statistics, encompassing a broader mandate that encompasses adaptability, responsibility, and a commitment to advancing society, fostering sustainable growth, and safeguarding the environment in the face of changing global dynamics. The global landscape is swiftly advancing towards the Fourth Industrial Revolution (IR 4.0), driven by the emergence of transformative technologies and innovations. These technological advances are reshaping business models, elevating operational efficiency, and enhancing productivity across industries. Notably, the construction sector is on the cusp of being profoundly impacted by this revolution (Buehler et al., 2018). In light of this imminent transformation, it is imperative for industry stakeholders to seize the opportunity and embrace innovative technologies such as big data and Building Information Modelling (BIM) as integral components of their operations. These technologies hold the potential to elevate project quality, efficiency, and health and safety standards.

In the Malaysian context, the Construction 4.0 Strategy Plan represents a strategic blueprint, aligning the Malaysian construction industry with the tenets of the Fourth Industrial Revolution (IR 4.0). This plan offers a structured framework, fostering collaboration among industry players, government agencies, and academia to effectively respond to the rapid digitalization underpinning IR 4.0. Significantly, the Construction 4.0 Strategy Plan spotlights 12 emerging technologies applicable throughout the project life cycle, each contributing enhanced value to construction endeavors. Notably, among these technologies, big data takes center stage (Construction Industry Development Board Malaysia, 2020). The convergence of IR 4.0 and the construction industry underscores the imperative of adapting to technological advances and harnessing them for sustained growth, innovation, and excellence in project execution, especially in countering cost overruns.

BACKGROUND OF STUDY

Poor cost management is a vital problem that has struggled the construction industry worldwide for the past few decades, especially methods related to cost overrun (Mustafa et al., 2023). The nature of construction industry is full of uncertainty throughout the construction project life cycle. These uncertainties make the cost management process to be difficult, which subsequently leads to cost overrun (Ali, 2018). Throughout recent decades, the construction industry has encountered substantial challenges to its reputation, predominantly because of the prevalent and consequential issue of cost overruns within construction projects (Ali, 2018). To underscore the pervasive global nature of this matter, Table 1 offers a compilation of documented occurrences of cost overruns, spanning beyond Malaysia to various international contexts.

Table 1: List of Cost Overrun in Construction Project

Year	Projects That Have Experience Cost Overrun	Percentage of cost overrun	Reference
	Malaysia		
2014	Kuala Lumpur International Airport 2 (KLIA 2)	Cost overrun from initial 1.6 billion to 4 billion (150%)	(Pua, 2017)
2014	359 Recent Completed Projects in Malaysia	Range from -80.38% to 88.76%	(Shehu et al., 2014)
2020	89% Construction projects in Malaysia	5%-10%	(Kamaruddeen et al., 2020)
	Other Countries		
1927-1998	258 transport projects located in twenty countries	Average of 28%	(Flyvbjerg et al., 2003)
2000-2013	122 Public Project in Qatar	N/A	(Ullah et al., 2018)
2014	49 Road Construction Project in Australia	Average of 13.55%	
N/A	Great Belt link in Denmark	54%	

Cost overrun has become a major hidden danger for all types of construction and has led to severe consequences for the construction industry. One of the major contributors to cost overrun is inaccurate cost estimation. The lack of data integration and interpretation, difficulty in handling the complex data in cost estimating process and lack of experience and time to estimates is hindering the project to achieve accurate cost estimation (Reyes-Veras et al., 2021, Garyaev & Garyaeva, 2019). Therefore, the construction industry should consider the adoption of big data analysis for cost estimation to effectively handle complex data and enhance the cost estimating process.

By implementing advance analytics technology, big data is able to provide a more accurate cost estimation for materials, labour and machinery and subsequently minimise the risk and lower down the range of cost overrun (Garyaev & Garyaeva, 2019; Jumas et al., 2018). In fact, big data adoption has been recognised as a potential solution to the increasing demand for current projects needs in construction industry (Reyes-Veras et al., 2021, Basaif et al., 2020). For instance, various research has proved that big data and predictive analytics (BDPA) shows positive impact on reducing the project's risk and able to predict the possible solution for the project accurately. However, unfortunately, the growth of big data in the construction industry is still in an infant stage and severely lagging compared to other industries (Maaz et al., 2018).

LITERATURE REVIEW

Construction Cost Estimation

Cost estimation is defined as the process of calculating and estimating budget that matches the financial capability required for a particular project to be successful without facing any possible financial constraint by taking into consideration of the direct cost, indirect costs and all other factors that might affect the project (Ullah et al., 2018). In project management, cost estimation encompasses the summation of all associated costs, incorporating both direct and indirect expenses, through the utilization of suitable estimating methodologies and reliable data.

Generally, a team of experienced cost estimators, which consists of quantity surveyors, project managers, engineers, architects, and Certified Professional Estimators (CPEs), will be involved in the process of construction cost estimation. These individuals have an extensive understanding in costs related issues throughout the project life cycle (Concord Group, 2023; Jumas et al., 2018). With the involvement of experts in the construction cost estimation, it can greatly increase the accuracy for the estimation.

An accurate cost estimation shall carefully identify, examine, and analyse all these costs and beyond that including fluctuation of materials price, location, climate, transportation, human resources, and equipment arrangement, building code, availability of utilities, politic and economy consideration (Concord Group, 2023). Apart from that, when the information is available, some experienced estimator will also take into consideration of soil condition, material lead time and surface topography in their construction cost estimation.

The importance of accurate construction cost estimation can be seen in many aspects; for instance, accurate cost estimation is crucial for decision-making, especially in calculating the project budget to ensure optimum resource allocation (Lee, 2020; Jumas et al., 2018). Besides, accurate construction estimation ensures that the project considers both foreseen and unforeseen cost, thus minimising the possibility of financial disruption and safeguarding the profit

margin for the project (ProEst, 2020). Furthermore, accurate construction cost estimation reduces the potential of variation orders or extension of project timeline. This will eventually lead to the better reputation of the business (Jumas et al., 2018). In short, accurate cost estimation often brings clarity, assurance, and success to the construction project.

The demand for greater project visibility and project performance has grown over the years in construction industry. Stakeholders are looking for more reliable and accurate cost estimates to forecast the project financial feasibility and gain confidence for their financial investment as there are limited resources and tighter financing than in the past. The stakeholders need to make sure that every cent they spent are being used wisely with maximum return (Mustafa et al., 2020). However, many barriers hinder the cost estimator in achieving accurate cost estimation in construction industry. Table 2 shows the barrier to achieving accurate cost estimation.

Table 2: Barrier in achieving accurate cost estimation

No	Barrier in achieving accurate cost estimation	Reference
1	1. Weak Cost Planning Knowledge Base 2. Poor Cost Databases and Understanding i. Unavailability of cost data ii. Unavailability of cost analysis iii. Poor understanding of the variables to consider in cost analysis iv. Organizations' poor understanding on the concept of cost planning 3. Inadequate Designs and Planning 4. External Conditions	(Kissi et al., 2016)
2	1. Inefficient techniques 2. Perception of model techniques 3. Unavailability of cost data 4. Lack of understanding and unstable economic	(Agyekum et al., 2018)
3	1. Not having access to historical cost databases 2. Unreasonable program baselines 3. Vague or incomplete scope	(Kamaruddeen et al., 2020)

Source: KICEM Journal of Construction Engineering and Project Management

Big Data Analytics (BDA)

Big Data is different from normal data, where it refers to a rapid growing data with vast amount of data sets that comprise a variety of heterogeneous formats, including structured, unstructured, and semi-structured data (Oussous et al., 2017). Due to the complex nature of Big Data, typical statistic tools are no longer to be effective in managing Big Data, hence requiring more advanced technologies and algorithms.

Many industries have been discussing the potential of big data in solving the problems that arise due the digitalisation and change them into a more intelligent methods of working. The data explosion brought on by the introduction of advanced technology in the modern world has marked the beginning of the big data era (Ismail et al., 2018). The data explosion refers to the significant increase in the volume of data generated and collected in various fields and industries due to advancements in technology (Ismail et al., 2018). This explosion is characterized by the exponential growth of data, both structured and unstructured, which presents new challenges and opportunities for analysis and utilization. For instance, referring to Taylor (2022), the volume of data generated reached a record of 64.2 zettabytes in the year 2020, and global data production is projected to grow up to 180 zettabytes in years 2025 (Taylor, 2022). Before the Big Data revolution, businesses were facing problems in handling enormous data sets effectively and storing all their data archives for long periods, since traditional technologies are expensive and have limited capacity with rigid management tools (Oussous et al., 2017).

In Malaysia, the amount of data created and used by the construction industry has grown tremendously due to the increasing usage of advanced technologies such as the Internet of Things, Cloud Computing and many other smart devices (Oussous et al., 2017). In tandem with the data explosion, the emergence of the big data phenomenon is anticipated to catalyse the digital transformation of the construction industry, fostering a favorable impact (Ismail et al., 2018).

Big data can be categorised into two main classes: big data analytics and big data engineering. In the context of this research, the primary focus will be on the domain of big data analytics. Big data analytics involve the development of multiple classification and forecasting systems to analyse, interpret and forecast the trends and patterns of the data. Big data analytics assists an organisation in extracting relevant information from the data base and monitor the pattern and foresee the impact on the business (Oussous et al., 2017). Besides, big data analytics only extract important insight from a complex source of raw big data (Pathak, 2021). In addition, Murkred and Zheng (2017) provided a definition of big data analytics as "the practice of assessing or analysing vast volumes of data to uncover concealed patterns, consumer preferences, market trends, and undisclosed relationships."

Process of Big Data Analytic

The fundamental distinction between big data analytics and traditional analytics becomes evident through the way data are analysed and managed. In nature, the framework for big data analytics is more complex compared to traditional analytics. The first step of performing big data analytics is data sourcing, which is an important process in big data analytics, where most data scientists have

categorised data into 3 distinct types: structured, semi-structured and unstructured data. In fact, big data is more likely to be a combination of structured, unstructured, and semi-structured data than to appeal as any data individually (CIDB, 2020). Structured data refers to data that is linear and kept in a relational database, semi-structured data refers to data that has certain structural properties but insufficient to be kept in a relational database, while unstructured data refer to data that are hard to make any connection with and difficult to process it.

Subsequently, to reduce storage requirements, expedite compilation, and enhance the efficiency of file transfers, the collected data will undergo compression to minimize the necessary storage bits for its representation. The obtained data will be processed and structured into statistical or spreadsheet applications, such as Excel, before moving on to the data processing stage. This process is known as data compression (Lee, 2020). The following step is data cleansing, where it involves the process of identifying, and removing the irrelevant, inaccurate, incomplete, and inconsistent data to improve the data quality (Siddiqa et al., 2016).

During the data processing phase, the exploratory data analysis will be carried out to analyse the data and summarise the key features of the data. Data processing models and algorithms is another part of data processing phase where it acts as a process for problem solving method (Lee, 2020). In this phase, the data processing platform such as Apache Hadoop and Apache Spark can be employed.

Lastly, the processed and cleaned data is now ready to proceed into the analysis phase. Data analysis can be categorised into four categories: descriptive, diagnostic, predictive, and prescriptive. Each category has their own stipulated functions and analyse the data with different model and algorithms, hence information acquired from each analysis will be different as well (Lee, 2020; Siddiqa et al., 2016). To better visualise the data, the sophisticated data will undergo data visualisation by transforming the data into accessible and intelligible information for decision-making in the form of charts, graphs, dashboards, or reports, which can be done with big data analytics application or statistical application as shown in Figure 1.

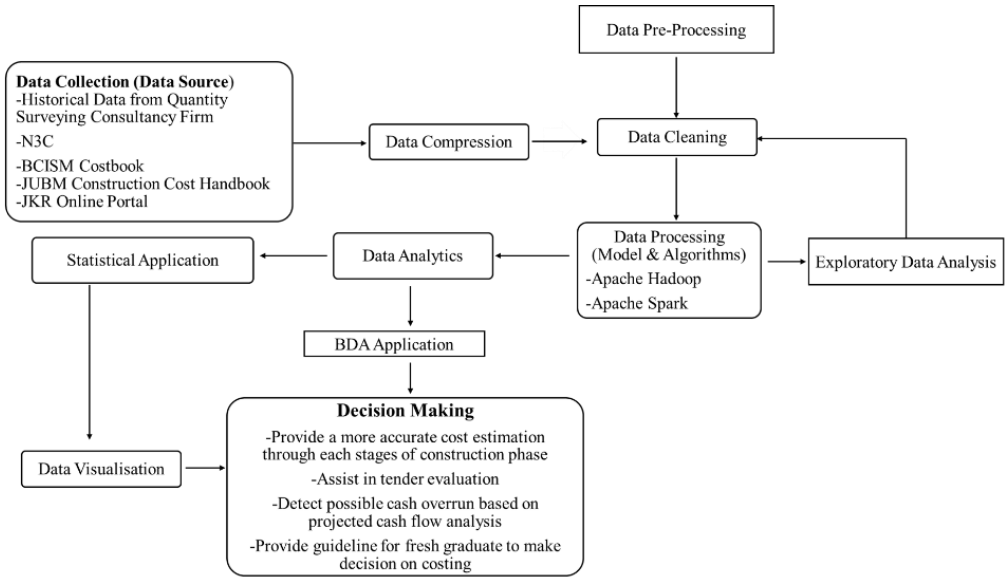

Figure 1: Framework of BDA on Construction Cost Estimation
(Modified from J. Lee, 2020 & Siddiqa et al., 2016)

METHODOLOGY

Questionnaire surveys were administered based on literature review to acquire the requisite data for fulfilling the research's aim and objectives. The digital questionnaire survey in the format of a Google Form were distributed via email and LinkedIn to 400 Consulting Quantity Surveying Practice that are registered with BQSM in Malaysia. A follow-up email and message were sent after one week to boost the response rate. 198 responses received out of 400 questionnaires sent, the response rate was 49.5%. The responses were automatically recorded in the Google Form. Lastly, a comparison between the primary data (data acquired from the questionnaire) and secondary data collection is conducted to provide a comprehensive conclusion in developing an improvised framework of BDA for Construction Cost Estimation based on the work by Lee (2020) & Siddiqa et al. (2016).

RESULTS AND DISCUSSION

The survey conducted as part of this research sought to gain insights into the prevailing patterns of cost overruns in construction projects within the Malaysian context. A crucial aspect of this inquiry involved inquiring about the implementation of BDA in construction cost estimation which involves the comprehension of big data analytics processes in the context of cost estimation, and an exploration of the challenges and potential solutions associated with the

integration of BDA. The survey respondents, primarily representing professionals in the construction industry yielded significant data, shedding light on the prevalent scenario of cost overruns within the Malaysian construction sector. The subsequent analysis of the survey responses revealed notable trends in this regard.

Understanding on big data analytics processes in construction cost estimation in Malaysia.

Table 3: Understanding of BDA processes in cost estimation.

Big Data Analytics (BDA) Processes	Mean	Median	Standard Deviation	Rank
Data Collection	3.55[b]	4.00	0.816	1
Data Compression	3.18	3.00	0.841	4
Data Cleaning	3.05	3.00	0.851	5
Data Processing	3.43	4.00	0.820	2
Data Analytics	3.25	3.00	0.875	3
BDA Application	2.78[c]	3.00	0.877	6

Based on the surveys, Table 3 shows that the overall understanding of implementing Big Data Analytics (BDA) in construction cost estimation is relatively low, with most respondents reporting only an average level of understanding on the BDA processes. This finding is similar with previous conducted research which show that the understanding of big data within the Malaysian construction industry was to be moderate (Nadia Maaz et al., 2018). The survey shows that, “Data Collection” process (μ= 3.55) have achieved the highest level of understanding among the 6 BDA processes followed by “Data Processing” process (μ= 3.43), "Data Analytics" (μ= 3.25), "Data Compression" (μ= 3.18), "Data Cleaning" (μ= 3.05), and "BDA Application" (μ= 2.78).

The challenge faced by the construction industry to adopt big data analytics in construction cost estimation.

According to the survey result as tabulated in Table 4, all the proposed challenges have received a median score of 4.00, indicating their significant impact that hinder the adoption of Big Data Analytics (BDA) in the construction in cost estimation. The constraints were measured analytically and ranked. Out of the 16 proposed challenges in adopting BDA, the top five most significant challenges are as follows: “Limited integration and interoperability between different data sources and systems” (μ=3.98), “Difficulty in obtaining data and maintaining data quality and consistency” (μ=3.96), “Resistance to change and lack of buy-in from stakeholders” (μ=3.95) “High initial and associated cost to adopt BDA” (μ=3.93) and "Lack of standardisation in data formats and quality" (μ=3.93).

High initial cost and lack of standardization share the same rank since their results on mean is similar. Meanwhile, the top five most notable challenges primarily revolve around issues concerning about data integration, data availability, data quality, awareness of BDA, and the high initial cost. It is of utmost importance to confront and overcome these obstacles to effectively introduce BDA into the construction industry. Through addressing these challenges head-on, organisations can unlock the full potential of BDA and optimise on its advantages, resulting in enhanced decision-making processes and increased efficiency in construction cost estimation.

Table 4: Significant level of constraints in adopting Big Data Analytics (BDA) in construction cost estimation.

Constraints in Adopting Big Data Analytics (BDA)	**Mean**	**Median**	**S. D.**	**RII**	**Rank**
Limited integration and interoperability between data sources and systems	3.98	4.00	0.587	0.7960	1
Difficulty in maintaining data quality and consistency	3.96	4.00	0.667	0.7919	2
Resistance to change and lack of buy-in from stakeholders	3.95	4.00	0.624	0.7909	3
High initial and associated cost to adopt BDA	3.93	4.00	0.741	0.7869	4
Lack of standardisation in data formats and quality	3.93	4.00	0.748	0.7869	4
Insufficient knowledge and expertise in BDA systems and process	3.91	4.00	0.674	0.7828	6
Limited understanding of the potential benefits of BDA	3.84	4.00	0.701	0.7677	7
No specific BDA guidelines for construction cost estimate	3.83	4.00	0.580	0.7657	8
Difficulty in ensuring data privacy and cyber security	3.83	4.00	0.761	0.7657	8
Difficulty in managing and analysing unstructured data	3.83	4.00	0.837	0.7657	8
Inadequate infrastructure and technology to support BDA	3.82	4.00	0.841	0.7636	11
Resistance from stakeholder to share data due to concerns about privacy and security	3.81	4.00	0.808	0.7616	12
Low acceptance of BDA in construction industry	3.80	4.00	0.758	0.7606	13

Constraints in Adopting Big Data Analytics (BDA)	**Mean**	**Median**	**S. D.**	**RII**	**Rank**
Limited availability of skilled BDA professionals in construction industry	3.80	4.00	0.688	0.7606	13
Insufficient accurate cost data for analysis	3.72	4.00	0.697	0.7444	15
Difficulty in aligning BDA strategies with organisational goals and objectives	3.62	4.00	0.729	0.7242	16

Solutions to enhance the adoption of BDA for construction cost estimation in Malaysia.

According to the results as tabulated in Table 5, it shows that all the solutions assessed received a median value of 4.00. This indicates that each of these solutions plays a significant role in enhancing the usage of BDA. The solutions were measured analytically and ranked. Out of the 14 proposed solution to enhance the adoption of BDA for construction cost estimation in Malaysia, the top five most significant solutions are ranked as follows: "Provide training and education programs to enhance the knowledge and skills of construction professionals in BDA." (μ=4.16), "Establish industry-wide standards and guidelines for BDA-based cost estimation" (μ=4.11), "Provide technical assistance and support to construction industry in the adoption and implementation of BDA-based cost estimation tools and processes" (μ=4.10), "Develop a BDA-based cost estimation tool that is user-friendly and can be easily integrated into existing software and systems." (μ=4.04) and "Conduct research and development to enhance the capabilities and accuracy of BDA-based cost estimation tools and processes." (μ=4.03).

Table 5: Significant level of solution in enhancing the usage of BDA in cost estimating in Malaysia construction industry.

Solution in enhancing the usage of Big Data Analytics (BDA)	**Mean**	**Median**	**S. D.**	**RII**	**Rank**
Provide BDA training and education programs to construction professionals.	4.16	4.00	0.600	0.8323	1
Establish industry-wide standards and guidelines for BDA-based cost estimation.	4.11	4.00	0.498	0.8212	2
Provide technical assistance and support for BDA-based cost estimation tools and processes.	4.10	4.00	0.510	0.8192	3
Develop user-friendly BDA-based cost estimation tool and software.	4.04	4.00	0.667	0.8081	4

Solution in enhancing the usage of Big Data Analytics (BDA)	**Mean**	**Median**	**S. D.**	**RII**	**Rank**
Conduct research and development on BDA-based cost estimation tools and processes.	4.03	4.00	0.513	0.8061	5
Initiative to foster a culture of innovation in new technologies, such as the adoption of BDA	4.02	4.00	0.617	0.8030	6
Encourage data sharing and collaboration among stakeholders	4.02	4.00	0.672	0.8030	6
Establish a centralised database for construction cost data that is accessible to all stakeholders in the industry.	4.01	4.00	0.600	0.8010	8
Improve data security and privacy by keeping the big data in an encrypted file	3.99	4.00	0.790	0.7990	9
Develop communication and outreach strategies to promote the benefits of BDA-based cost estimation.	3.97	4.00	0.649	0.7949	10
Implement standardised data formats to ensure consistency and accuracy of data.	3.97	4.00	0.528	0.7949	10
Provide incentives for stakeholders to adopt BDA-based cost estimation tools and processes.	3.95	4.00	0.693	0.7909	12
Establish partnerships with academic institutions and research organisations to advance the use of BDA in construction cost estimation.	3.94	4.00	0.618	0.7879	13
Establish a regulatory framework that supports the use of BDA in construction cost estimation and ensures compliance with data privacy and security regulations.	3.85	4.00	0.701	0.7707	14

The top five significant solutions identified in this research that can contribute to the development of a comprehensive strategy for enhancing the integration of BDA in the construction industry can be summarised as providing BDA training, establishing BDA standards, offering BDA technical support, developing user-friendly BDA processes, and conducting research and development on BDA applications. These solutions have been derived from the survey results and are crucial for ensuring the successful implementation of the BDA framework, resulting in precise cost estimation practices. The improvised framework of BDA for Construction Cost Estimation is then developed based on the work by Lee (2020) & Siddiqa et al. (2016) as shown in Figure 4.

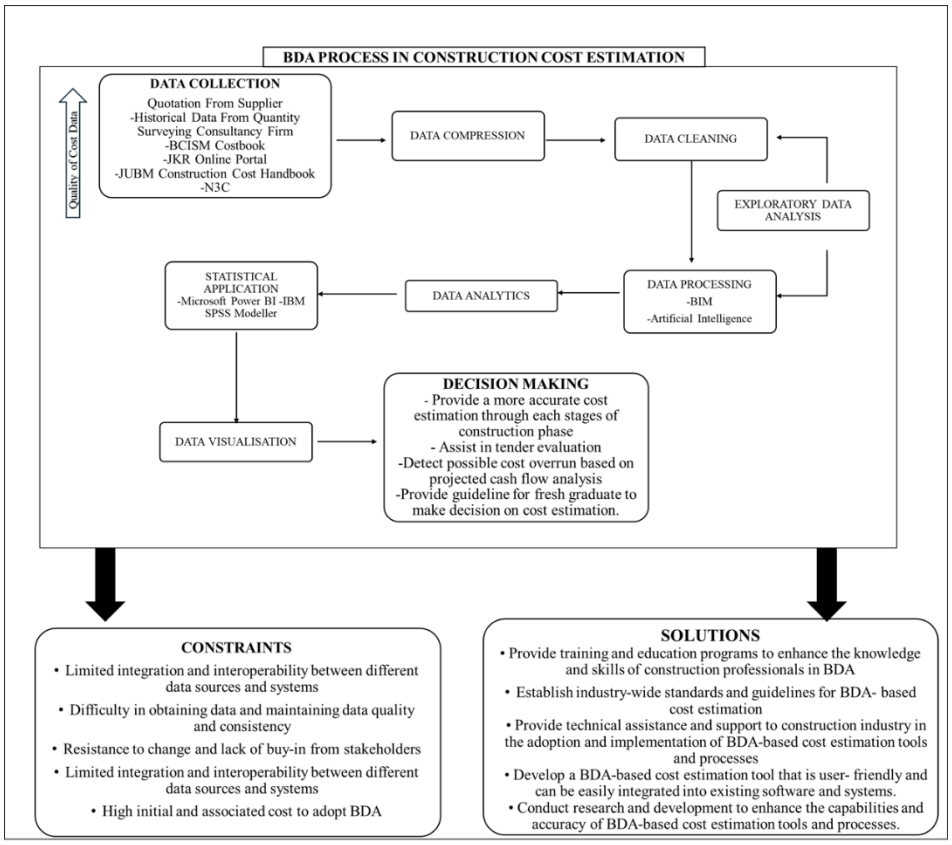

Figure 4: Proposed BDA Framework for Construction Cost Estimation

CONCLUSION

This research concludes and indicates a relatively low level of overall understanding regarding the implementation of Big Data Analytics (BDA) in construction cost estimation in Malaysia. Moreover, among the 16 proposed challenges in adopting BDA, the top five most significant challenges include limited integration between different data sources, difficulties in data acquisition, resistance to change, high initial and associated costs, and the lack of standardization in data formats and quality. Finally, the survey findings highlight the top five most significant solutions to enhance the adoption of BDA for construction cost estimation in Malaysia: providing training and education programs, establishing industry-wide standards and guidelines, offering technical assistance, developing a user-friendly and easily integrated BDA-based cost estimation tool, and conducting research and development to enhance the capabilities of BDA-based cost estimation tools and processes. The BDA framework emerges as a fundamental tool for cost estimators, notably quantity

surveyors, facilitating the digital transformation of the cost estimation process and substantively enhancing the precision of contemporary cost estimation methodologies.

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Received: 18th Mar 2024. Accepted: 6th July 2024