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Leveraging the Knowledge Management Process for Sustainable Development in Small- and Medium-Sized Construction Companies: The Analytic Hierarchy Process Method

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Abstract: To navigate the complexities and uncertainties of the construction industry effectively, small- and medium-sized construction companies (SMCCs) require a robust management approach rooted in their accumulated experiences. From the perspective of knowledge management (KM), this study examined how SMCCs implemented the knowledge management process (KMP) to enhance their performance in a highly competitive and rapidly evolving market. It also explored the characteristics of SMCCs in terms of KM-related practices, investment allocations and strategic plans for leveraging KMP to improve performance. This study collected responses from managers of SMCCs with more than 10 years of working experience in residential, commercial and industrial projects in Ho Chi Minh City, Vietnam, on how they drive their business in the Vietnamese construction industry using KMP factors. Employing the analytic hierarchy process (AHP) approach, the study ranked the activities of KMP, which encompasses five main criteria with 28 associated activities, from the perspective of SMCCs. The research findings indicated that KMP criteria, namely knowledge utilisation (KU), knowledge dissemination (KD), knowledge responsiveness (KR), knowledge storage (KS) and knowledge acquisition (KA), were prioritised in order of values of 45.6%, 25.1%, 13.9%, 7.9% and 7.5%, respectively. The findings suggest that SMCCs should focus on implementing KMP based on two crucial factors, which are KU and KD and adopt a people-based approach that emphasises tacit knowledge with technology support. Using empirical data, this study revealed how SMCC managers drive their business activities for SMCCs in the construction market segment. By integrating KMP into their existing construction activities, SMCCs can optimise their operating and management processes, ultimately enhancing their sustainable competitiveness in the market.

Keywords: Analytic hierarchy process, Construction company, Knowledge management process, Small- and medium-sized, Vietnam

INTRODUCTION

Small- and medium-sized enterprises (SMEs) play an important role in the national economy. Nowotarski and Paslawski (2017) confirm that the SME sector plays an important role in the European economy and suggest that

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the Industry 4.0 concept be introduced into SMEs to extend knowledge and enhance development for this group. In Vietnam, SMEs contributed 45% of the gross domestic product (GDP) in 2020 (Ministry of Information and Communications, 2022), of which the construction industry contributed approximately 5% to 6% during 2016 to 2020. Particularly, in the construction industry, small- and medium-sized construction companies (SMCCs) have made significant contributions towards meeting social needs, creating jobs and contributing taxes to the government budget. Ali (2021) highlighted that SMCCs significantly contribute to socio-economic development and enhance the achievement of sustainable development goals in Nigeria.

SMCCs typically execute their contracts with small profit margins and high risks, which greatly affects their projects' success, customer satisfaction and reputation in the market (Malesev and Cherry, 2021). This, in turn, affects their development and poses several challenges. In the Vietnamese construction industry, continuous changes in construction techniques, materials and management processes have resulted in fierce competition among SMCCs in terms of the pricing and quality of construction services (Toan, Anh and Tam, 2023). This is due to the rapid increase in the number of SMCCs, the strong negotiating power of clients and the high risks associated with the industry, such as a lack of human resources and rising material prices (Anh, 2021). To tackle these challenges, SMCCs attempt to improve their adaptability through their marketing strategies, digital transformation and management systems.

Malesev and Cherry (2021) reported that digital and social media marketing strategies that consist of company websites and other social networks, including Facebook, YouTube, Instagram and X, help SMCCs get more clients and increase their client engagement and brand awareness. Maskuriy et al. (2019) suggested that to improve competitiveness, construction practitioners should partner with researchers in the information and communications technology (ICT) industry to enhance the use of the new technology of Industry 4.0 in their work processes and managerial activities. Butnariu and Luca (2020) reported that relational marketing that builds relationships with clients and other project parties develops trust-based relationships and reduces project risks. Lazaro-Aleman et al. (2020) highlighted that applying technology to the design and construction phases, such as using 3D models in the design phase to enhance customer experience and demonstrate construction methods, raises the visualisation of reports for stakeholders. It also increases management efficiency, reduces the risk of design conflicts, decreases documentation time and costs and improves productivity (Tayib et al., 2022). These solutions for enhancing SMCCs' adaptability in terms of current budgets, employee adaptability, used processes and level of technology adoption should be considered by top management.

This requires an overview of the organisation's processes (both construction and business) to identify the critical processes that should be focused on. SMCCs can utilise a knowledge management (KM)-based perspective to categorise business activities into processes, assess current knowledge management process (KMP) implementation and develop a plan for performance enhancement. The rapid evolution of digital technologies and sustainability requirements demands a more integrated approach. The current study provided empirical evidence for recent advances in the integrated approach by developing a comprehensive framework that considers technological capabilities and organisational readiness in KMP implementation.

KMP refers to an organisation's ability to acquire, store, disseminate, use and respond to changes in the market (Chen and Fong, 2013; Mohamad and Zin, 2019). Researchers and practitioners in the construction industry have adapted KMP in many aspects. For instance, Hallowell (2012) mentioned that construction companies develop safety management strategies using KMP, including identifying, capturing, storing and transferring safety knowledge. Olomolaiye and Egbu (2005) examined the impact of human resource policies on knowledge management. Núñez et al. (2018) proposed a mobile cloud-computing-based KM platform to manage lessons learned in different construction projects of SMCCs. Dang et al. (2020) stated that SMCCs with a higher level of KM capability implementation can achieve a higher degree of performance in market development. Furthermore, Chen and Fong (2013) stated that KM evolution depends on KMP cycle, which carries out an organisation's learning mechanisms. Lu et al. (2019) mentioned that, to deal with the challenges of the market and technological changes, SCCMs could adopt a KM-based managerial strategy (i.e., using ICT systems) to effectively manage the information, experience and knowledge used to improve their construction and client services. Based on the KMP concept, this study adapted KMP-related activities to form an assessment of SMCCs' KMP implementation in the Vietnamese construction industry.

In the Vietnamese construction industry, the evaluation of KMP implementation is necessary for SMCCs to develop strategies and allocate investments for adaptability improvement (i.e., technology adoption) using the KM-based perspective. The evaluation of KMP implementation to guide new investments in the post-pandemic period is supported by current economic and social issues. For example, digitising management activities and applying ICT for project information storage and dissemination to improve effective communication between stakeholders are tendencies of SMCCs in the new normal period (Ministry of Information and Communications, 2022). Available and free communication tools (e.g., Zalo, Line and Viber) are also being developed rapidly and have become popular and easily accessible to SMCCs. Regarding employees' adaptation, reports or training activities have been transformed into online or semi-online formats. Moreover, new-

generation engineers have become more familiar with construction simulation software (e.g., Navisworks, Revit and SketchUp) and construction information modelling (Anh, 2021). The prediction of market trends using simulations and construction models is a common requirement of investors to improve their experiences with 3D illustrations for design.

Therefore, integrating these conditions creates a favourable situation for digital transformation, which also leads to the proliferation of new solutions (i.e., new marketing strategies, technology and software). However, it also raises SMCCs' dilemma in choosing suitable solutions and planning development strategies. To support SMCCs in understanding their current situations and planning for digital transformation, evaluating KMP implementation becomes a potential tool to meet their demands. It provides an overview of how KMP activities transmit information throughout construction and business processes. This also helps SMCCs identify and point out suitable solutions to their situations and use them to support decisions regarding investment allocation for technology, process and human resources.

This study employed a novel mixed-methods approach that combines quantitative analytic hierarchy process (AHP) analysis with qualitative insights from industry practitioners. This method aligns well with the current study's research goals, particularly in obtaining prioritised insights from experts due to its advantages in handling small sample sizes (Vaidya and Kumar, 2006; Ishizaka and Labib, 2011). On the other hand, techniques, such as exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), are more appropriate for data structure exploration rather than supporting decision-making in complex situations (Kline, 2016). This study expected that aspects of a specific KMP development framework would be assessed and discussed to help SMCCs tailor their investment allocation to their unique characteristics.

The research question was: "How can a comprehensive KMP implementation framework be developed and assessed specifically for SMCCs to enhance their strategic decision making in resource allocation and digital transformation initiatives?" The specific objectives of this study were to identify (1) KMP factors to establish a framework that construction companies should implement for developing their strategies through a literature review and (2) elements in KMP framework to which SMCCs can allocate their resources using the AHP method. To achieve the research objectives, this study was conducted based on the steps outlined in the research framework (as shown in Figure 1).

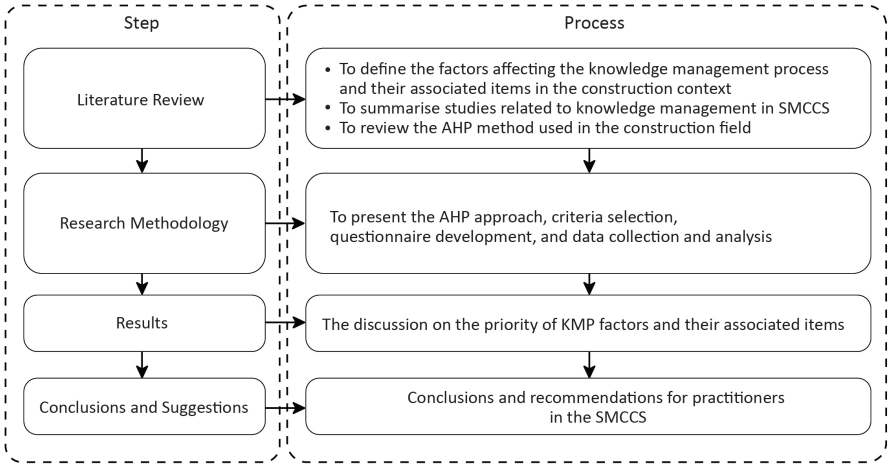

Figure 1. Research framework

The research framework consisted of four phases, each designed to advance the understanding of KMP implementation in SMCCs. The framework began with a literature review to identify, analyse and synthesise previous studies on KMP factors, their contextual applications and the use of AHP methodology in construction management. This phase transitioned into a research methodology wherein AHP serves as the primary analytical instrument, facilitating the development of hierarchical criteria structures and enabling pairwise comparisons through expert-informed questionnaires. The analytical phase then proceeded to quantitative evaluation, utilising AHP matrices to derive priority weights and consistency ratios, thereby establishing a hierarchical framework of KMP factors and their weights, which indicate their relative significance for KMP implementation. Finally, in the conclusion phase, the framework provided a discussion that translates analytical outcomes into recommendations, systematically mapping prioritised KMP factors to actionable implementation strategies.

Although previous studies have explored KMP implementation in construction-related contexts, this research still contributes to the existing knowledge. First, it develops a comprehensive KMP assessment framework tailored specifically to SMCCs in developing economies. This addresses a critical gap in the literature, as most KMP frameworks have been designed for large companies or developed markets thus far. Second, this study combined KMP implementation assessment with the AHP methodology to create a quantitative decision-support tool that helps SMCCs prioritise their limited resources for digital transformation initiatives. Third, unlike most previous studies that focus on isolated aspects of KM, such as knowledge sharing or knowledge utilisation, this study adopted a holistic approach by considering

the interconnections between knowledge acquisition, storage, dissemination, responsiveness and utilisation processes within the specific constraints and characteristics of SMCCs. These contributions provide both theoretical advancement in KMP literature and practical value for SMCC managers striving to enhance their organisational capabilities through strategic KM implementation.

LITERATURE REVIEW

Previous Knowledge Management-related Studies on Small-and Medium-Sized Construction Companies

Several studies have been conducted on the application of KM in SMCCs in both developed and developing countries to improve organisational performance (as shown in Table 1). Researchers and practitioners in the construction industry have identified the characteristics of SMCCs as having a small number of employees, limited budgets, management based on the owner of the company and a focus on specialised services. These characteristics result in barriers and opportunities for SMCCs to adopt KM-based applications (Dang et al., 2020; Durst, Bruns and Edvardsson, 2017; Mohamed et al., 2018). Three main approaches are suggested for KM adoption, namely (1) people-based, (2) people-based with information technology (IT) support and (3) IT-based (Standards Institution of Israel, 2011). The people-based approach focuses on humans to manage their tacit knowledge (e.g., experiences of workforces), whereas the IT-based approach focuses on systems to manage explicit knowledge (e.g., designs, cost estimation and project documents) (Standards Institution of Israel, 2011).

Hon and Chan (2014) reported that KM in the safety of construction projects relies merely on supervisors' motivation and workers' self-regulation. They suggested that SMCCs should focus on tacit knowledge and cultivate a knowledge-sharing culture. Yamasaki et al. (2018) added that knowledge sharing in SMCCs should not be considered tacit or explicit knowledge. Appropriate methods for sharing knowledge (e.g., job training and seminars), along with the improvement of leadership, are important activities to improve KM implementation in organisations. The cost and benefit of this people-based approach are suitable for the financial status of SMCCs. However, this approach is considered at the project and organisation levels and is carried out by individual companies.

Table 1. KM-related studies in SMCCs

Country Scale	Source	KM Approach	Country	Level	Topic
Developed country	Tan, Carrillo and Anumba (2012)	People-based with IT support	United Kingdom	O	Knowledge-based systems: Investigating the use of a software tool as the central system of the KM framework.
	Durst, Edvardsson and Bruns (2013)	People-based	Germany	O	Knowledge creation and sharing: Investigating how SMCCs create new knowledge.
	Park et al. (2013)	IT-based	Korea	I	Application of KM technologies: Investigating to facilitate KM activities within SMCCs by distributing a set of tailored KM technologies.
	Hon and Chan (2014)	People-based	Hong Kong	P	KM in safety: Investigating how safety knowledge of construction projects is managed.
	Valdez-Juárez et al. (2016)	People-based	Spain	O	KM for innovation and business performance: Exploring the ability of knowledge management to achieve innovation and business performance.
	Durst, Bruns and Edvardsson (2017)	People-based	Austria	O	Knowledge retention: Increasing our understanding of how SMCCs retain critical knowledge.
	Yamasaki et al. (2018)	People-based with IT support	Japan	O	Knowledge sharing: Investigating how engineers who participated in regional training programs shared their knowledge inside their organisation.
	Hartono et al. (2019)	People-based	Singapore	O	Knowledge management maturity: Developing alternative theoretical models to explain the possible association between knowledge management maturity (KMM) and firm performance within a project-based firm setting.

(Continued on next page)

Table 1. *Continued*

Country Scale	Source	KM Approach	Country	Level	Topic
Developing country	Hoła, Sawicki and Skibniewski (2015)	IT-based	Poland	I	Knowledge map: Presenting an IT model of a knowledge map to support KM.
	Alashwal, Abdul-Rahman and Asef (2017)	People-based	Malaysia	O	Knowledge acquisition and sharing in risk management: The influence of organisational learning on risk management maturity
	Mohamed et al. (2018)	People-based	Malaysia	O	Knowledge sharing: Investigating the factors that promote knowledge sharing initiatives in quantity surveying firms.
	Dang et al. (2020)	People-based	Vietnam	O	Knowledge management capability: Investigating the effect of firms' knowledge-management capability on their market development performance.
	Adi, Hiyassat and Lepkova (2021)	People-based with IT support	Jordan	O	KM model: Developing a knowledge management model that construction companies can apply for effective knowledge management implementations in their businesses.
	Egwunatum and Oboreh (2022)	People-based with IT support	Nigeria	O	KM practices: Investigating to assess the factors limiting a full-scale implementation of effective KM practices among SMCCs.

Note: I = Industry; O = Organisation; P = Project.

Some studies support the people-based with IT support approach to enhance KM implementation in SMCCs. For example, Park et al. (2013) proposed a set of KM technologies to synthesise them into a web-based construction KM portal system for inter-organisational sharing of construction knowledge. Hoła, Sawicki and Skibniewski (2015) presented an IT model of a knowledge map to support KM implementation in SMCCs in Poland. The model included seven knowledge domains: (1) system and environment, (2) assets and resources, (3) processes, (4) documents, (5) completed and ongoing projects, (6) analysis and corrections and (7) lessons learned. However, past studies that enhance KM implementation using an IT-based approach have commonly been conducted at the industry level by professional associations or the government.

Table 1 provides a summary of KM activities in increasing SMCCs' construction performance. However, KM implementation plans should be tailored for specific goals, given the differences in scopes, investment budgets and demands.

Roles of Knowledge Management Process in the Technological Adoption of Small-and Medium-Sized Construction Companies

KMP comprises dynamic processes of creating, sharing, storing, using and managing information and knowledge within organisations (Chen and Fong, 2015; Novák, 2017). It is supported by information management tools in each phase of the project (Oesterreich and Teuteberg, 2016). For example, Oti Tah and Abanda (2018) proposed the integration of lessons learned from KM with building information modelling (BIM) to improve knowledge utilisation in projects. The more the management requirements, the greater the BIM investment is required. Makabate et al. (2022) argued that the adoption of BIM-related technologies depends on the specific needs of SMCCs. In the design phase, using BIM 3D modelling helps in presenting design ideas effectively. In the construction phase, BIM helps manage construction progress and promotes coordination among stakeholders to reduce misunderstandings. In the post-construction phase, BIM is used for operation and maintenance. Lazaro-Aleman et al. (2020) highlighted that SMCCs could reduce the document approval time of stakeholders by 75% through digital transformation using BIM technologies. To avoid changes in internal procedures becoming "a nightmare", construction companies have implemented a knowledge management system (KMS) framework that is similar to the ConstruKnowledge KMS proposed by Vaz-Serra and Edwards (2020). This framework leverages basic ICT collaboration tools to streamline the development and use of KM within the company, thereby minimising disruptions to existing internal procedures. The selection of IT tools needs to be suitable for the organisation's KMP plan. Although the benefits of KM-based technology are recognised, the investment costs should be considered by SMCCs based on the development strategy.

Knowledge Management Process Factors and Their Associated Items in the Construction Industry

KMP is a managerial function used to manage the flow of knowledge (Darroch and McNaughton, 2003). Egbu (2004) defines KMP as a cyclic process by which knowledge is created, shared, transferred, stored, exploited and measured for the benefit of construction companies. KMP embraces activities of construction projects and is associated with the data, information and lessons learned created and reused by construction companies. Mohamad and Zin (2019) defined KMP as "a range of activities for creating, acquiring, storing, disseminating and using new ideas and knowledge to enhance learning and performance in organisations."

KMP activities are interrelated and form a process (i.e., a linear or cyclical process) (Ahmad and An, 2008). For example, Gonzalez and Martins (2017) state that KMP factors (i.e., acquisition, storage, distribution and use) form a linear process to improve performance. Similarly, Magnier-Watanabe and Senoo (2008) mention that KMP factors (i.e., acquisition, storage, diffusion and application) are integrated into a linear process of the KM value chain in companies to achieve higher performance. Nonaka and Takeuchi (2009), in contrast, state that the dynamics between tacit and explicit knowledge are captured by the cyclical process of four KMP factors (i.e., socialisation, externalisation, combination and internalisation). Chen and Fong (2013) develop a systems dynamics model to capture the improvement of KMP cycles in the construction industry. They concluded that KMP cycles, including knowledge acquisition (KA), knowledge dissemination (KD), knowledge responsiveness (KR) and knowledge utilisation (KU), operate as a reinforcing loop for KM leverage to enhance companies' performance. Chen and Fong (2015) mention that a company's learning routine is the cyclical process of four KMP factors enhancing business performance, namely KA, KD, KU and knowledge identification (KI).

In the construction industry, KMP factors have been mentioned in various ways. For example, Suresh et al. (2017) mentioned that KMP factors of management activities in construction projects comprise practices to identify, capture, codify, store, transfer and create knowledge among project participants to manage the costs of projects effectively. Ping Tserng and Lin (2004) stated that storing project information in a database is an important KMP activity to enhance knowledge maturity in construction companies. Wibowo, Waluyo and Zhabrinna (2018) concluded that KMP factors in the KP cycle, including creation, sharing, acquisition, documentation, application, responsiveness, transfer and dissemination, have significant influences on construction companies' performance.

KU has five sub-criteria, namely "Using accumulated knowledge to solve problems" (KU1), "Using knowledge to deal with competitive conditions" (KU2), "Using existing knowledge to improve company business processes" (KU3), "Using new knowledge to improve company business processes" (KU4) and "Using knowledge to adapt strategic directions" (KU5). New knowledge is created while using previous knowledge to improve a company's business processes with innovation. Maqsood and Finegan (2009) mentioned that the capability of construction companies is improved continuously by innovation through organisational learning mechanisms using KMP. Cheung and Qi (2017) mentioned that construction organisations should create an encouraging culture to empower their employees and enhance their technical and innovation capacity through research and development and knowledge exchange with other firms and professional institutes.

Similarly, KD also comprises five sub-criteria, namely "Encouraging two-way communication" (KD1), "Disseminating knowledge through staff mentoring" (KD2), "Disseminating market trends and developments among internal departments" (KD3), "Disseminating knowledge within the company using updated technology" (KD4) and "Disseminating hard copies (e.g., reports and newsletters) to stakeholders" (KD5). Communication is an important KM activity that helps disseminate information and knowledge, especially between people (i.e., employees and managers). For example, Chen and Mohamed (2010) stated that tacit KM activities involving human interaction are essential for construction companies to achieve their long-term organisational goals. It has a stronger strategic role than explicit KM in the construction industry. Zhang and He (2016) also mentioned that trust has an effect on tacit knowledge sharing within integrated project teams. Saini, Arif and Kulonda (2017) investigated the critical success factors (CFSs) affecting the transfer and sharing of tacit knowledge in lean and agile construction processes. They concluded that 'trust between construction organisations' is the foremost CFS. This expresses the importance of humans in knowledge dissemination for KMP implementation.

KR has five sub-criteria. They are "Responding to changes in client needs" (KR1), "Responding to market changes in the market plan" (KR2), "Responding to clients' reactions to technological changes" (KR3), "Responding to competitor strategies" (KR4) and "Responding to employees" (KR5). Darroch (2005) mentioned that a company's relationship with clients is a tacit knowledge activity that helps reduce the gap between internal company activities and performance in the market. Wibowo, Waluyo and Zhabrinna (2018) stated that KR-related activities can help construction companies improve their performance. In addition, KR promotes better services for clients and initiates KA to obtain knowledge from them.

Meanwhile, KS consists of six sub-criteria: "Storing knowledge using the data warehousing technology" (KS1), "Authorising the accessible permission into the database" (KS2), "Conducting data screening before saving them into the database" (KS3), "Conducting procedures for knowledge storage" (KS4), "Storing knowledge in hard copies" (KS5) and "Storing lesson learned into the database" (KS6). Park et al. (2013) mentioned that applications of KM technologies could combine codification and personalisation to synchronise and support KMP in accumulating company knowledge. Fong and Choi (2009) mentioned that companies can store a large portion of their knowledge in a highly accessible form as explicit knowledge, thereby preserving it as organisational memory rather than leaving it as a private individual asset. It initiates easy access to knowledge for company employees to conduct KMP activities.

Finally, KA comprises seven sub-criteria, namely "Acquiring knowledge from market research" (KA1), "Acquiring knowledge from the employee's KPI processes" (KA2), "Acquiring knowledge from client feedbacks" (KA3), "Acquiring knowledge from the financial reporting systems" (KA4), "Acquiring knowledge from competitor strategies" (KA5), "Acquiring knowledge from previous project's experiences" (KA6) and "Acquiring knowledge from the standard benchmarking systems" (KA7). Yousaf and Ali (2018) mentioned that both KA and KR are important for construction companies' innovation, which is a competitive advantage in the market environment. These statements support this study's result that SMCCs can benefit from the market through interactions with clients and market research. From this perspective, the ability of business owners is emphasised as a key determinant of competitiveness for SMCCs, as it helps companies adapt to changes in the market and provide services that meet clients' demands (Mohamad and Zin, 2019). In this study, five key KMP factors were extracted from the construction-related literature (as shown in Table 2).

Table 2. KMP factors and their associated items

KMP Factor	Associated Item
KA	1. Market research (KA1) 2. Employee's key performance indicators (KPI) processes (KA2) 3. Client feedback (KA3) 4. Financial reporting system (KA4) 5. Competitor strategies (KA5) 6. Previous project's experiences (KA6) 7. Standard benchmarking system (KA7)
KD	1. Two-way communication (KD1) 2. Staff mentoring (KD2) 3. Market trends and developments among internal departments (KD3) 4. Using updated technology (KD4) 5. Hard copies to stakeholders (KD5)

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Table 2. *Continued*

KMP Factor	Associated Item
KR	1. Changes in client needs (KR1) 2. Market changes in market plan (KR2) 3. Client's reactions on technological changes (KR3) 4. Competitor strategies (KR4) 5. Employees (KR5)
KS	1. Data warehousing technology (KS1) 2. Authority for the accessible data (KS2) 3. Data screening (KS3) 4. Procedures for knowledge storage (KS4) 5. Hard copies (KS5) 6. Lessons learned (KS6)
KU	1. Accumulated knowledge to solve problems (KU1) 2. Knowledge to deal with competitive conditions (KU2) 3. Existing knowledge to improve company business processes (KU3) 4. New knowledge to improve company business processes (KU4) 5. Knowledge to adapt strategic directions (KU5)

Notes: Corresponding studies include Chen and Fong (2015), Suresh et al. (2017), Wibowo, Waluyo and Zhabrinna (2018), Mohamad and Zin (2019) and Khoa and Chinda (2023).

RESEARCH METHODOLOGY

Analytic Hierarchy Process Approach

AHP is a method for dealing with complex problems related to multiple-criteria decision-making. It provides a comparison of considered options for decision makers (Saaty, 2004). It subdivides the main problem, defined by decision makers, into different levels using a hierarchical form. At each level, pairwise comparisons are established based on the elements in the hierarchical structure and assessed by experts. The approach provides important weights of elements and rankings of alternative solutions in a preference list (as shown in Figure 2).

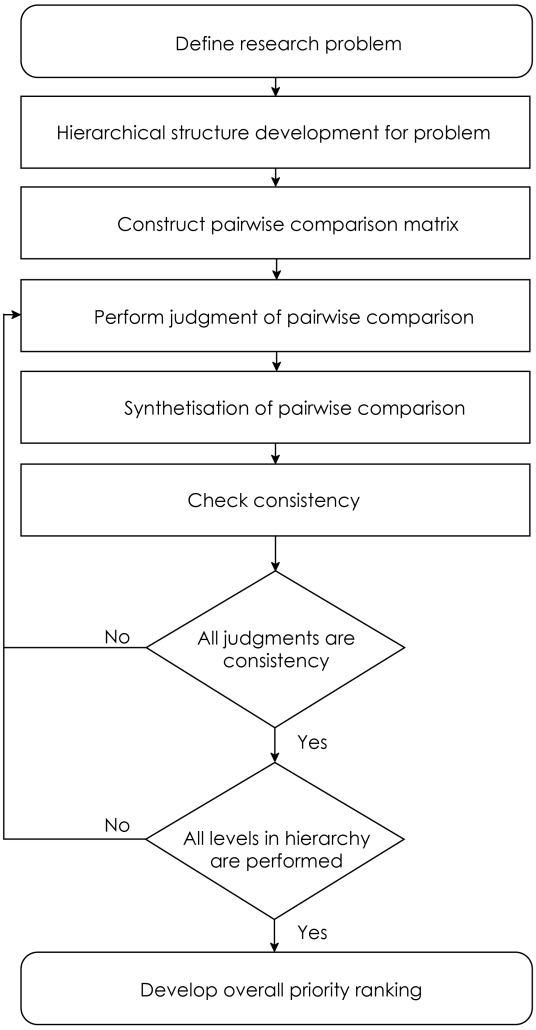

Figure 2. Outline of the AHP approach

The AHP method has been utilised in various KM-related topics in the construction industry. For example, Koc, Ekmekcioğlu and Işık (2023) used the AHP method to examine the sustainable supplier selection process in the Turkish construction industry and concluded that economic sustainability and KM capabilities are two important factors on which suppliers should concentrate to achieve the best results. Albooyeh and Yaghmaie (2019) utilised the fuzzy AHP method to evaluate the KM model in Iranian construction companies and indicated that data is the most important aspect of KM factors. Arif, Mohammed and Gupta (2015) examined factors affecting knowledge sharing among Jordanian construction companies and concluded

that trust, management and communication are the three most important components that constitute knowledge sharing in companies. Senaratne et al. (2021) mentioned that research studies examining the utilisation of AHP along with the application of social network analysis to KM practices in the construction industry are still required.

AHP has been playing the primary role as a decision-making tool to prioritise and evaluate various factors impacting construction projects, such as supporting risk management, decision-making and sustainable practices. For example, Darko et al. (2019) stated that AHP is widely used in construction management and in structuring decision-making problems to address risk management and sustainable construction challenges. In addition, it is used to analyse complex situations and make informed decisions by structuring problems into a hierarchy of more easily comprehensible sub-problems. Tabejamaat, Ahmadi and Barmayehvar (2024) used AHP to prioritise key factors, such as technical capabilities, economic considerations and pollution reduction, in the context of using BIM to enhance knowledge management in large-scale construction projects. Moreover, AHP is used to develop decision-making models for sustainable construction management. Erdogan, Šaparauskas and Turskis (2019) reported that AHP helps in setting goals, defining requirements and managing resources effectively, as demonstrated in the development of the model to select the best contractor in Turkey. In this study, the AHP method was used to assess KMP implementation in SMCCs. It is expected that the results will provide insights into KMP implementations and how SMCCs allocated their investment in KM development to achieve the Industry 4.0 target.

Research Design

Research process and criteria selection

The criteria used in the AHP analysis were adopted from the construction- and KM-related literature (as shown in Table 1). They formed a hierarchical model of KMP development, as shown in Figure 3, adapted from Khoa and Chinda (2023).

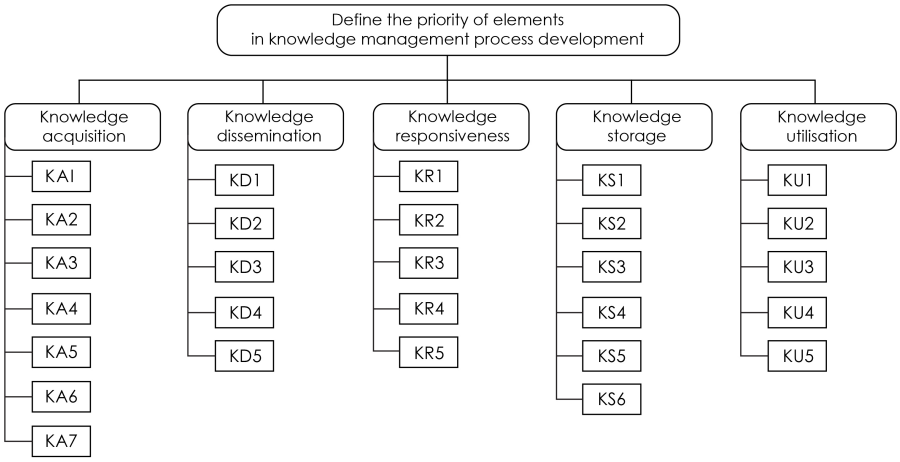

Figure 3. Hierarchical model of KMP in SMCCs

Interview question development

Based on the hierarchical model shown in Figure 3, the interview question was developed using the AHP fundamental scale to gather data for the AHP analysis. The scale was arranged from 1 to 9 points for pairwise comparison. The odd points, including 1, 3, 5, 7 and 9, were defined as intensity, including equal, moderate, strong, very strong and extreme importance, respectively. In contrast, the even points, namely 2, 4, 6 and 8, were used to express intermediate values (as shown in Table 3) (Saaty, 2004). The interviewees involved in the interview process provided a score for each pair of criteria (or sub-criteria). For example, if the interviewee believed that KA had an extreme importance in initiating the KMP programme in SMCCs compared with KD, a score of 9 was given to the KA criterion.

Table 3. The pairwise comparison scale

Intensity of Importance	Explanation	Score
Equal	Both aspects are equally important	1
Moderately	An aspect is moderately preferred over another	3
Strongly	An aspect is strongly preferred over another	5
Very strongly	An aspect is very strongly preferred over another	7
Extremely	An aspect is extremely preferred over another	9
Intermediate values	–	2; 4; 6; 8

Prior to conducting the interviews, a pilot test was conducted with the experts in the construction industry to ensure meaningful interpretation of the criteria and sub-criteria in the hierarchy levels. Three experts from the industry, senior managers and researchers, confirmed the viability of measuring each question through the item objective congruence index. This finalised the interview questions used in the data collection process.

Data collection and analysis

The interview sessions were set to collect data from experts. In this study, five experts and professionals in management positions with more than 10 years of working experience in residential, commercial and industrial projects in Ho Chi Minh City, Vietnam, were involved in the interviews. According to Alnaqbi and Hazza (2023), a minimum of five experts involved in the AHP analysis is acceptable. Each expert provided scores for the pairwise comparisons. The scores were input into the Expert Choice software to calculate the consistency ratios (CR), refer Equations 1 to 3 (Ishizaka and Labib, 2009). The acceptable CR values are based on the matrix sizes and random index (RI) values (as shown in Table 4) (Chinda et al., 2023). The weights in Saaty's approach (the vector) are normalised components of the eigenvector corresponding to the largest eigenvalue (λ_{max}):

$$Aw = \lambda_{max} W \qquad \text{Eq. 1}$$

where A is an inverse symmetrical matrix of the n criteria. In addition, λ_{max} represents the largest eigenvalue of the inverse symmetrical n-order matrix ($\lambda_{max} \geq n$). If the matrix is absolutely consistent and the elements of the columns are proportional, $\lambda_{max} = n$. Matrix consistency is defined by the difference $\lambda_{max} - n$ and the order of the matrix , in which the smaller the difference, the higher the consistency of the matrix of the expert's estimates. Consistency index (CI) is defined as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad \text{Eq. 2}$$

The relationship between the calculated CI of a particular matrix and the average RI value is referred to as the consistency relationship. CR determines the level of matrix consistency:

$$CR = \frac{CI}{RI} \qquad \text{Eq. 3}$$

Table 4. Random index (RI)

Matrix size	1	2	3	4	5	6	7	8	9	10
RI	–	–	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Donegan and Dodd (1991)

RESULTS

The average matrix of the pairwise comparison of the five KMP criteria, calculated based on the assessment of experts and the priority vector, is shown in Table 5. The CR of this matrix was acceptable, with 0.02 which was less than 0.1, validating of the priority vector. In this vector, the weights of KA, KD, KR, KS and KU were 0.075, 0.251, 0.139, 0.079 and 0.456, respectively. Based on the weight values, the ranking of five KMP criteria, sorted from high to low, began with KU (the first with the highest-weight criterion), KD, KR, KS and finally KA (the fifth with the lowest weight criterion). To gain further information on the priorities, the average matrices of the pairwise comparison of sub-criteria, CR value for validation and their priority vectors are shown in Table 6.

Table 5. Averages of the pairwise comparisons of the main criteria

Criteria	KU	KD	KR	KS	KA	Priority Vector	Ranking
KU	1.00	1.50	5.04	3.84	6.55	0.456	1
KD	0.67	1.00	1.63	3.52	2.95	0.251	2
KR	0.20	0.61	1.00	2.26	1.94	0.139	3
KS	0.26	0.28	0.44	1.00	0.95	0.079	4
KA	0.15	0.34	0.52	1.05	1.00	0.075	5

Note: CR value = 0.02 ≈ 0 (consistency confirmed).

Table 6. Averages of the pairwise comparison of the sub-criteria

Averages of the Pairwise Comparisons of the Sub-criteria (KU)								
	KU1	KU2	KU3	KU4	KU5	Local Priority	Global Priority	Global Ranking
KU1	1.00	2.14	0.42	0.20	0.22	0.077	0.035	8
KU2	0.47	1.00	0.42	0.14	0.15	0.048	0.022	14
KU3	2.41	2.41	1.00	0.26	0.37	0.130	0.059	5

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Table 6. *Continued*

Averages of the Pairwise Comparisons of the Sub-criteria (KU)								
	KU1	**KU2**	**KU3**	**KU4**	**KU5**	**Local Priority**	**Global Priority**	**Global Ranking**
KU4	5.02	7.07	3.90	1.00	1.27	0.409	0.186	1
KU5	4.64	6.87	2.72	0.79	1.00	0.336	0.153	2
CR value = 0.01 < 0.10 (consistency confirmed)								
Averages of the Pairwise Comparisons of the Sub-criteria (KD)								
	KD1	**KD2**	**KD3**	**KD4**	**KD5**	**Local Priority**	**Global Priority**	**Global Ranking**
KD1	1.00	1.60	2.35	1.24	1.74	0.286	0.072	3
KD2	0.62	1.00	1.74	0.84	1.10	0.189	0.048	7
KD3	0.43	0.57	1.00	0.40	1.43	0.129	0.032	10
KD4	0.80	1.19	2.52	1.00	2.17	0.262	0.066	4
KD5	0.58	0.91	0.70	0.46	1.00	0.134	0.034	9
CR value = 0.02 < 0.10 (consistency confirmed)								
Averages of the Pairwise Comparisons of the Sub-criteria (KR)								
	KR1	**KR2**	**KR3**	**KR4**	**KR5**	**Local Priority**	**Global Priority**	**Global Ranking**
KR1	1.00	0.81	0.43	1.03	1.61	0.157	0.022	14
KR2	1.24	1.00	0.75	1.56	2.04	0.221	0.031	11
KR3	2.32	1.32	1.00	2.89	5.58	0.386	0.054	6
KR4	0.97	0.64	0.35	1.00	2.19	0.151	0.021	16
KR5	0.62	0.49	0.18	0.46	1.00	0.085	0.012	19
CR value = 0.01 < 0.10 (consistency confirmed)								
Averages of the Pairwise Comparisons of the Sub-criteria (KS)								
	KS1	**KS2**	**KS3**	**KS4**	**KS5**	**KS6**	**Local Priority**	**Global Priority**	**Global Ranking**
KS1	1.00	4.84	1.43	2.26	5.04	2.70	0.316	0.025	13
KS2	0.21	1.00	0.19	0.26	1.89	0.22	0.051	0.004	26
KS3	0.70	5.33	1.00	2.40	4.92	1.82	0.262	0.021	16
KS4	0.44	3.90	0.42	1.00	4.32	0.51	0.137	0.011	21
KS5	0.20	0.53	0.20	0.23	1.00	0.15	0.039	0.003	28
KS6	0.37	4.58	0.55	1.96	6.69	1.00	0.196	0.015	18
CR value = 0.04 < 0.10 (consistency confirmed)								

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Table 6. *Continued*

Averages of the Pairwise Comparisons of the Sub-criteria (KA)										
	KA1	**KA2**	**KA3**	**KA4**	**KA5**	**KA6**	**KA7**	**Local Priority**	**Global Priority**	**Global Ranking**
KA1	1.00	2.63	2.86	5.83	4.36	3.47	5.55	0.381	0.029	12
KA2	0.38	1.00	0.70	1.89	1.02	0.77	1.37	0.107	0.008	23
KA3	0.35	1.43	1.00	4.08	1.80	2.09	1.20	0.164	0.012	19
KA4	0.17	0.53	0.25	1.00	0.54	0.42	0.47	0.049	0.004	26
KA5	0.23	0.98	0.56	1.85	1.00	0.64	0.79	0.085	0.006	25
KA6	0.29	1.30	0.48	2.37	1.55	1.00	1.86	0.122	0.009	22
KA7	0.18	0.73	0.83	2.12	1.27	0.54	1.00	0.091	0.007	24
CR value = 0.02 < 0.10 (consistency confirmed)										

According to the results, the CRs of all pairwise comparisons of the sub-criteria were smaller than 0.10, confirming the validity of the priority vector calculations (as shown in Table 6). KU criterion ranked first with the highest priority vector value due to its sub-criteria priority. In terms of global ranking, KU4 was at the highest position, with the highest weight of 0.186. Furthermore, KU5 scored the second global place with a weight of 0.153. KU3 was at the fifth global place with a weight of 0.059.

KD had the second-highest priority vector value due to the contributions of KD1, KD4, KD2, KD5 and KD3, resulting in global ranking positions of 3, 4, 7, 9 and 10, respectively. The global priority weights of these sub-criteria were 0.072, 0.066, 0.048, 0.034 and 0.032, respectively. Similarly, KR placed third in KMP due to its sub-criteria's global priority values. For instance, KR3 is in the sixth global position with a priority value of 0.054. The other sub-criteria, including KR2, KR1, KR4 and KR5, are in the 11th, 14th, 16th and 19th positions, respectively. The two remaining KMP criteria, KA and KS, were given the lowest priorities due to their lowest sub-criteria rankings.

DISCUSSION

The results of the current study discovered that KU and KD accounted for a combined proportion of over 70% of KMP factors. This highlights SMCCs' emphasis on leveraging existing knowledge to enhance their operations. This finding aligns with the prevalent culture within SMCCs of drawing upon the expertise of senior staff in construction specialties. This practice aligns with their characteristics and differentiates them from large companies in terms of KM system investments. Durst, Edvardsson and Bruns (2013) noted that SMCCs typically operate with a flat organisational structure and a free-floating

management style, leading to a preference for people-based KM activities over IT-based approaches. SMCCs employ various methods to promote KMP implementation, including knowledge dissemination through workforce meetings, workshops and discussions; collaboration with customers, suppliers and subcontractors; training programmes and further education initiatives (Durst, Bruns and Edvardsson, 2017). The weights assigned to KU- and KD-related sub-criteria underscored the high priority placed on these aspects of KMP. Within the list of 28 sub-criteria (Table 6), the top five sub-criteria representing the most important KMP activities with a high global priority all fall under the KU and KD categories. These sub-criteria, with their respective global priorities, were KU4 (18.6%), KU5 (15.3%), KD1 (7.2%), KD4 (6.6%) and KU3 (5.9%). KU-related activities, including KU4 (which has the highest impact on KMP), KU5 and KU3, occupied three of the top five positions in terms of importance, emphasising the significance of utilizing new knowledge to improve business processes. To enhance company business processes and adapt strategic directions (KU4, KU3 and KU5), Mohamad and Zin (2019) advocated for SMCCs to consider investing in KM to foster innovation in both technology and administration, thereby enhancing competitiveness. For instance, companies have adopted 3D technology, replacing traditional drawings, for customer consulting processes, resulting in more accurate and efficient material estimates. Additionally, the use of IT to improve communication and coordination has led to shorter project timelines and reduced costs. Notably, KD1 and KD4 emphasised knowledge dissemination activities involving management teams and employees within SMCCs. Mohamed et al. (2018) highlighted the importance of companies encouraging knowledge-sharing initiatives through the support of senior management. This support encompasses communicating the value of KM activities, motivating and rewarding employees who excel in KM implementation and providing KM training to the workforce.

Meanwhile, KR, KS and KA received limited attention from top managers due to the inherent challenges faced by SMCCs. These challenges include a small workforce, high staff turnover, a basic organisational structure, limited resources and reliance on informal KM practices heavily influenced by company owners. Hartono et al. (2019) observed that investing in a KM system can be costly to maintain and may take time to yield tangible benefits. SMCCs also prioritised people-based approaches when initially implementing KM practices. These people-based activities offer a cost-effective and short-term solution for effectively deploying and leveraging the knowledge embedded within their human resources. However, this increased reliance on critical human members poses a risk of knowledge loss for SMCCs when employees depart (Daghfous, Belkhodja and Angell, 2013). For example, utilising foremen to manage construction teams on-site can enhance the effectiveness of training and guiding new workers while maintaining control over construction processes. However, when foremen resign, the company risks losing the expertise they have accumulated and applied to company projects.

Partial investment by SMCCs in KU and KD reflected an adaptation to the prevailing conditions within the Vietnamese construction industry. SMCCs had begun to integrate KM into their management processes; however, the effectiveness of these implementations was hindered by a lack of attention to other KMP processes. This situation suggests that the KM capability of SMCCs has not yet reached its full potential and presents opportunities for further development in the future. Investing in the remaining KMP factors (KR, KS and KA) could enhance KM capability and lead to significant performance improvements for SMCCs, ultimately contributing to increased market share. Dang et al. (2020) examined the relationship between KM capability and performance while considering the effects of company size. They conclude that the KM capability of SMCCs has a higher positive effect on performance compared with large-sized companies in the Vietnamese construction industry.

Despite the uneven distribution of investments in KMP initiation, SMCCs could still enhance their KMP implementation. In the initial phase of KMP implementation, which is aimed at improving the remaining KMP factors (KR, KS and KA), SMCCs considered utilising readily available off-the-shelf basic applications offered by third parties. For instance, communication tools, such as Zalo, Line and Viber, along with construction simulation software, such as Navisworks, Revit and SketchUp, were widely used and easily accessible to new-generation engineers (Anh, 2021). This initial step serves as a crucial foundation for the future implementation of comprehensive and effective KMP systems. Park et al. (2013) advocated the enhancement of KMP through the codification approach (people-to-documents), which leverages IT support (KS-related) to structure knowledge. They proposed a web-based system (e.g., wiki blogs and an expert index) that facilitates the access of codified knowledge by SMCCs, enabling the sharing of information and knowledge between individuals and organisations within the construction industry. This approach offers substantial benefits to construction companies by utilising social networking within construction communities without incurring additional costs.

This study's findings were validated through discussions with a chief executive officer (CEO) of an SMCC with over a decade of experience in the civil and industrial construction industry. The CEO acknowledged that their company's current financial constraints limited its ability to make full investments in KMP. Consequently, the company prioritised activities that can be executed effectively by utilising the expertise of its employees and existing basic management systems. This focus on KU was reflected in the allocation of approximately 50% of the total resources across the five KMP criteria.

This approach aligns with the study's recommendations, which suggest that SMCCs should initially concentrate on KU and KD to initiate the adoption of KMP practices within the constraints of limited resources. By leveraging

existing knowledge and infrastructure, SMCCs can establish a foundation for future advancements in KM capabilities. The CEO's endorsement of this approach highlights the practical application of the study's findings in addressing real-world business challenges. Furthermore, it underscores the importance of tailoring KM strategies to align with the specific circumstances and resource constraints faced by SMCCs.

CONCLUSIONS

This study examined the prioritisation of KMP activities within SMCCs. The empirical findings revealed the ranking of KMP aspects based on their priority weights, namely KU with a weight of 0.456, KD with a weight of 0.251, KR with a weight of 0.139, KS with a weight of 0.079 and KA with a weight of 0.075. These findings align with the people-based approach to KMP strategies advocated in previous research conducted in the context of developing countries. Notably, the top five KMP items were identified: KU4, KU5, KD1, KD4 and KU3. The results provide valuable insights for SMCC managers regarding crucial KM activities, current implementation practices and potential long-term development plans in developing countries. They highlight the challenges faced by SMCCs in allocating limited budgets to implement all five KMP factors simultaneously. Focusing on critical aspects (KU and KD factors) can provide SMCCs with short-term advantages and suitability, whereas incorporating the diversity of all KMP factors can promote more sustainable development in the long run.

On the one hand, the findings of the current study support the notion that knowledge utilisation and dissemination are essential aspects for SMCCs. They also contribute to the KM research domain by emphasising that KM in the context of SMCCs should prioritise tacit knowledge initially, followed by efforts to improve performance by transitioning tacit knowledge into explicit knowledge. This approach balances the benefits of KM with the investment costs associated with innovation and technology, as suggested by scholars. Moreover, KM is confirmed as a component of management standards and can aid SMCCs in generalising their conventional operations using an appropriate KM framework encompassing responsiveness, acquisition, storage, dissemination and utilisation.

On the other hand, the KMP structure, associated items and the AHP method served as convenient support tools for management teams in evaluating a company's existing KMP activities. The results provide evidence for discussions and decision-making related to KMP investment and development plans, as well as technology application within SMCCs, with the aim of fostering new innovations and enhancing market competitiveness. In terms of policy formulation, the findings indicate that SMCCs prioritise knowledge utilisation and dissemination. This aligns with the approach advocated in previous

studies on how SMCCs implement KMP to improve performance. It involves employing a people-based KMP approach through knowledge utilisation and sharing activities (i.e., KU and KD) among project members, along with two-way communication, to enhance operational efficiency. Conversely, the application of KM systems (i.e., the KS criterion), which demands substantial investment costs and time, remains a barrier for SMCCs. The results also provide an understanding of KMP activities that SMCCs are keen on implementing to strengthen their competitive edge in the market.

It is important to acknowledge that the study's findings should be interpreted and applied with caution. When considering the implementation of KMP and KM-based technology, SMCCs should carefully evaluate their specific needs and circumstances before making investment decisions. To provide more specific guidance for SMCCs, future studies should focus on developing roadmaps for KMP development and technology adaptation using the prioritisation matrix.

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