Journal of Civil Engineering and Management
ISSN 1392-3730 / eISSN 1822-3605
2023 Volume 29 Issue 6: 487–500
https://doi.org/10.3846/jcem.2023.19533

MANAGERIAL OPPORTUNITIES IN APPLICATION OF BUSINESS INTELLIGENCE IN CONSTRUCTION COMPANIES

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Received 12 March 2023; accepted 23 May 2023

Abstract. In construction projects, managers make multiple decisions every day. Most of these decisions are relatively unimportant; some of them are critical and could lead to the success or failure of a construction project. To ensure construction companies make effective managerial decisions, decision making requires performing an initial technical and economic analysis, comparing different decision-making solutions, using a planning system, and ensuring project implementation based on the provided plans. Therefore, the use of powerful systems such as business intelligence (BI), which play a central role in management and decision-making, is essential in project-based companies. The current study aims to determine and evaluate the main managerial opportunities in the application of BI in project-based construction companies using a descriptive survey approach. An empirical research questionnaire consisting of 60 factors and 7 categories was adopted. The questionnaire, after confirming its validity and reliability, was distributed to 100 experts engaged in 5 active project-based construction companies who were familiar with BI topics. To analyse the data, a one-sample *t*-test and the Friedman test were performed using the SPSS software. The findings indicated that the importance of the identified opportunities for the use of BI in project-based construction companies is above average and that, in the case of using BI in such companies, these opportunities can be used to improve project performance. The results of the current study can help managers and other stakeholders as an effective decision-making tool to better implement BI in project-based companies.

Keywords: business intelligence, construction companies, construction project, project-based companies.

Introduction

Construction projects, especially large and complex projects, have a profound impact on society, the environment, and the development and growth of local and national economies. During construction, essential structures such as public and private infrastructure and buildings are developed. To complete the construction project, significant financial, human, and physical resources are required. The extent of investment in construction projects indicates the need for new frameworks and an environment for proper implementation (Hajiani et al., 2018). The development and deployment of new management approaches and new technologies is required for the proper implementation of construction projects (Sindhwani et al., 2022; World Economic Forum, 2016).

Analysis of current construction projects shows that an increase in the duration of projects with the loss of potential opportunities, which, based on variations and changes in current conditions, including economic, political, and other types of crises, can result in significantly higher additional costs in these projects (Fadhil & Burhan, 2021; Musarat et al., 2021). To improve the current situation, it is necessary to strengthen the traditional management of construction projects and create tools that increase the efficiency and flexibility of the process while also including preventive actions. This tool is business intelligence (BI), which refers to novel strategies and technologies used to transform data into meaningful and actionable insights for executives and managers.

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Business intelligence is a broad term that combines architectures, tools, databases, analytical tools, applications, and methodologies that allow interactive access to real-time data, enable data manipulation, and provide valuable insights for managers to make better and more informed decisions (Turban, 2015). Furthermore, BI also includes a set of theories, methods, processes, and technologies to convert raw data to useful and meaningful information, then into decisions, and finally to actions (Rud, 2009). BI systems merge internal and external data with different formats and from various sources and gather them in data warehouses to support management decisions (Rausch & Stumpf, 2013). Managers use various tools to analyse past and present data to obtain new insights and improve decision making (Cataldo et al., 2022; Gudfinnsson et al., 2015). BI software makes analysis and report making much faster and more reliable (Djerdjouri, 2019; Gad-Elrab, 2021). BI systems give unlimited help to gain, analyse, and interpret the data to further decision making to develop business processes and procedures (Balachandran & Prasad, 2017). Hence, experts and project managers using BI can make effective decisions that improve overall project performance and gain competitive advantage. BI use within management processes enables companies to drive revenue or reduce costs and consequently increase profit (Azma & Mostafapour, 2012; S. Williams & N. Williams, 2007). In general, BI is an effective tool for a targeted analysis of projects and competition to make the strategic decisions and changes required to achieve the project objective. Rationality and intuition are important dimensions of the strategic decision process (Thanos, 2023). Although intuitive methods based on experience and professional knowledge enhance project success and performance (Abubakar et al., 2019), BI enables a project manager to use all available capabilities and convert them into a vast set of information and knowledge and gain a competitive advantage in the industry (Djatna & Munichputranto, 2015). Furthermore, intuition has a positive effect on decision outcomes in unstable decision environments and a negative effect in stable decision environments (Kowalczyk & Buxmann, 2015).

In large and complex projects, both in the private and public sectors, decision making is a continuous process (Golestanizadeh et al., 2023). These decisions can have different levels of importance and different short- and long-term effects and involve various individuals and roles at different levels of the project (Brichni et al., 2017). In fact, the decision-making process in construction projects is too dynamic and complex for the use of intuitive methods, resulting in the use of analytical methods and mathematical models. Possible future events and decision-making for their management in construction projects are of utmost importance, and the lack of attention to time factors and changes in technology and environmental and social conditions can result in significant damage and problems in these projects (Ndekugri et al., 2008). To support complex decision-making processes, BI mathematical and analytical tools exploit the available data to create information and knowledge (Sabherwal & Becerra-Fernandez, 2011). The application and knowledge of the features of BI systems can help experts and managers in construction projects not only during planning and decision making, but also to have a deeper understanding of possible opportunities and challenges, offer more applicable and better solutions for the management of construction project. In general, BI can be used both during project planning and implementation of projects and helps project managers select options that are more likely to result in project success during crises and critical decisions.

Construction project managers can measure, monitor, manage processes, and project performance using BI. The use of BI allows project managers to continuously control their operational activities and face less time loss, integrated data, and finally high performance indicators and improved project quality (Işik et al., 2021). Furthermore, by applying BI, construction project managers can achieve a precise understanding of the complex conditions of the project and simplify decision-making processes on financial and economic issues. In this way, they can provide up-to-date analyses and provide a forecast of the financial and economic operations of the project (Uçaktürk et al., 2015). They can also get the right information to the right people at the right time (Wieder & Ossimitz, 2015), make more accurate decisions (Turban et al., 2011). With the right decisions, construction project managers can not only perform an increase in the project, but also make their company more agile and gain a competitive advantage over other construction companies by discovering and identifying management opportunities (Bose, 2009; Petrini & Pozzebon, 2009).

Due to the increasing volume of construction projects conducted by project-based construction companies, construction project managers need various tools of business intelligence to determine important metrics and analyse various aspects of construction projects; assess the opportunities and challenges faced in construction projects; and analyse long-term plans and decisions to increase the success rate and return of construction projects. However, despite the importance of BI as a basis for development and competitive advantage in the management of construction projects and companies, most managers, investors, and stakeholders in these projects pay little attention to the use of BI, which can result in failure, delays, or low return on construction projects. Increasing the application of BI in management can help overcome many problems, especially in construction projects. On the other hand, despite the importance of BI in construction projects, very few studies have investigated its use. Most studies have focused on the analysis of core BI capabilities for business performance (Chen & Lin, 2021), BI in risk management (Wu et al., 2014), BI implementation to improve firm internationalization speed and agility (Cheng et al., 2020), BI application on cost reduction in construction project management (Mandičák et al., 2016), and BI as a knowledge management tool to make better base business decisions (Abusweilem & Abualous, 2019). The current study aims to identify the most important management opportunities in the use of BI in project-based construction companies to encourage managers in these companies to use BI to make project management decisions. These companies can then use BI to create opportunities for investment in new construction projects, as well as risk management, reduce construction costs, and minimize project implementation time to satisfy contractors, employer consultants, and other project stakeholders. Additionally, by using this approach, construction managers can focus on essential project objectives without wasting time, money, or energy. In fact, the current study seeks to answer the following questions: (1) What are the management opportunities created in project-based construction companies due to the use of business intelligence? and (2) What is the importance of identified opportunities due to the use of business intelligence by project-based construction companies?

1. Business intelligence and construction companies

Management of the factors that affect the performance of construction projects is essential to ensure the success of the project. Decision making is often an integral part of project management and is seen in all duties of project managers, including the determination of project policies and goals, the selection of implementation methods, the evaluation of the project, and other management activities. In general, decision making is one of the essential elements of project management. The selection of the best option available during the decision-making process is complex and includes some uncertainty. This can result in great challenges and complexity for project managers. Hence, construction project managers must have a more appropriate approach to deal with various issues that affect the project. Successful managers use scientific bases throughout the project process and are familiar with novel technologies for better project management and decision-making. One of the tools that can help managers deal with uncertain and ambiguous issues is BI. Using BI can result in significant development in the management of construction projects, as the most important advantage of BI during the decision-making process is to provide an effective tool to support and facilitating these decisions through analysis systems. Since effective decisions in construction projects require the gathering and use of applied knowledge, some data are more valuable than others. The selection and refinement to identify, gather, select, and use information in construction projects can be optimized using BI, which improves the efficiency of the implementation systems in construction projects and plans. However, BI can provide relevant, up-to-date, and credible project information and provides the ability to analyse and understand the concepts of a project through discovery and analysis. In general, the design of dynamic, organic, agile, and flexible structures in the shortest possible time in order to understand and respond appropriately to environmental changes is among the main advantages of BI.

According to Hosseinzadeh et al. (2022), the application of innovative business management systems can positively impact the marketing, management, internal operations, logistics, and performance of companies. Business innovation is accompanied by an improvement in profit growth (Mai et al., 2019), and the evaluation of profit and revenue is also part of a project evaluation (Cova et al., 2021). Furthermore, Paradza and Daramola (2021) concluded that through the use of BI, a company can improve organisational process, executive management decision-making, knowledge management, and risk management. Additionally, by managing risks, businesses can handle potential problems and ensure the success of their projects (Akcay, 2021; Luo et al., 2022), and BI tools can improve risk management, providing a 360-degree risk overview that allows the organisation to identify and mitigate these risks effectively (Amini et al., 2021). Decision making is a key to business and project success in any sector, especially in construction that requires the handling and management of various information and knowledge, and various systems and methods for decision support are emerging (Zhu et al., 2021). To stay competitive and improve its own performance, a company must make decisions, often promptly, based on accurate and timely information, and BI as a technology-driven process helps to make these decisions faster and more accurate (Djerdjouri, 2019). Similarly, Niwash et al. (2022) found that BI has a positive effect on competitive advantage and business performance. BI tools can track, analyse, and display key performance indicators (KPI) metrics to monitor the health of a business (Pande et al., 2022). Recent innovative technologies, such as artificial intelligence (AI), can support businesses through disruption (Naz et al., 2022).

Construction project managers are always faced with many profound challenges during project execution, and this means that they must deal with multiple issues (Huynh et al., 2021). According to Lopes and Boscarioli (2020), the application of BI and analytics tools can improve the performance of the management and decision-making process in the construction sector. In addition, professionals seek cost-effective solutions that result in rapid and accurate results and can shorten and simplify the process. In general, undefined goals, unrealistic schedules, insufficient software, poor communication, and other factors can cause problems in the project management process. BI systems can be used to improve the project implementation process and automatise project processes, predict various occurrences, reduce financial challenges and risks of the project; and finally, correctly analyse the relevant project data to gain more reliable information and finally improve project performance. Girsang et al. (2018) investigated the use of BI as a tool to validate construction company reports and concluded that construction companies in Indonesia have to develop and improve resources and construction technologies to provide accurate reports to governments and investors, identify market needs, project schedule, project costs, and the required level of experience in the company. It can be concluded that BI can facilitate rapid data storage, analysis, processing, and visualisation.

According to Xie et al. (2022), due to the high cost of construction projects, project managers have to use BI to improve forecasting and cost management decisions. On the other hand, BI systems can improve project agility, help managers make quick and accurate decisions, improve project performance, and control project costs. J. Pondel and M. Pondel (2016) concluded that the use of BI can integrate business processes and provides a novel data gathering and processing method for projects. These data can be used for decision making during projects, especially in critical situations. Additionally, BI can facilitate the suitable planning and sharing of knowledge during a project and improve the performance of the project. BI tools and big data can also provide project managers, shareholders, and members with valuable information and knowledge.

2. Research methodology

The current study was conducted to evaluate the most important management opportunities using BI in project-based construction companies using a descriptive and survey method with applied goals. In this vein, management opportunities were first identified through a literature review and the list of opportunities was strengthened through interviews with 10 experts in the field. The participants in the interview were managers and senior experts who have worked in the field of construction projects and were familiar with the topics of information technology including business intelligence. They had sufficient knowledge and experience regarding the opportunities that using this technology can bring for managers. Having an experience of more than 10 years for managers and work experience of more than 15 years for senior experts and relevant university educators have been the main criteria for selecting these people. These experts were selected by snowball sampling among experts and activities in the field of construction in the public and private sectors. Snowball sampling is a non-probability sampling method which is used when the sample is not conveniently available. In this method, the study participants select the next participants (Rubin & Babbie, 2017). Using this method, the expert selected for a survey was asked to provide information about others who might also be suitable for interviews. This process was continued until the selection of 10 experts by previous participants.

Using this list, a questionnaire that included 60 management opportunities using BI in project-based construction companies in 7 categories (information management, financial management, process management, performance management and evaluation, risk management, implementation management and stakeholders' management) was prepared. In the questionnaire, the respondents were asked to give their opinions on how much each of the identified indicators can be considered as management opportunities in the application of business intelligence in companies and construction projects. should be presented based on a 5-point Likert scale of measurement (i.e., very high, high, moderate, low, very low).

The validity of the questionnaire was limited to content validity, face validity, and structural validity. Face validity indicates the suitability of the questionnaire items to the topics they aim to assess (Taherdoost, 2016). To ensure face validity, the questionnaire was given to the experts for review. In the current study, the content validity was calculated using the content validity ratio (*CVR*) using the Lawshe equation. To determine whether the identified factors presented in the questionnaire can measure factors that affect the use of BI in project-based construction companies, 10 experts who participated in the previous step were asked to rate each item using a three-point Likert scale (required, useful but not necessary, not necessary). After gathering the opinions of experts, the frequency was calculated and the Lawshe equation (1) was used to calculate the *CVR*. The validity of each item was compared with Table 1, which shows the minimum acceptable value based on the number of experts. Since the validity of the content was above the minimum acceptable value of 0.62, all management opportunities and categories presented in Table 2 can measure BI opportunities for construction companies. The total content validity of the questionnaire was calculated as 0.93, which confirms the content validity of the questionnaire:

$$CVR = \frac{\left(n_e - \frac{N}{2}\right)}{\frac{N}{2}}, \qquad (1)$$

where CVR – content validity ratio; n_e – number of experts specify whether an item is necessary for the questionnaire; N – total number of experts evaluating the questionnaire.

Table 1. Minimum values of content validity ratio (Lawshe, 1975)

Number of experts	5	6	7	8	9	10	11	12
Minimum value	0.99	0.99	0.99	0.85	0.78	0.62	0.59	0.56
Number of experts	13	14	15	20	25	30	35	40
Minimum value	0.54	0.51	0.49	0.42	0.37	0.33	0.31	0.29

Table 2. Content validity ratio (Lawshe, 1975) of opportunities for the use of business intelligence in project-based construction companies

No.	Category	Opportunities	Neces-sary	Useful but not necessary	Unneces-sary	*CVR*
Q_1	Information management	Information support for using other projects' data	9	1	0	0.8
Q_2		Sending and receiving data from other systems	10	0	0	1
Q_3		Evaluating the amount of use of external data in project	10	0	0	1
Q_4		Up-to-date nature of project information	10	0	0	1
Q_5		Increasing information security level of the project	10	0	0	1
Q_6		Access to an automated warehousing system for the gathering and storage of data and information during project lifecycle	10	0	0	1
Q_7		Using suitable inputs for various project processes	9	0	1	0.8
Q_8		Reliability of the output of business intelligence systems for decision-making	9	0	1	0.8
Q_9		Availability of high-quality information	10	0	0	1
Q_{10}		Decreasing the volume of redundant data in project	10	0	0	1
Q_{11}		Facilitating access to data and information in all project parts	9	1	0	0.8
Q_{12}		Preparing backups and documentation of project information at various points in its lifecycle	10	0	0	1
Q_{13}		Integration of information during the project lifecycle from feasibility study to implementation and completion stages	10	0	0	1
Q_{14}		Integration of managers' information needs	9	1	0	0.8
Q_{15}	Financial management	Having a proper investment and economy outlook	10	0	0	1
Q_{16}		Predicting the profitability/loss of a project	10	0	0	1
Q_{17}		Decision-making for investment in new projects is based on the analysis of data from pervious projects	10	0	0	1
Q_{18}		Reducing decision-making costs	10	0	0	1
Q_{19}		Evaluating and controlling the budget used for project-related activities	9	1	0	0.8
Q_{20}		Timely allocation of resources based on project schedule	10	0	0	1
Q_{21}		Identification of opportunities to decrease costs and optimal use of resources	10	0	0	1
Q_{22}	Process management	Increasing productivity in project internal processes and transparency of key processes	10	0	0	1
Q_{23}		Compatibility of the business intelligence system with project processes	9	1	0	0.8
Q_{24}		Simplicity of adding new processes to the project and new topics to data warehouse	9	1	0	0.8
Q_{25}		Modification and implementation of management decision-making processes, creating accurate knowledge based on comprehensive and accurate real project data	10	0	0	1
Q_{26}		Ability to online analyses of project processes	10	0	0	1
Q_{27}		Speed and precision in reporting, analysis, and planning related to project processes	10	0	0	1
Q_{28}	Performance management and evaluation	Constant analysis of various data and attention to the performance of various project parts	10	0	0	1
Q_{29}		Constant analysis and evaluation of competitors' activities	10	0	0	1
Q_{30}		Monitoring project status, analysis of deviations from ideal conditions, productivity analysis, and prediction of trends in the project	10	0	0	1
Q_{31}		Access to modelling and prediction tools and visual aids such as dashboards and score cards for evaluating project performance	10	0	0	1
Q_{32}		Accurate setting of goals and the ability to evaluate their results	10	0	0	1
Q_{33}		Analysis of replacement methods in project planning and implementation and suggesting corrective and preventive actions	10	0	0	1
Q_{34}		Coordinating investment conditions based on organizational goals	10	0	0	1

End of Table 2

No.	Category	Opportunities	Neces-sary	Useful but not necessary	Unneces-sary	*CVR*
Q_{35}	Risk management	Control and management of risk in projects	10	0	0	1
Q_{36}		Decreasing uncertainty in various decision-makings related to the project	9	1	0	0.8
Q_{37}		The ability to better support project risk management	10	0	0	1
Q_{38}		Identification of various threats and their removal in order to advance the project	9	1	0	0.8
Q_{39}		Early identification of threats and opportunities in the project	9	1	0	0.8
Q_{40}		Finding places or conditions resulting in error in the project	9	1	0	0.8
Q_{41}		Once easing, confidence regarding strategic decisions	10	0	0	1
Q_{42}		Using business intelligence by managers to determine their strategies, encourage partners and stakeholders for continued cooperation or remove competition	10	0	0	1
Q_{43}	Implementation management	Evaluating future project requirements	9	0	1	0.8
Q_{44}		Preventing deviation from initial project aims	9	1	0	0.8
Q_{45}		Accurate identification of the needs of various active users in the project	10	0	0	1
Q_{46}		Using repeatable patterns and methods in project design	10	0	0	1
Q_{47}		Better preparedness for flexibly and rapid response to changes in project environment	10	0	0	1
Q_{48}		Better support for decision-making requirements of project management	10	0	0	1
Q_{49}		Identifying strategic project goals and planning to achieve these goals	9	1	0	0.8
Q_{50}		Prioritization of project implementation steps based on the value of each step	9	1	0	0.8
Q_{51}		Creating suitable communication channels between the project team and senior management	10	0	0	1
Q_{52}		Implementation of the project based on the project schedule or earlier with no delays	9	0	1	0.8
Q_{53}		Flexibility and modular nature and the ability to change and reuse all or part of the project based on the current conditions and environments of various units	10	0	0	1
Q_{54}		Rapid response to key project problems	10	0	0	1
Q_{55}		Attention to various employee needs and concerns during the planning and implementation of project	9	1	0	0.8
Q_{56}		Controlling resources and proper equipment allocation for better project implementation	10	0	0	1
Q_{57}	Stakeholder management	Identification of potential stakeholders for marketing activities related to the project	9	0	1	0.8
Q_{58}		Creating knowledge on stakeholders' requirements and needs and factors affecting them	10	0	0	1
Q_{59}		Categorizing stakeholders and creating varied methods for dealing with each group	10	0	0	1
Q_{60}		Improving relationships with project stakeholders	9	1	0	0.8

Furthermore, in order to investigate the structural validity of the questionnaire, confirmatory factor analysis was used applying the SmartPLS software. Factor loading coefficient between 0.4 and 0.6 is acceptable, and if it is greater than 0.6, it is very desirable (Fenstad et al., 2016; Pantouvakis et al., 2008). As can be seen in Figure 1, the factor load for all items in the questionnaire is greater than 0.4; therefore, it can be concluded that the model is adequate. However, in order to evaluate the convergence or divergence of the model in SmartPLS software, the convergent validity, divergent, validity and model fitting were examined using the Fornell and Larcker criterion, and the results are reported in Tables 3 and 4. The data was also analysed using the one-sample t-test and the Friedman test in SPSS software.

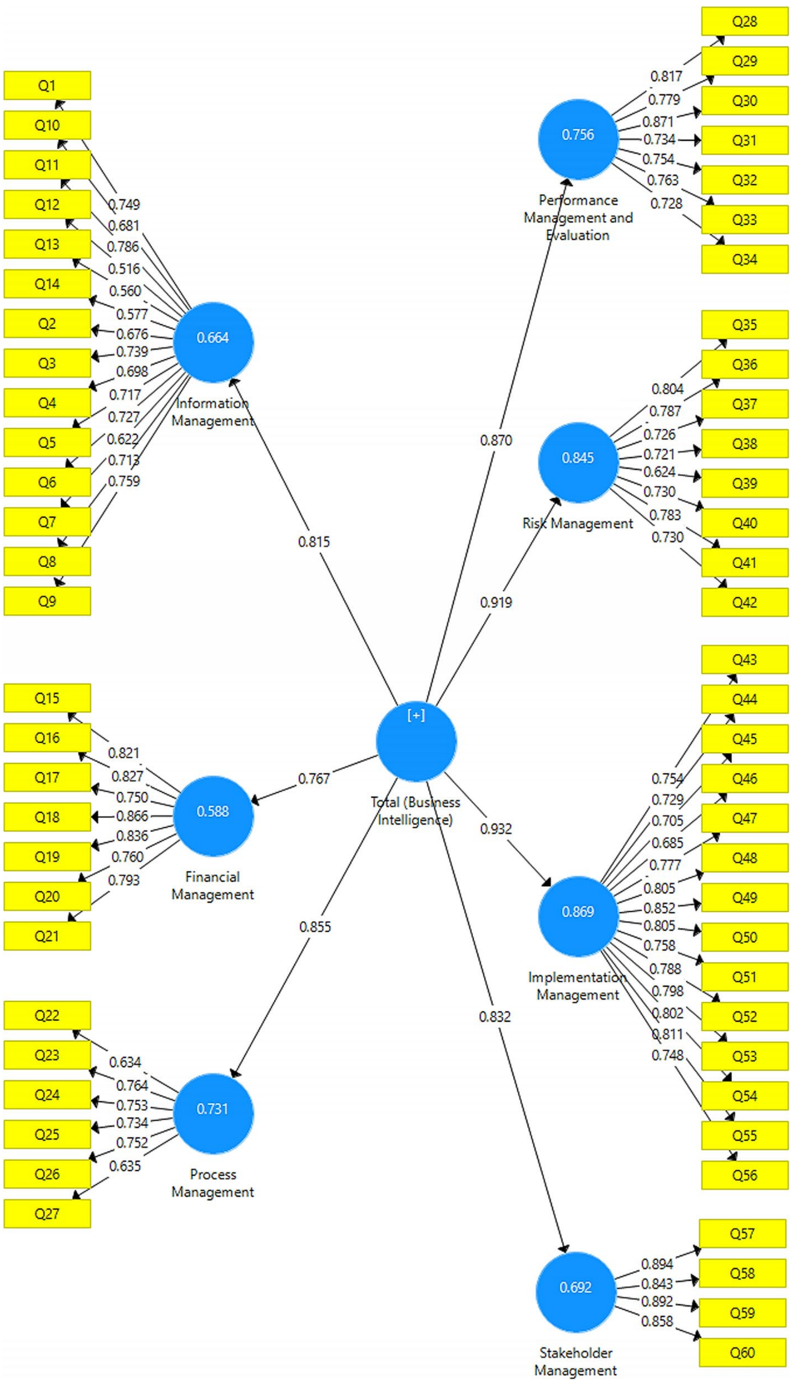

Figure 1. Loading factors of management opportunities for the use of business intelligence in construction companies

Table 3. Convergent validity, reliability and fitting factors

Variable	Cronbach's alpha values	Combined validity	Convergent validity, AVE	Communality	R^2	Q^2	f^2	*GoF*
Financial management	0.911	0.929	0.654	0.427	0.588	0.355	1.429	
Implementation management	0.948	0.954	0.599	0.358	0.869	0.482	6.627	
Information management	0.911	0.924	0.500	0.250	0.644	0.280	1.981	
Performance management and evaluation	0.891	0.915	0.607	0.368	0.756	0.423	3.101	0.516
Process management	0.807	0.861	0.510	0.260	0.731	0.341	2.723	
Risk management	0.881	0.906	0.548	0.300	0.845	0.429	5.470	
Stakeholders' management	0.895	0.927	0.761	0.579	0.692	0.491	2.250	

Table 4. Divergent validity of the model using Fornell and Larcker criterion

No.	Category	1	2	3	4	5	6	7
1	Financial management	0.808						
2	Implementation management	0.612	0.774					
3	Information management	0.657	0.632	0.707				
4	Performance management and evaluation	0.599	0.761	0.630	0.779			
5	Process management	0.713	0.712	0.695	0.677	0.714		
6	Risk management	0.586	0.693	0.658	0.710	0.716	0.740	
7	Stakeholders' management	0.516	0.835	0.598	0.628	0.610	0.824	0.872

Cronbach's Alpha values higher than 0.7 are often acceptable. However, Moss et al. (2008) suggested a threshold of 0.6 for Cronbach's alpha value for a small number of items. In structural models, composite reliability is a better criterion compared to Cronbach's alpha value. The composite reliability value higher than 0.7 for each construct indicates acceptable internal reliability of the measurement models, and values lower than 0.6 show a lack of reliability in the model (Werts et al., 1974). According to Fornell and Larcker (1981), convergent validity can be assessed by the average variance extracted (AVE), and AVE higher than 0.5 indicates acceptable validity. R^2 is a criterion that depends on the changes of each of the model variables and is determined based on independent variables. According to Chin (1998), and Hock and Ringle (2010), values close to 0.67 are suitable, values near 0.33 are normal, and values near 0.19 are weak fitting. The predictive quality criterion, Q^2, shows the predictive power of the model. According to Henseler et al. (2009), the positive Q^2 values indicate good model fitting and that the model has good predictive power. The f^2 criterion indicates the strength of interactions between model constructs and, according to Cohen (1988), values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects of a construct on other constructs. The *GoF* factor is used to evaluate the credibility or quality of the model. This factor is calculated using Eqn (2). Wetzels et al. (2009) state that 0.1, 0.25, and 0.36 indicate weak, medium, and strong value thresholds for *GoF*, respectively:

$$GoF = \sqrt{\text{average}\left(\text{Communality}\right) \times \text{average}\left(R^2\right)}. \quad (2)$$

The results presented in Table 3 indicate that Cronbach's alpha value and composite reliability for all categories are higher than 0.7. Therefore, the model has good reliability. Furthermore, the convergent validity for all groups is higher than 0.5, which indicates acceptable convergent validity. The values of R^2 indicate a good fitting of the structural model. Furthermore, based on Q^2 values, it can be concluded that the model has good predictive power and can predict values. The f^2 values also indicate that the effect size is acceptable, and the *GoF* value 0.516 indicates good fitting of the model.

The relation between each category and its factors compared to the relation between that category and other categories is determined using divergent validity. Fornell and Larcker (1981) state that divergent validity is acceptable when AVE for each category is higher than the shared variance between the category and other categories in the model (square of correlation coefficient between categories). As shown in Table 4, the model has acceptable divergent validity.

Finally, and after evaluating the validity and reliability of the questionnaire, among the companies active in the field of construction projects implementation, 5 companies were selected which were larger in terms of the number of employees and executive specialists than other companies and were also known as leading construction companies. Then, among the managers and senior experts of the projects, people who were experts in the field of business intelligence and the opportunities that this technology can bring for managers, experts were selected as the sample size. In fact, 100 experts who had gained more than 10 years of work experience and actively participated in at least 3 construction projects were selected based on stratified sampling.

3. Results of the survey

3.1. Identification of the management opportunities created by applying business intelligence

To analyse the data, inferential statistics including the one-sample *t*-test and the Friedman test were carried out in SPSS software. According to Table 5, the mean score for the entire questionnaire was 4.055 according to the participants and the mean scores for different categories of the questionnaire were 4.036 for financial management, 3.908 for implementation management, 4.118 for information management, 4.147 for performance management and evaluation, 4.100 for process management, 4.070 for risk management and 3.987 for stakeholders' management. On the other hand, the *P*-value is less than 0.05.

As shown in Table 5, the management opportunities identified during the use of BI in project-based construction companies in different categories (information management, financial management, process management, performance management and evaluation, risk management, implementation management, and stakeholders' management) have significant differences with a mean score of 3. Furthermore, based on the upper and lower

Table 5. Results of the one-sample t-test for management opportunities for the use of business intelligence in construction companies

Category	Frequency	Mean	SD	Test value = 3			Lower limit	Upper limit
				t	df	P-value		
Financial management	100	4.036	0.618	16.771	99	1.159	0.913	1.159
Implementation management	100	3.908	0.728	12.466	99	1.053	0.763	1.053
Information management	100	4.118	0.628	17.789	99	1.243	0.993	1.243
Performance management and evaluation	100	4.147	0.693	16.535	99	1.284	1.009	1.284
Process management	100	4.100	0.685	16.050	99	1.236	0.964	1.236
Risk management	100	4.070	0.736	14.521	99	1.216	0.923	1.216
Stakeholders' management	100	3.987	0.841	11.740	99	1.154	0.820	1.154
Overall questionnaire values	100	4.055	0.593	17.777	99	0.000	0.937	1.173

Table 6. Significant results for management opportunities and identified categories using the Friedman test

	Chi-square value	Degree of freedom	Significance level	Test result
Categories	9.979	6	0.026	H_0 rejected
Opportunities	190.187	59	0.000	H_0 rejected

limits of the positive confidence interval, it can be concluded that the importance of identified opportunities during the use of BI in project-based construction companies is above average, meaning that by using BI, these companies can use the identified opportunities.

3.2. Assessment of the management opportunities created by applying business intelligence

The results presented in Table 6 show that the level of significance is less than the 0.05 threshold ($P < 0.05$); therefore, it can be concluded that there is a significant difference between different categories and opportunities identified during the use of BI in project-based construction companies.

According to the results of the Friedman test presented in Table 7, the category of performance management and evaluation was the first regarding importance with a mean score of 4.40, process management was the second with a mean score of 4.21, risk management was the third with a mean score of 4.14, information management was the fourth with a mean score of 3.97, fifth was implementation management with a mean score of 3.89, sixth was stakeholders' management with a mean score of 3.81, and financial management was in the seventh place with a mean score of 3.60. Furthermore, opportunity Q_{45} (*Accurate identification of the needs of various active users in the project*) was in the first place with a mean score of 36.70, opportunity Q_7 (*Using suitable inputs for various project processes*) was in the second place with a mean score of 36.06, opportunity Q_{27} (*Speed and precision in reporting, analysis, and planning related to project processes*) was third with a mean score of 35.64, and opportunity Q_{15} (*Having a proper investment and economy outlook*) was the last with a mean score of 25.53 in the ranking of management opportunities using Friedman test.

4. Analysis of the results

As stated previously, BI can be effective in various management categories including information management, financial management, process management, performance management and evaluation, risk management, implementation management, and stakeholders' management. The results of the current study were similar to the results reported by Hosseinzadeh et al. (2022), Paradza and Daramola (2021), Lopes and Boscarioli (2020), Girsang et al. (2018), Xie et al. (2022), J. Pondel and M. Pondel (2016). According to the results of the current study, the performance management had the first importance ranking in the t-test and Friedman test. These findings indicate that by using BI, construction project managers can remove barriers and problems that result in project deviation, evaluate progress toward predefined goals, measure project productivity, and use constant data analysis to focus on different aspects of the project and other factors that affect it, leading to better project performance management. Hence, it can be concluded that the use of BI is queried during the management of construction projects to improve performance management and evaluation.

The process management category had the second importance ranking in the t-test and Friedman test. Interpreting these results shows that experts and managers in a construction project can use BI to predict, organize, and identify current inefficiencies in project processes; facilitate the decision-making process, and can also use BI to provide a faster and simpler analysis of project processes. This helps construction project managers use BI to increase the transparency and facilitate the management of project processes.

The risk management category had the third importance ranking in the t-test and Friedman test. Regarding the risk management category, the aim is to minimize uncertainty in the project, identify opportunities and threats in the project, and control and manage project risks using various tools. In this regard, the role of BI is not limited to gathering and integration of data and creating a risk warehouse for risk management; instead, experts and project managers can use BI tools such as artificial intelligence and data mining to make predictions, define various scenarios, conduct crisis tests, prepare risk management strategies, and create internal evaluation of project risks. Hence, using BI and its novel technological tools can help make intelligent risk management decisions to mitigate risks in the project. This indicates that the use of BI is necessary to achieve better project risk management.

The information management category had the fourth importance ranking in the *t*-test and Friedman test. These results indicate that, using BI and its analysis tools, project managers and experts can facilitate the extraction of qualitative information from available data and create the required knowledge for better project management and achieving project objectives. Achieving high-quality information and reducing data redundancy, online updating of project data, and other factors presented in the current study can also be used to make correct decisions in projects. This, therefore, strengthens the need and role of BI in construction projects.

Table 7. Mean ranking scores for opportunities and management categories for the use of business intelligence in project-based construction companies determined using Friedman test

Category (Mean rank score)	Category rank	Opportunities	Mean rank score	Rank within the group	Overall rank
Information management (3.97)	4	Q_1	30.84	6	24
		Q_2	25.91	14	58
		Q_3	31.18	4	20
		Q_4	28.97	11	44
		Q_5	26.58	12	55
		Q_6	30.08	8	30
		Q_7	36.06	1	2
		Q_8	29.02	10	43
		Q_9	34.01	3	6
		Q_{10}	34.96	2	4
		Q_{11}	30.97	5	23
		Q_{12}	30.60	7	25
		Q_{13}	29.87	9	33
		Q_{14}	26.16	13	56
Financial management (3.60)	7	Q_{15}	25.53	7	59
		Q_{16}	29.06	1	42
		Q_{17}	27.58	6	53
		Q_{18}	28.52	2	48
		Q_{19}	27.73	5	51
		Q_{20}	28.17	3	49
		Q_{21}	28.08	4	50
Process management (4.21)	2	Q_{22}	33.38	2	10
		Q_{23}	28.65	6	47
		Q_{24}	29.73	5	36
		Q_{25}	30.00	4	31
		Q_{26}	32.37	3	16
		Q_{27}	35.64	1	3
Performance management and evaluation (4.40)	1	Q_{28}	31.74	5	18
		Q_{29}	33.76	1	7
		Q_{30}	29.48	7	38
		Q_{31}	33.49	2	8
		Q_{32}	30.51	6	26
		Q_{33}	32.59	4	14
		Q_{34}	32.70	3	13

End of Table 7

Category (Mean rank score)	Category rank	Opportunities	Mean rank score	Rank within the group	Overall rank
Risk management (4.14)	3	Q_{35}	30.48	6	27
		Q_{36}	27.12	8	54
		Q_{37}	30.84	5	24
		Q_{38}	33.21	2	11
		Q_{39}	33.43	1	9
		Q_{40}	33.06	3	12
		Q_{41}	32.56	4	15
		Q_{42}	30.19	7	29
Implementation management (3.89)	5	Q_{43}	29.79	9	35
		Q_{44}	31.35	4	19
		Q_{45}	36.70	1	1
		Q_{46}	34.47	2	5
		Q_{47}	32.04	3	17
		Q_{48}	30.47	6	28
		Q_{49}	29.83	8	34
		Q_{50}	29.46	11	39
		Q_{51}	28.75	13	46
		Q_{52}	29.89	7	32
		Q_{53}	31.10	5	22
		Q_{54}	28.79	12	45
		Q_{55}	27.66	14	52
		Q_{56}	29.50	10	37
Stakeholder management (3.81)	6	Q_{57}	29.11	3	41
		Q_{58}	29.19	2	40
		Q_{59}	26.13	4	57
		Q_{60}	31.12	1	21

The implementation management category had the fifth importance ranking in the *t*-test and Friedman test. The results indicate that the use of BI can help identify the needs and requirements of project stakeholders and facilitate information gathering, induction and analysis of various methods for decision making during complex problems. Due to the effect of BI on accuracy, data processing, management, and duty analysis, it can have a significant effect in improving implementation management in construction projects.

The stakeholders' management category had the sixth importance ranking in the *t*-test and Friedman test. These results indicate that project managers must analyse information about stakeholders in order to find an appropriate balance between the different requirements of stakeholders and market conditions and achieve effective communication with customers. Moreover, managing interactions with customers using novel technologies, including business intelligence, can help to achieve more accurate, faster, and more rapid interactions with stakeholders. Furthermore, by gathering information regarding stakeholders in a database, project managers will be able to categorize these stakeholders according to different strategies and criteria. Therefore, these results point to the need to use BI in a construction project and to emphasize the stakeholders in these projects.

Finally, the financial management category had the seventh importance ranking in the *t*-test and Friedman test. These results show that using BI, it is possible to improve the financial management of projects, including cost estimation, budgeting, cost control, supervision, and reporting, and to systematically predict, control, and manage cash flow networks and project costs during implementation. Consequently, construction project managers can use BI to better manage financial affairs in construction projects.

Conclusions

The current study was carried out to identify the most important management opportunities during the use of business intelligence (BI) in project-based construction companies. Furthermore, management opportunities gained through the use of BI were extracted from a literature review and refined through one round of interviews with 10 experts, resulting in the identification of 60 management opportunities. The researcher-made questionnaire was then prepared based on 60 management opportunities under 7 categories including information management, financial management, process management, performance management and evaluation, risk management, implementation management and stakeholders' management based on the 5-point Likert scale. The face validity, content validity, and structural validity of the questionnaire was evaluated and confirmed as well as its reliability was evaluated and confirmed. The questionnaire was distributed among 100 experts active in 5 active project-based construction companies familiar with BI who were selected using stratified sampling. After gathering the questionnaires, the SPSS software was used for data analysis. The results indicated that the importance of management opportunities obtained through the use of BI in project-based construction companies is higher than average, and all identified management opportunities can be considered as somewhat strong key opportunities obtained through the use of BI in project-based construction companies. Furthermore, in the ranking of different categories, performance management and evaluation, process management, risk management, information management, implementation management, stakeholders' management and financial management achieved ranks from 1 to 7, respectively. Finally, the ranking of identified management opportunities in all categories – 'Accurate identification of the needs of various active users in the project' (Q_{45}), 'Using suitable inputs for various project processes' (Q_7) and 'Speed and precision in reporting, analysis, and planning related to project processes' (Q_{27}) – were identified as the 3 most important management opportunities obtained through the use of BI in project-based companies.

Project managers engaged in construction companies struggle with a large volume of data in various fields, including financial affairs, company needs, work deadlines, suppliers, production, etc. According to the findings of the current research, it can be acknowledged that by using business intelligence and creating construction control and analysis dashboards, it will cover all aspects and needs of these companies, including information review. Various projects, checking the profile of clients and project beneficiaries, project type, project start and end date status, checking how close the project is to completion, tracking the amount of completed work, cost breakdown, budget planning and development. In addition, it is also effective in creating business opportunities for managers, because obtaining the right information at the right time is the basis of successful decision-making and possibly the survival of the organization. Based on this, it is suggested that the managers of construction companies and projects put business intelligence at the top of their organizational planning in order to identify environmental opportunities faster than other commercial competitors. This requires that these companies increase the amount of investment in the use of business intelligence in construction projects.

Interviewing subject matter experts due to the lack of comprehensive studies in the field of BI in the construction industry, especially in developing countries, is an issue that can be considered as a main limitation for this research. This limitation is highlighted by the participation of experts in the interview from only one country. Future studies can increase the number of construction experts participating in a similar study to improve the generalizability of the results. Furthermore, as suggested by Sarvari et al. (2020), comparing the opportunities created through the application of business intelligence in projects based on the development level of countries (developed vs. developing countries) in order to determine any similarities and differences can also lead to valuable project results. Moreover, since the aim of this research was to recognize the management opportunities resulting from business intelligence in the construction industry, only the mean ranking score using the Friedman's test was used to rank the identified opportunities. To cover this limitation and obtain a more accurate list of high-importance opportunities, it is suggested that future studies may use multi-indicator decision-making methods or their fuzzy versions. Finally, the results of the current study can help stakeholders better decision-making regarding the use of business intelligence in project-based companies.

Author contributions

The paper is the joint efforts of the authors, their contributions vary on conceptualisation, methodology, analysis, investigation, resources and writing.

Disclosure statement

The authors declare that they have no competing financial, professional and personal interests from other parties.

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