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Assessment of Construction Competitiveness through Knowledge Management Process Implementation

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Abstract: In the turbulent construction market, the knowledge management process (KMP) is one of the most valuable tools of sustainability to help construction companies deal with dynamic changes and enhance their construction competitiveness (CC). To effectively utilize KMP in construction, this study aims to explore the interrelationships between key KMP factors and their influences on the CC, utilizing the structural equation modeling (SEM) approach. The objectives include extracting key KMP factors necessary for the CC enhancement, identifying direct and indirect relationships between the KMP and CC factors, and developing a self-assessment form to assist construction companies in evaluating their KMP performance and planning for long-term improvement. The results show that the five key KMP factors, namely knowledge utilization (KU), knowledge dissemination (KD), knowledge responsiveness (KR), knowledge storage (KS), and knowledge acquisition (KA), have direct and indirect effects on CC and that the feedback of CC is sent back to KMP factors for continuous improvement. The KU factor is crucial for short-term improvement. Construction companies should utilize stakeholders' current practices and experiences to solve problems, conclude lessons learned, and pinpoint practices for future uses. The KS factor, on the other hand, should be emphasized for long-term plans to enhance KMP implementation and CC achievements. A long-term investment plan should be initiated in the database system to properly and effectively implement digital transformation in the 4.0 Era. The self-assessment form developed from the study results assists construction companies in assessing their KMP implementation and planning for sustainable development.

Keywords: assessment form; construction competitiveness; knowledge management process; interrelationship; structural equation modeling

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1. Introduction

In the new global economy, the emergence of knowledge has become a predominant part of enhancing dramatic innovation in the business environment [1]. Knowledge is an essential component of organizational assets and plays a crucial role in company competitiveness [2]. Managing knowledge involves how knowledge is acquired, disseminated, and utilized when needed to respond promptly to changes in the marketplace [3]. A company's competitive advantage in knowledge management (KM) depends on its ability to absorb its member's knowledge and create new valuable knowledge [4]. The more knowledge-intensive companies are, the more competitive power they gain [5]. With this, the demand for leveraging the value of knowledge has been booming in many industries in terms of treating the knowledge manifested in human expertise as a tangible resource to ensure their competitive advantage in the long term [5,6].

The construction industry contributes to economic development by providing comprehensive construction services to meet the growing needs of buildings and infrastructure. It has unique characteristics compared with other industries. It has high work complexity and risk, is knowledge-intensive, and requires innovation to meet clients' specific requirements and ensure that all solutions best fit their client's requests [7,8]. Each project is uniquely constructed at different locations with different labor, materials, and machinery. The construction is also impacted by various factors, such as weather, labor productivity, material supply, and pandemics. Thukral [9] stated that the construction sector is highly affected by the COVID-19 pandemic as it is a labor-intensive industry. The effects are a lack of a workforce, interruption of the construction process, disturbance of the project's plan, and contract disputes with project participants. To enhance the long-term competitiveness of the construction industry, companies must improve their internal operations and establish long-term client relationships [3]. The survival and prosperity of an industry depend mainly on its market development, which is affected by its overall competitiveness [7].

Vietnam, one of the developing countries in Southeast Asia, has been experiencing fast economic growth. The gross domestic product (GDP) steadily increased from USD 193.241 billion in 2015 to 271.158 billion in 2020 [10]. In addition, the total investment capital of the industry gradually increased over the years and reached USD 5.7 billion in 2020. Vietnamese construction companies face high challenges from competitors in the same business environment due to the country's rapid growth [10]. High competition in the construction market has put construction companies under pressure to maintain relationships with old clients, initiate new relationships, innovate work processes to meet clients' requirements, and create sustainable competitive advantages instead of focusing on price competition. KM is key to improving construction competitiveness through experiences, knowledge, and social networks [11,12]. The KM concept has received significant concerns from researchers in the recent construction management literature. It enhances individual and team performance and improves the project and organization performance over time [11,13]. It focuses on knowledge management processes (KMPs), which include, for example, knowledge acquisition, knowledge storage, knowledge dissemination, knowledge utilization, and knowledge responsiveness to improve the company's performance. Positive correlations among the KMP factors and CC in terms of client satisfaction, time, cost, quality, profit, innovative work process, and productivity are found in many construction studies. For example, Wang and Meng [14] mentioned that having a database to install site problems and corrections enhances knowledge storage in companies. This improvement may reduce rework and raise client satisfaction. Yap and Toh [5] stated that effective KM practices that include delivering practical knowledge to the right person at the right time, supporting decision-making, and improving operational efficiencies might help construction companies achieve sustainable development and competitive advantages. Yu and Yang [15] agreed that KM should be employed to solve problems, predict changes, and reduce project risks. These help project managers control project performance effectively in terms of time, cost, and quality.

Nevertheless, the interrelationships between crucial KM factors and CC still need to be explored more specifically to consider these relationships further and help companies make suitable development plans. Andreeva and Kianto [16] examined the relationships between KM and competitiveness. They concluded that KM activities related to human resource management and ICT significantly affect the company's competitiveness. Mohamad and Mat Zin [2] concluded that KM has a significant positive influence on the competitiveness of construction companies. This study, therefore, aims to examine how the activities under the KMP, or KMP factors, affect each other in the flow of knowledge and how they influence the improvement and competitiveness of construction companies in Vietnam. A self-assessment form is developed to be used for assessing current KMP implementation in the companies and pinpointing KMP factors that require high efforts for implementation. To achieve the research aim, the research objectives are listed as follows:

- To examine key KMP factors affecting the CC in construction companies.
- To explore interrelationships between key KMP factors and CC.
- To develop a self-assessment form of KMP implementation for construction companies to assess their current KM implementation and suggest plans to improve KMP and enhance CC in the long term.

The study flow includes the introduction, literature review, research methodology, results and discussion, and conclusion. In the introduction part, the problem statement and research gap are explained. Literature on KMP and CC is reviewed to list key KMP and CC factors. A conceptual model is developed and used in the questionnaire survey for data collection. Collected data are screened using several data screening techniques to increase confidence in the data for the analyses. Exploratory factor analysis (EFA) is then performed to confirm key KMP and CC factors in the conceptual model. The interrelationships among key KMP and CC factors, and the directions of their relationships, are explored using the structural equation modeling (SEM) method. A self-assessment form is finally developed to be used to assess the company's current KMP practice and suggests key KMP factors to be improved to further enhance CC. The study results are expected to assist construction companies in better understanding KMP factors and their influences on CC improvement, so their suitable plans can be adopted to achieve sustainable development.

2. Literature Review

2.1. KMP Factors in the Construction Industry

Academic articles related to KM in the construction industry are identified and collected using the Scopus database to extract key KMP factors and their associated attributes. Scopus is considered a large database used by many authors in conducting literature reviews [17]. It can be accessed through the website to obtain relevant articles using a query, which is designed based on the goal of the reviews. The process includes identifying search keywords, creating search queries on the Scopus database, and filtering search results using functions, such as language, document type, and publication date. In this study, the queries of "knowledge management", "construction industry", and "construction competitiveness" are applied. The Nvivo software, version 10, QSR International, is also used to increase the efficiency of keyword searching in the downloaded articles to screen the irrelevant articles. The final 90 KMP- and CC-related articles are used to extract the KMP items necessary for the CC enhancement.

The literature review reveals that the concept of knowledge is very diverse and its applications in the construction industry depend on the KM's perceptions of the companies. For example, the construction project team utilized the KM concept to find the critical individual-level knowledge-related factors and explain how the effectiveness of knowledge is affected by individuals' absorptive and articulating capacities [18,19]. KM is used for looking at solvers for the construction process, such as managing construction accident cases and improving time-cost performance [20]. Information technology may be used to help map tacit and explicit knowledge with the market enhancement plan to achieve the best results [7,21,22]. Liu et al. [23] stated that knowledge exchange should be encouraged onsite and offsite to stimulate relationships between stakeholders.

The complexity of knowledge concepts and diversified approaches in KM make the theory complicated [24]. Given the intangible nature of knowledge, there is no universal consensus on defining KM [7]. However, it is recognized as a fundamental process that depends more on human activities than information technology. The construction process, which includes developing the abstract solution, simulating designs, and transforming designs into construction sites, is a knowledge-intensive process that requires the high capabilities of people in the companies. In a construction project, KMP factors focus mainly on human experiences and their interrelationships that may be implemented differently depending on knowledge viewpoints [18,25]. For example, if the perspective on knowledge is an object that can be stored and manipulated, then KMP factors may concentrate on establishing and managing knowledge stocks [26]. On the other hand, if knowledge is considered to be people's awareness, then the primary KMP activities may focus on learning, sharing, and creating communication and interaction among people to enhance knowledge [27]. If knowledge is approached as a process, then KMP factors may involve knowledge flows and how the KMP operates [28,29].

KMP is used in construction companies to manage internal and external functions to achieve higher CC. Different studies define different KMP factors. Hassan and Raziq [30], for example, stated that KMP, with three activities, namely knowledge acquisition, knowledge dissemination, and knowledge responsiveness, has significant effects on innovation in small- and medium-sized enterprises. Gold et al. [28] and Abu Bakar et al. [31] defined four KMP factors, namely knowledge acquisition, knowledge conversion, knowledge application, and knowledge protection, to improve organizational effectiveness. Chen and Mohamed [6] mentioned that knowledge responsiveness, acquisition, utilization, and dissemination are four key KMP factors to improve company performance. Mohamad and Mat Zin [2] added that by implementing KMP, construction companies could enhance their work innovation. Yu and Yang [15] stated that five KMP factors, including knowledge creation, knowledge collection, knowledge sharing, knowledge transferring, and knowledge usage, are crucial in enhancing CC. Fong and Choi [21] commented that six key KMP factors, namely knowledge acquisition, knowledge creation, knowledge storage, knowledge distribution, knowledge usage, and knowledge maintenance, should be undertaken in professional quantity surveying firms to enhance CC.

In this study, five key KMP factors are extracted from the 90 screened KMP- and CC-related articles. They include knowledge acquisition (KA), knowledge dissemination (KD), knowledge responsiveness (KR), knowledge storage (KS), and knowledge utilization (KU) with a total of 28 associated items (see Table 1).

Table 1. Five KMP factors with 28 associated items extracted from the literature.

Construct	Item	Description	Reference
KA	KA1	Acquiring knowledge from clients	[21,29,31–34]
	KA2	Acquiring knowledge from competitors	
	KA3	Acquiring knowledge through the employee's KPI processes	
	KA4	Acquiring knowledge through financial reporting systems	
	KA5	Acquiring knowledge through market research	
	KA6	Acquiring knowledge through previous project experiences	
	KA7	Acquiring knowledge from the standard benchmarking systems	
KD	KD1	Disseminating hard copies (e.g., reports, newsletters, policy, and procedure manuals) to stakeholders	[2,13,30,34–36]
	KD2	Disseminating knowledge through staff mentoring	
	KD3	Disseminating knowledge of products and processes within the company using updated technology	
	KD4	Disseminating market trends and developments among internal departments	
	KD5	Disseminating knowledge using encouraging two-way communication	
KR	KR1	Responding positively to changes in client needs	[2,4,30,34,37,38]
	KR2	Responding to the client's reactions to technological changes	
	KR3	Responding to competitor strategies	
	KR4	Responding to employee needs	
	KR5	Responding to market changes in the market plan	
KS	KS1	Authorizing the accessible permission into the database	[14,21,24,39–41]
	KS2	Conducting data screening before saving them into the database	
	KS3	Storing knowledge using the data warehousing technology	
	KS4	Storing knowledge in hard copies (e.g., reports, newsletters, policy, and procedure manuals)	
	KS5	Storing lessons learned into the database (knowledge storage system)	
	KS6	Having procedures for knowledge storage	
KU	KU1	Using existing knowledge to improve company business processes	[2,13,42,43]
	KU2	Using knowledge to deal with competitive conditions	
	KU3	Using knowledge to adapt strategic directions	
	KU4	Using accumulated knowledge to solve problems	
	KU5	Using new knowledge to improve company business processes	

2.1.1. Knowledge Acquisition Factor

Knowledge acquisition (KA) is the process of acquiring knowledge from activities in the working processes [21]. ElFar, et al. [32] mentioned that KA can be considered at organizational and individual levels. At the organizational level, KA is expressed through interactive activities that collect project activity data, store investor profiles, and update new technology [44]. This level of KA helps construction companies improve their performance and efficiency by providing insights into their operations. At the individual level, KA is expressed through the mental model as behavior and attitudes. This level of KA helps employees learn and grow by providing them with opportunities to share their knowledge and experiences [45]. In construction companies, KA is represented by activities that collect data and information during operations to accumulate and absorb knowledge from practical activities. It helps companies improve their safety, quality, and productivity [46].

The KA factor is associated with seven items that are frequently mentioned in the literature. Details are as follows.

- The acquisition of knowledge from clients (KA1) item: Yusof and Bakar [47] mentioned that knowledge can be acquired from clients through their feedback on services. ElFar et al. [32] stated that construction companies can acquire knowledge from customer relations to catch their needs and intentions.
- The acquisition of knowledge from competitors (KA2) item: Alrubaiee et al. [40] mentioned that construction companies could acquire knowledge from competitors through their strategies and processes. Valdez-Juárez et al. [33] added that companies should acquire knowledge from competitors to update their business strategies.
- The acquisition of knowledge through the employee's KPI processes (KA3) item: Liao and Wu [48] mentioned that the acquisition knowledge process affected employees through activities (i.e., identifying best practices, exchanging experiences, and competing performance between individuals). Bing Chong et al. [49] mentioned that knowledge could be extracted from workers through mapping knowledge.
- The acquisition of knowledge through the financial reporting systems (KA4) item: Ahmad and An [39] mentioned that data (e.g., financial data, cost, and profit) may be used to improve the body of knowledge in companies. Akram et al. [50] stated that a good KA should have a financial reporting system that is well-developed to manage financial activities and support managers in decision-making.
- The acquisition of knowledge through market research (KA5) item: Parker [51] mentioned that construction companies could extend their knowledge through markets. Jayasingam et al. [46] stated that practices associated with the acquisition of ideas and solutions could come from real market needs. Abu Bakar et al. [31] mentioned that acquisition refers to activities conducted to obtain knowledge from the business environment.
- The acquisition of knowledge through previous project experiences (KA6) item: Gonzalez and Martins [29] stated that previous experiences should be acquired to update and improve project performance. Kale and Karaman [52] mentioned that companies can acquire knowledge from defects, design changes, and planning to improve subsequent projects.
- The acquisition of knowledge from the standard benchmarking systems (KA7) item: Niu [53] stated that benchmarking is a good tool for KA of companies. Hassan and Raziq [30] mentioned that companies should develop a process for benchmarking performance to support the acquisition of knowledge.

2.1.2. Knowledge Dissemination Factor

Knowledge dissemination (KD) is a process used by construction companies to share knowledge and to saturate knowledge within the organization [43]. It is an activity carried out to disseminate knowledge to make sure that organizational knowledge is received by all employees. The activities of disseminating knowledge depend on the type of knowledge, i.e., tacit and explicit knowledge [54]. Tacit knowledge is personal knowledge that is difficult to codify and share, while explicit knowledge is easily transferred. For tacit knowledge, the transmission and spread of experienced activities depend on human characteristics with personality and cooperative working attitude. KD activities for tacit knowledge must be designed to encourage people to share their knowledge and experiences, for example, mentoring, coaching, and storytelling [11]. KD activities for explicit knowledge, on the other hand, can be more formal, such as through training, documentation, and knowledge repositories [55]. Activities in construction organizations should encourage experience sharing that is retained as codified data in the knowledge storage system. Construction companies should create a culture of knowledge sharing and make it easy for team members to access, share, and update.

The KD factor is associated with five items that are frequently mentioned in the literature. Details are as follows.

- The dissemination of hard copies to stakeholders (KD1) item: Mohamad and Mat Zin [2] mentioned that disseminating knowledge to stakeholders through hard copies (e.g., reports, newsletters, policy, and procedure manuals) improves competitiveness in construction companies. Chen and Fong [13] added that disseminating hard copies to stakeholders helps update project information and improve knowledge in construction companies.
- The dissemination of knowledge through staff mentoring (KD2) item: Chen and Fong [37] mentioned that staff mentoring could disseminate knowledge among members to maintain interactive themes for KD in companies. Ulhaq et al. [56] stated that transferring the captured knowledge to employees through mentoring and coaching can support the individual's decision-making.
- The dissemination of knowledge of products and processes within the company using updated technology (KD3) item: Almomani et al. [35] mentioned that knowledge of products and processes disseminated using the technology will enhance the marketing innovation of companies. Allameh and Abbas [57] recommended that companies should use technology to disseminate business process knowledge to improve innovation and performance.
- The dissemination of market trends and developments among internal departments (KD4) item: Hassan and Raziq [30] mentioned that market information should be freely disseminated in companies. Lo et al. [58] added that disseminating market trends to all employees improves KD, leading to improved organizational effectiveness.
- The dissemination of knowledge by encouraging two-way communication (KD5) item: Jayasingam et al. [46] mentioned that knowledge is disseminated among people throughout the organization through meetings between departments, managers, and employees. Wibowo et al. [43] mentioned that KD should be performed to ensure that the organizational knowledge is received by all members.

2.1.3. Knowledge Responsiveness Factor

Knowledge responsiveness (KR) is a process used by construction organizations to interact with knowledge sources. It is crucial to improve the quality of products (projects), services, and market development. Chen and Mohamed [3] define KR as "the ability of an organization to respond to the various types of knowledge it can access in its external and internal environments". Mohamad and Mat Zin [2] further stated that KR is a form of responding or reacting to knowledge. KR is a critical process for construction organizations to stay competitive in the market. By effectively responding to knowledge, organizations can improve their decision-making, innovation, and productivity.

The KR factor is associated with five items that are frequently mentioned in the literature. Details are as follows.

- The response to changes in client needs (KR1) item: Saini et al. [12] mentioned that responsiveness to client demand improves agility, which is the ability to adapt to continual changes in companies. Wibowo et al. [43] stated that the KR involves activities carried out as a response to clients to improve the success of projects.

- The response to the client's reactions to technological changes (KR2) item: Akram et al. [50] stated that responding to technological changes helps companies take the best ideas from disparate functions. Yousaf and Ali [34] stated that the ability to respond to technological changes on clients improves operational effectiveness.
- The response to competitor strategies (KR3) item: Hassan and Raziq [30] mentioned that the competitors' strategies reflect the current state of the market. Darroch [38] added that responding to competitor strategies helps firms gain more information about market trends and update their strategies proactively and effectively.
- The response to employee needs (KR4) item: Wibowo et al. [43] mentioned that responding to employees' needs helps the company make adjustments in management. This also motivates employees to participate in KM activities.
- The response to market changes in the market plan (KR5) item: Dang et al. [4] mentioned that the model of KM capability (i.e., infrastructure and process) that responds to market changes is crucial to improving market performance. Mohamad and Mat Zin [2] stated that reacting to changes in the market helps companies improve innovation in products and processes.

2.1.4. Knowledge Storage Factor

Knowledge storage (KS) is a process used by construction companies to keep the knowledge that exists in the form of archives or data. Fong and Choi [21] mentioned that the knowledge needs to be processed and integrated before being stored to ensure its accuracy. Suresh et al. [44] pointed out that companies should create data platforms that store organizational knowledge and make it accessible to all divisions. This allows everyone in the company to benefit from the knowledge accumulated over time. New technologies, such as database management and data warehousing technologies, can help to increase the company's ability to store and manage data [54]. KS is a critical process for construction companies that want to improve their efficiency and productivity. By capturing and storing knowledge, companies can avoid mistakes from previous projects and learn from the mistakes and successes of other companies through meetings of construction associations.

The KS factor is associated with six items that are frequently mentioned in the literature. Details are as follows.

- The authorization of accessible permission into the database (KS1) item: Albooyeh and Yaghmaie [24] mentioned that the successful implementation of a data storage system requires user participation through the use and updating of new knowledge. Allowing employees to access data at the appropriate level of responsibility is essential for the implementation of KS.
- The data screening before saving them into the database (KS2) item: Alrubaiee et al. [40] mentioned that data screening is a necessary step to ensure the reliability of data. It is a critical step in providing reliable analysis results for managers when making decisions. Tennakoon et al. [59] stated that construction project activities are driven by knowledge, and this knowledge can be stored in databases called knowledge management systems once subject experts have validated it.
- The storage of knowledge using the data warehousing technology (KS3) item: Novák [41] mentioned that the use of data storage technology is an essential part of KM. Suresh et al. [44] stated that centralized data storage provides connectivity in information management. This helps improve project management and reduce project costs.
- The storage of knowledge in hard copies (KS4) item: Fong and Choi [21] mentioned that storing data in hard copy (i.e., reports, newsletters, policy, and procedure manuals) is a traditional method in the construction industry. It is widely used in the management of construction sites in the form of drawings, acceptance records, and progress reports. Shahzad et al. [60] mentioned that hard copy, an explicit type of knowledge, requires amplification mechanisms such as procedures, IT systems, and cultural work to maximize the benefits of the combination stage of the KM process.

- The storage of lessons learned in a database (KS5) item: Park et al. [61] mentioned that the knowledge of employees needs to be stored in a knowledge storage system so that it can be easily queried and analyzed to support decision-making.
- The procedures for knowledge storage (KS6) item: Wang and Meng [14] mentioned that to collect data effectively, construction companies need to establish data collection procedures and disseminate them to all departments. This helps improve the consistency and efficiency of data collection and storage.

2.1.5. Knowledge Utilization Factor

Knowledge utilization (KU) is a process that applies knowledge gained from previous projects to solve problems. It helps optimize project costs and times and leads to organizational benefits [44]. Fong and Choi [21] stated that practitioners in the construction industry overwhelmingly agreed that knowledge gained from previous projects is helpful in solving problems on new projects. ElFar et al. [32] also mentioned that closed-out reports from previous projects could be used to improve the efficiency of new projects. KU may also be used to generate new knowledge. When knowledge is used in new situations, it is often analyzed and evaluated, resulting in new insights and understandings [54]. Construction companies may utilize knowledge to improve their efficiency, profitability, and innovation to stay ahead of their competitors.

The KU factor is associated with five items that are frequently mentioned in the literature. Details are as follows.

- The use of existing knowledge to improve company business processes (KU1) item: Mohamad and Mat Zin [2] mentioned that construction companies can use the knowledge gained from their operations to improve business processes by reusing experiences from similar projects. This depends on the level of knowledge that the company possesses and the level of KM maturity.
- The use of knowledge to deal with competitive conditions (KU2) item: ElFar et al. [32] commented that knowledge is used to deal with changes in the business environment. It helps companies adapt to a dynamic market (i.e., new materials and new technologies). Egbu [62] mentioned that KM is a critical enabler for innovation to deal with competitive conditions.
- The use of knowledge to adapt strategic directions (KU3) item: Dang et al. [7] mentioned that the development of construction companies is affected by their ability to adapt to the market. The use of knowledge to build plans and strategies to create appropriate products and services will help businesses increase the efficiency of market development.
- The use of accumulated knowledge to solve problems (KU4) item: Garcia and Mollaoglu [18] mentioned that the knowledge used by individuals to solve problems reflects their ability to apply knowledge. Chen and Fong [13] stated that the knowledge accumulated by employees increases their problem-solving ability, leading to improved efficiency of the companies.
- The use of new knowledge to improve company business processes (KU5) item: Wibowo et al. [43] mentioned that the use of knowledge will create new knowledge to improve the company's performance. It also increases the innovation of the business through the creation of improvements (i.e., using information systems for estimating and quoting instead of using experience).

2.2. Construction Competitiveness in the Construction Industry

Construction competitiveness (CC) is the company's ability to compete in the market [63]. It may be classified into international, national, industrial, company, and project levels and assessed through various perspectives, such as profits, quality of work, project completion time, and customer satisfaction [2]. Various studies mention different measures of CC. Shen et al. [63], for example, mentioned that competitiveness is a company's capability to adapt to market changes and retain business growth. High competitiveness may be reflected by high client satisfaction, employee satisfaction, profit, quality work, productivity, market share, and innovation [2,25,64]. Alrubaiee et al. [40] mentioned that the CC is measured by financial aspects, such as profitability, market share, and sales. Andreeva and Kianto [16] stated that the CC construct consists of market share, success in the market, growing rate, profit, and innovative level.

Managing knowledge may enhance the performance of construction companies, as it creates value-added for the companies' competitiveness [65]. The relationships between KMP factors and the company's competitiveness are examined in many industries. Hussinki et al. [66], for example, showed that KM practices positively affect the innovation and market performance of manufacturing companies in Finland. In Jordanian telecommunication and information technology companies, KMP positively affects profitability, market share, sales, and customer satisfaction [40]. In the crossing-industry field of Iran, KMP improves organizational performance in terms of productivity, financial performance, staff performance, innovation, work relationships, and customer satisfaction [67]. In Hong Kong, knowledge evolution strategies in IT services, manufacturing, and finance, which combine the advantages of both internal and external knowledge, influence organizational finance, customer, internal process, and learning and growth performance [68].

In this study, key measures of the CC based on KMP implementation are listed from the 90 screened articles from the Scopus database. Novák [41], for example, confirmed positive relationships between the KMP and performance indicators, including finance, innovation, growth, operation, competitive advantage, and value creation. Dang et al. [7] examined the effects of KM capability, as infrastructure and process capability, on the market development performance of project-based construction companies in Vietnam. They concluded that KM strongly influences small- and medium-sized companies in terms of increased new clients, market share, and company reputation. The effects of KM capability on business performance (i.e., financial, consumer, learning and growth, supplier, and internal perspectives) are also explored in Egyptian construction companies [32]. In the Malaysian construction industry, the growth performance is related to KMP in terms of acquisition, conversion, application, and protection [31]. The learning mechanisms of construction companies in Hong Kong, represented by activities in the KMP to match client needs in the turbulent market environment, affect business performance in terms of finance, customer, process, and learning and growth [42]. Duodu and Rowlinson [69] mentioned that intellectual capital (human, social, and organizational capital) has direct and indirect effects on firm performance, including quality, productivity, revenue, market share, client satisfaction, capacity to meet challenges, employee satisfaction, and profits. Kim [70] mentioned that the level of organizational success is measured by project performance data (cost, quality, safety, and schedule). By reusing and sharing knowledge, the company can ensure quality, reduce the time and cost of project completion, and enhance CC [39]. According to Soewin and Chinda [64], the performance of construction projects is expressed through time, cost, quality, safety and health, client satisfaction, environment, financial performance, people, information technology, and innovation. Lielgaidina and Geipele [71] mentioned that the success of the construction management team is on-time project completion.

In summary, the CC factor is expressed by six indicators: (1) profit (PF), (2) client satisfaction (CS), (3) labor productivity (LP), (4) innovative work process (IN), (5) timely project completion (TM), and (6) project quality (QL). They are frequently mentioned in the construction-related literature (see Table 2).

Table 2. CC items extracted from the literature.

Reference	Profit (PF)	Client Satisfaction (CS)	Labor Productivity (LP)	Innovative Work Process (IN)	Timely Project Completion (TM)	Project Quality (QL)
Abu Bakar et al. [31]	x		x			
Alrubaiee et al. [40]	x	x				
Chan [72]	x	x	x	x	x	x
Chen and Fong [13]	x	x	x	x	x	
Chen and Fong [37]	x	x	x	x	x	
Chen and Huang [73]				x		
Chen and Liang [68]	x	x		x		
Chen and Mohamed [3]	x	x	x	x	x	
Cheung and Qi [74]				x		
Dang et al. [4]		x				
Dang et al. [7]		x				
Darroch [38]	x	x				
Darroch and McNaughton [75]	x	x				
Deng and Smyth [76]	x	x	x		x	x
Duodu and Rowlinson [69]	x	x	x			x
ElFar et al. [32]	x	x	x			
Enshassi et al. [77]	x	x	x	x	x	x
Fong and Chen [42]	x	x	x	x	x	
Gholami et al. [67]		x	x			
Gold et al. [28]				x		
Graham and Thomas [78]		x	x			
Gunasekera and Chong [25]	x				x	x
Hassan and Raziq [30]				x		
Hussinki et al. [66]	x			x		
Jayasingam et al. [46]			x			
Mohamad and Mat Zin [2]	x			x		
Soewin and Chinda [64]	x	x	x	x	x	x
Sweis et al. [79]	x	x				x
Yousaf and Ali [34]				x		

2.3. Conceptual Model of KMP and CC Factors

The five KMP and CC factors from the literature form a concept model of KMP and CC factors, see Figure 1. The hypothesized relationships are extracted from the literature. For example, Gholami et al. [67] mentioned that the acquisition and storage of knowledge enhance organizational performance. These represent the relationships between the KA and CC factors and the KS and CC factors. Lin [80] stated that the KA, KS, and KD factors enhance the electronic business diffusion process. ElFar et al. [32] mentioned that business performance (i.e., financial and customer perspective) is enhanced by the KMP through the acquisition, dissemination, and utilization of knowledge. These represent the relationships among the KA, KD, KU, and CC factors. Details of the hypothesized relationships are as follows.

- H1: Knowledge storage positively affects knowledge acquisition. Gonzalez and Martins [29] mentioned that the data warehousing of previous projects could create the appropriate conditions for organizational learning that help companies enhance knowledge acquisition from their information stored. Novák [41] stated that acquired knowledge can be maintained and transferred to other explicit things such as written documents, electronic databases, codified human knowledge, and documented organizational procedures and processes. The transformation of knowledge type between explicit and tacit knowledge creates new knowledge that extends and updates existing knowledge in companies [81].
- H2: Knowledge storage positively affects the knowledge dissemination. Al-Qubaisi et al. [36] mentioned that adopting IT in distributing knowledge could help companies

increase the effectiveness of knowledge dissemination. Wang and Meng [14] mentioned that stored information tools (e.g., building information modeling) can provide a convenient way to manage information across different project phases, enable knowledge exchange between departments, and define relationships between current and previous construction activities to integrate relevant knowledge. Singh and Mirzaeifar [82] proposed a framework based on memory systems to assess the transactions of distributed content knowledge resources in modern construction projects. This helps increase the effectiveness of knowledge dissemination for project management.

- H3: Knowledge acquisition positively affects the knowledge dissemination. Chen and Fong [13] mentioned that the new knowledge acquired should be disseminated to all departments to adapt to new ideas and situations. Lessons learned from previous projects and clients can be shared through effective communication among team members to retain new knowledge and enhance work practices [34]. Teerajetgul et al. [83] mentioned that knowledge acquisition and sharing by employees consist of work trust, collaboration, and individual competency influencing onsite construction works. New knowledge acquired from markets and projects is also distributed through updated processes, guidelines, and manuals, resulting in increasing intensive activities of knowledge dissemination [13,38].
- H4: Knowledge responsiveness positively affects knowledge acquisition. Yousaf and Ali [34] mentioned that acquiring quality and quantity of information from clients is assisted by achieving effective responses to clients. To deal with new changes in the market, knowledge acquisition activities get knowledge from the market that updates and extends the existing knowledge [37]. The higher the intensity of the knowledge responsiveness, the higher the interaction with the knowledge source, and the higher the intensity of knowledge acquisition [13].
- H5: Knowledge dissemination positively affects knowledge utilization. Alashwal et al. [84] mentioned that distributing knowledge to stakeholders increases coordination and effective decision-making when dealing with project changes. Sharing knowledge among members of the project team increases the effectiveness of using knowledge to reduce mistakes and improve productivity [85,86]. The higher the intensity of knowledge dissemination, the more activities using knowledge [13].
- H6: Knowledge utilization positively affects knowledge responsiveness. Mohamad and Mat Zin [2] mentioned that data should be used and analyzed before responding to clients and competitors to demonstrate how companies transform their data and knowledge into projects and business practices. Using knowledge in production and business activities creates new knowledge, which can be used to respond to market changes [37]. Therefore, use knowledge as a trigger to increase interaction with the market by responding to changes in customers and competitors [16].
- H7: Construction competitiveness positively affects knowledge storage. Novák [41] mentioned that organizational databases and expert experiences influence organizational performance in financial, innovational, growth, and operation performance. Tennakoon et al. [59] mentioned that information on projects is stored in the systems (e.g., BIM), which helps companies manage all phases of projects effectively, resulting in a satisfaction increase in owners and stakeholders. To improve the project's success, the information demand of management increases to tackle the risks and the changes in projects [87]. The growing market share when companies get more competitive requires more information and data for marketing activities [88]. These information demands of companies lead to a higher intensity of knowledge storage.
- H8: Construction competitiveness positively affects knowledge acquisition. Jayasingam et al. [46] stated that KA significantly affects strategic and process improvement by acquiring market, client, and employee ideas and solutions. Pietersen [89] mentioned that performance outcomes represent new knowledge that reveals the competitive position of the company, resulting in the intensity of knowledge acquisition. The demand for the management of data and information is higher when construction

competitiveness increases, resulting in a higher intensity of activities of knowledge acquisition [29].

- H9: Knowledge dissemination positively affects construction competitiveness. Ren et al. [8] stated that strategies, including standardizing project management, using information and post-project evaluation systems, and encouraging a shared culture to enhance inter-project communication and transfer intention, provide superior advantages for construction companies. Arif et al. [90] mentioned that sharing knowledge improves the productivity of construction projects and affects the strategy and operation of companies. Teerajetgul and Chareonngam [91] mentioned that tacit knowledge is disseminated and re-combined based on networks among individuals in projects, facilitating a steady evolution of best practices. The higher the intensity of knowledge dissemination, the higher the construction competitiveness.
- H10: Knowledge responsiveness positively affects construction competitiveness. KR enhances the interaction between the company and its client to update information, adapt work practices following client comments, and enhance work innovation [38]. Hassan and Raziq [30] stated that knowledge responsiveness helps companies be proactive to changes and more innovative when they interact with clients and competitors. Butnariu and Luca [92] mentioned that the development of trust-based relationships depends on relational marketing with stakeholders in order to bring added value to the involved parties of projects. The higher the intensity of the knowledge responsiveness, the more construction competitiveness.
- H11: Knowledge utilization positively affects construction competitiveness. Chen and Fong [13] mentioned that effective use of knowledge may enhance business performance in terms of finance, client, process, and learning and growth [13]. Construction companies could use experiences and knowledge from previous projects to enhance performance [84]. Using KM could also help construction project managers control cost-effectively, resulting in construction competitiveness [44]. The higher the intensity of knowledge utilization the more CC improvement.

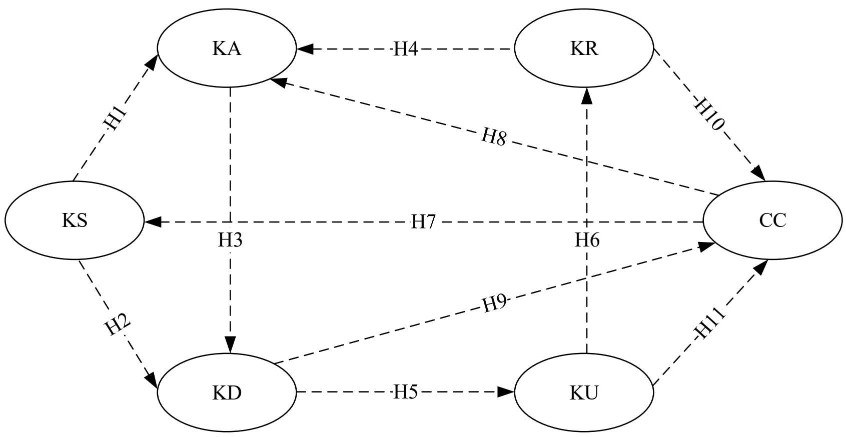

Figure 1. Conceptual model of KMP and CC factors.

3. Research Methodology

3.1. Research Framework

The research framework is proposed in Figure 2. Literature related to KMP and CC factors in the construction industry is reviewed to define the problem statement and research gap and lead to the research aim and objectives. The conceptual model of KMP and CC factors is developed with several hypothesized relationships. A questionnaire survey is then developed based on the conceptual model. The pilot test is performed to adjust and confirm the questionnaire survey to be used for data collection. Data screening is conducted to increase confidence in the data collected. The screened data are then performed with the exploratory factor analysis (EFA) to confirm key KMP and CC factors in the Vietnamese construction context. A confirmatory factor analysis (or measurement model) is employed to examine the interrelationships among crucial KMP and CC factors utilizing the structural equation modeling (SEM) method. The structural model is employed to define the directions of relationships among crucial KMP and CC factors. Discussion of the analysis results and recommendations are provided at the end of this paper.

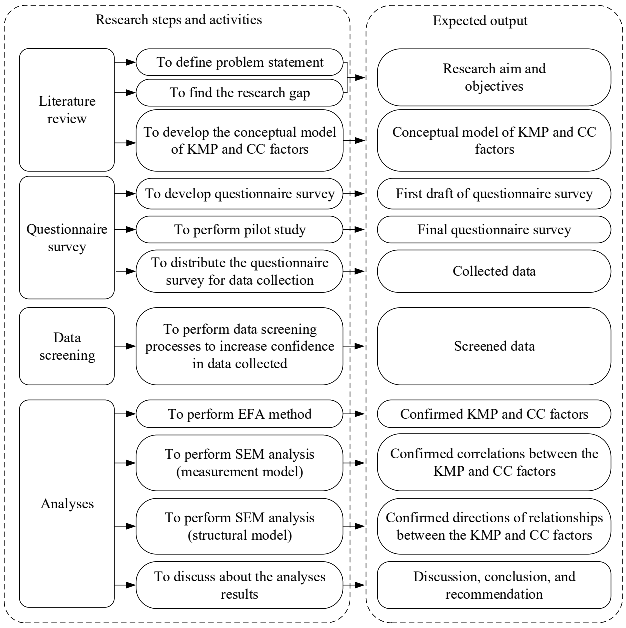

Figure 2. The research framework of this study.

3.2. Questionnaire Survey Development and Pilot Test

The questionnaire survey consists of three parts (general information, KMP constructs, and CC construct). The first part includes eight questions to collect demographic information of the respondents, such as working positions, years of working experiences, and KM-related experiences. The second part lists 28 statements related to five KMP factors. The respondents are asked to rate their opinion on the agreement of each statement using the 5-point Likert scale, where 1 represents strongly disagree, 3 represents neither agree nor disagree, and 5 represents strongly agree [18,93]. In the third part, respondents are asked to use a 5-point Likert scale to rate their agreement on six statements of the CC factor.

The developed questionnaire survey was sent to 11 experts who work in construction companies and universities in Vietnam during July–August 2021 for the pilot test. Nine of them have more than ten years of working experience. Half of them work in the construction industry as project managers and executives, and half are in academics. All of them are familiar with KM concepts and have experiences related to KMP implementation, such as collecting and storing project data, training employees, and analyzing data to control projects. They suggest two adjustments on KMP and CC factors, including the use of the "lesson learned" term in the "KS5" item instead of the "codified human knowledge" term, and adding employee satisfaction (ES) as an associated item of the CC factor. These are consistent with Duodu and Rowlinson [69] that employee satisfaction is related to the company's intellectual capital, which fits with the knowledge production function.

After the adjustments, the final version of the questionnaire survey is achieved with 28 items for KMP factors and seven items for the CC factor. The surveys are distributed using emails, social networks, and online meetings to suit the work-from-home strategy during the COVID-19 pandemic.

3.3. The Exploratory Factor Analysis and the Reliability Test

The 28 items under five KMP factors and seven items under the CC factor are tested with the exploratory factor analysis (EFA) to confirm their groupings. The EFA is used before performing the SEM as it confirms critical constructs and their associated items. The Kaiser–Mayer–Olkin (KMO) and the Bartlett Test of Sphericity are performed to confirm the data validity used in the EFA [25]. The value of the KMO index should be more significant than 0.5, and Bartlett's test result should be significant with a *p*-value of less than 0.05 [25,94]. The EFA is performed using the principal axis factoring and the varimax rotation methods with the cut-off factor loading of 0.3 [46,83,94,95]. These are consistent with, for example, Hair, et al. [94], who suggested factor loadings of 0.3 in the EFA. The KMP and CC factors extracted from the EFA are further performed with the reliability test (Cronbach's Alpha) to confirm the internal consistency of the extracted constructs and their associated items.

3.4. The Structural Equation Modeling Approach

Confirmed key KMP and CC factors and their associated items from the EFA results are performed with structural equation modeling (SEM) to examine their interrelationships. The SEM approach has been widely used in construction management studies as it is convenient for solving complex multivariate problems and verifying the proposed hypotheses [94]. For example, Vitharana and Chinda [96] utilized an SEM approach to examine critical factors affecting lower back pain due to whole-body vibration exposure by construction workers in Sri Lanka. Wen and Qiang [86] applied a longitudinal SEM to analyze the reciprocal relationship between coordination and knowledge sharing in construction project-based organizations. Yap et al. [97] examined the influence of project communication management and project learning as preventive measures to mitigate time-cost overruns using a partial least-squared-based structural equation modeling (PLS-SEM) analysis.

Various methods examine interrelationships of factors, such as regression models, hierarchical regression analysis, analytic hierarchy process, and value-at-risk analysis. For example, Pal et al. [98] examined critical factors in managing relationships in international engineering, procurement, and construction projects in China utilizing logistic regression and neural networks. Lau and Rowlinson [99] utilized an analytic hierarchy process to examine trust relations in the construction industry. In this study, however, the SEM method is utilized to examine the causal relationships between the crucial KMP and CC factors for several reasons. The SEM is a statistical technique that assesses each factor's direct and indirect effects on the other factors. It also avoids excessive multi-collinearity in other statistical techniques, such as multiple regression.

The SEM consists of two models: the measurement and structural models [100]. The measurement model is used to confirm the critical KMP and CC factors with their associated items and examine correlations among the KMP and CC factors using the two-headed arrows in the model. The structural model, on the other hand, explores the directions of the relationships among those KMP and CC factors using one-headed arrows in the model. Three model fit indices are used to assess the model fit to accept the measurement and structural models. They are chi-square per degree of freedom (χ^2/pdf), root mean square error of approximation (RMSEA), and comparative fit index (CFI). The χ^2/df value suggests an acceptable fit for the SEM approach [11]. RMSEA assesses the difference between the hypothesized model and the population covariance matrix. CFI represents the relative improvement in fit when comparing the baseline model with the hypothesized model [94]. The χ^2/df value should be less than three to accept the model [30]. Values of RMSEA ≤ 0.08 and CFI ≥ 0.80 are considered acceptable [86,101,102].

The model fit may be improved using the modification indices (MI) displayed in the model's output. It is an index calculated for possible relationships in the model output. It shows which variables should be correlated to improve the model fit [94]. However, the model adjustment based on MI values should be consistent with theories to achieve a better model fit [94].

4. Analyses Results

4.1. Data Collection and Data Screening Results

The questionnaire surveys were distributed to construction companies in Ho Chi Minh (HCM) City, Vietnam, from August–November 2021. A list of 1177 respondents who work in construction companies in HCM City, Vietnam, is established for the survey. The personal emails of respondents are collected from various channels, such as the Vietnam Construction Association, construction companies that sign the Memorandum of Understanding (MOU) with the universities, alum networks of civil engineering programs, postgraduate programs of construction management, and postgraduate programs of civil engineering and industrial construction. Using the emailed survey link is convenient because respondents can quickly fill in their information on their devices at any time [18]. Two hundred seventy-five responses, accounting for 23.36% of the total respondents, are returned. According to Sun et al. [103], responses from 210 datasets are considered adequate for the EFA and SEM analyses. Dang et al. [4] surveyed the Vietnamese construction industry and received a response rate of 20.25%. The 275 datasets achieved from this survey are then appropriated for the analyses. The 275 datasets are performed with the data screening processes, including normality (skewness and kurtosis) and outlier (5% trimmed mean and boxplot) tests to exclude datasets that are not normally distributed and are potential outliers [104]. The results remove three datasets as they have high frequencies of outliers in the box plots, resulting in the final 272 datasets for further analysis.

Based on the final 272 datasets, around 70% of respondents have more than 5 years of working experience. Half of them work as project engineers and project managers with significant roles in project construction management in private companies (73.2%). Most of them work in large-sized construction companies with over 200 employees. Almost all the respondents (94.5%) specialized in commercial, residential, and industrial building construction. The respondents are aware of the importance of KM in the organization. They involve in, for example, data collection (e.g., cost/time data of previous projects) and data storage processes to improve business efficiency. Detailed information of the respondents is provided in Table 3.

Table 3. The demographic information of the respondents.

Information	Percentage
Experience	
Up to 5 years	29.8
6–10 years	30.9
11–15 years	30.1
>15 years	9.2
Position	
Project engineer	27.2
Project manager	19.1
Officer	18.8
Team leader/Site manager	14.7
Division manager	10.7
Others	9.5
Job title	
Project & construction management	34.9
Technical supervision/construction	21.7
Management/administration	13.6
Structural design	11.0
Planning	4.0
Others	14.8

Table 3. *Cont.*

Information	Percentage
Type of company	
Private company	73.2
Public Company	17.3
Foreign direct investment	9.5
Number of employees	
<100 employees	31.7
100–199 employees	27.9
≥200 employees	40.4

The mean and standard deviation values of the 28 items of the KMP factors and seven items of the CC factor are in Table 4.

Table 4. The mean and standard deviation values.

Item	Mean	Standard Deviation
KA1	3.95	0.79
KA2	4.05	0.86
KA3	3.86	0.84
KA4	3.75	0.83
KA5	4.03	0.84
KA6	4.31	0.77
KA7	3.97	0.86
KD1	3.60	0.93
KD2	3.97	0.83
KD3	4.13	0.82
KD4	3.99	0.73
KD5	4.14	0.73
KR1	4.22	0.78
KR2	4.01	0.80
KR3	3.74	0.91
KR4	3.90	0.90
KR5	4.16	0.79
KS1	3.79	0.87
KS2	3.93	0.80
KS3	3.93	0.89
KS4	3.37	1.03
KS5	3.98	0.76
KS6	3.98	0.77
KU1	3.91	0.83
KU2	3.97	0.78
KU3	4.05	0.78
KU4	4.01	0.80
KU5	4.18	0.75
IN	4.08	0.80
TM	3.97	0.84
CS	4.01	0.75
QL	4.07	0.78
ES	3.91	0.81
LP	4.03	0.75
PF	3.94	0.87

Prior to conducting the EFA, the common method variance (CMV) is checked. It is the variance that is attributable to the measurement method rather than to the construct the measures represent. In this study, Harman's one-factor test is used to test the CMV [105]. It is a widespread statistical tool to detect the CMV, which represents one component that accounts for more than 50% of the covariance between items when using the EFA approach [106]. The results show a CMV of 43.36%, which is less than 50%, indicating no CMV problems in this study.

4.2. EFA Results

The KMO and Bartlett Test of Sphericity are tested to indicate the suitability of the data to be used with the EFA. The results show an acceptable KMO value of 0.983, and the Bartlett Test of Sphericity is significant at 0.000, thus confirming the suitability of the data for the EFA. The EFA is performed with the 272 data, and the results confirm the groupings of 28 KMP items into five KMP factors and seven CC items into the CC factor, with 56.92% of the total variance (see Table 5). Factor 1 is accounted for by five items, measuring the KU factor as previously hypothesized. Factor 2 is named the KR factor and is associated with six items. Surprisingly, the "KA6" item is relocated from the previously hypothesized KA to KR factors. This may be because acquiring knowledge through previous project experiences (the KA6 item) is frequently responsive to old knowledge [39]. Factor 3 is associated with seven items under the KA factor. The "KD1" item, previously hypothesized under the KD factor, is relocated to the KA factor. Dissemination of information by hard copies to stakeholders (the KD1 item) could help the company easily acquire feedback and knowledge when needed [107]. Factor 4, the KS factor, is associated with six items, as previously hypothesized. Factor 5, the KD factor, is confirmed with its four associated items. Lastly, the CC factor is confirmed with seven items to explain its construct.

Table 5. EFA and reliability analysis results.

Item	Factor Extracted						α Value
	KA	KD	KR	KS	KU	CC	
KA4	0.643						0.852
KD1	0.596						
KA3	0.393						
KA5	0.378						
KA7	0.324						
KA2	0.303						
KA1	0.302						
KD5		0.521					0.798
KD2		0.387					
KD3		0.367					
KD4		0.318					
KR5			0.747				0.812
KR1			0.684				
KR2			0.565				
KA6			0.522				
KR3			0.402				
KR4			0.353				
KS6				0.710			0.858
KS2				0.607			
KS1				0.587			
KS5				0.516			
KS3				0.423			
KS4				0.315			
KU2					0.725		0.883
KU5					0.703		
KU4					0.688		
KU3					0.659		
KU1					0.649		

Table 5. *Cont.*

Item	Factor Extracted						α Value
	KA	KD	KR	KS	KU	CC	
IN						0.781	
TM						0.757	
CS						0.743	
QL						0.743	0.887
ES						0.733	
LP						0.700	
PF						0.641	

To examine the internal consistency of the six factors extracted, the Cronbach's Alpha test is performed [13,64,108]. The alpha value ranges from 0 to 1, where values greater than 0.7 are acceptable [94]. The results, as in Table 5, depict the alpha values ranging from 0.798 to 0.887, indicating the internal consistency of KMP and CC constructs with their associated items, including the items that are relocated from their previously hypothesized constructs.

The confirmed five KMP factors and the CC construct are tested with Pearson's correlation test to preliminary examine their correlations prior to conducting the SEM. The correlation results are shown in Table 6. The results show that the correlation coefficients of six constructs (i.e., five KMP factors and the CC factors) are significant at the 0.01 level. The values range from 0.574 to 0.766, indicating the satisfactory discriminant validity of the constructs [13,109].

Table 6. Pearson's correlation coeficient.

Variable	KA	KD	KR	KS	KU	CC
KA	1					
KD	0.713 **	1				
KR	0.766 **	0.630 **	1			
KS	0.741 **	0.700 **	0.611 **	1		
KU	0.662 **	0.719 **	0.574 **	0.605 **	1	
CC	0.629 **	0.687 **	0.602 **	0.584 **	0.680 **	1

Note **. Correlation is significant at the 0.01 level (2-tailed), $n = 272$.

4.3. SEM Results

4.3.1. Measurement Model Results

Five KMP factors and CC construct achieved from the EFA form the baseline model to be tested with the measurement model using the SEM approach to examine the correlations among them and their relationships with the CC factor. The two-headed arrows are used in the model to hypothesize the correlations among five KMP and CC factors (see Figure 1). The model is tested, and the results show a recursive model with the fit indices values listed in Table 7 revealing a need to adjust the model to improve the model fit. The MI values suggest several correlations to be added to the model to improve the model fit further. As a result, three correlation paths are (i.e., TM ↔ QL, KD1 ↔ KS4, and KU2 ↔ KU4) added to the model as they have large MI values (29.37, 28.26, and 26.98, respectively). Soewin and Chinda [64] mentioned that time and quality are related to improving project success (TM ↔ QL). Ping Tserng and Lin [110] stated that information saved in paper-based format is challenging to search, may over-occupied the storage space, and requires effort to store and disseminate (KD1 ↔ KS4). Dang et al. [4] suggested that construction companies can use accumulated knowledge to deal with competitive conditions (e.g., technology and market changes and client needs) and solve problems (e.g., errors and mistakes at work) (KU2 ↔ KU4). Effective knowledge utilization through these activities may increase business performance [6].

Table 7. Fit indices results.

Fit Index	Recommended Value	Baseline Model	Best-Fit Measurement	Best-Fit Structural
χ^2/df	<3 [30]	3.0	2.9	2.4
RMSEA	≤0.08 [101]	0.09	0.08	0.07
CFI	>0.8 [86]	0.8	0.8	0.9

After the modification, the measurement model is run, and the best-fit measurement model is achieved (see Figure 3) with the fit indices in Table 7. The best-fit measurement model shows correlation coefficients among key KMP and CC factors, ranging from 0.3–0.79, all considered acceptable (i.e., correlation coefficients should be at least 0.3) [94]. These confirm the hypothesized relationships between the five KMP factors and the CC construct in Figure 1. The relationship between the KS and KD factors is the strongest, with a correlation coefficient of 0.79. Yousaf and Ali [34] agreed that a robust knowledge dissemination system could improve knowledge sharing among organizational members, and this knowledge could be retained and integrated for future use. Arif et al. [90] added that communication technologies should be invested in so that the correct data and information can be sent and received to the right person at the time to enhance work productivity. The KS factor strongly correlates with the KA factor, with a correlation coefficient of 0.77. Fong and Choi [21] stated that solutions in the current project could be stored in the database, maintained and updated by employees, and reused as existing knowledge to solve new problems.

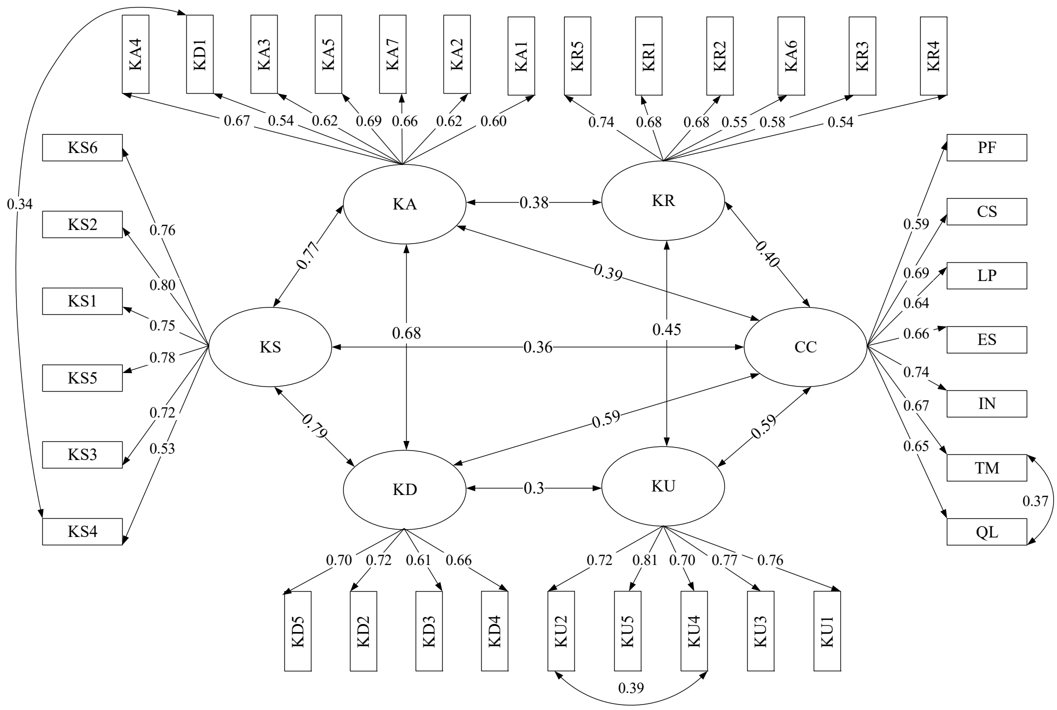

Figure 3. The best-fit measurement model.

Correlations between the KA and KR, KA and KD, KD and KU, and KU and KR factors are confirmed and supported by various works of literature. Fong and Chen [42] mentioned that a quick response to clients' claims helps construction companies acquire new business ideas. Knowledge acquired from various resources, such as communication among co-workers/managers, project information, and KPI systems, should be disseminated to employees and managers to improve individual and organizational performance [39].

Among the five key KMP factors, the KU and KD factors have strong relationships with CC, with a correlation coefficient of 0.59. Alashwal et al. [84] stated that utilizing knowledge to solve daily site problems improves project team performance. The knowledge dissemination process may be encouraged by project managers to enhance members' work efficiency and project performance [11,12]. Contradictory, the KS factor is found to have the lowest correlation coefficient with the CC factor. This may be because KM systems in Vietnamese may not have been deployed effectively due to skill and technology inefficiency. This is consistent with Vaz-Serra and Edwards [111] who state that KM systems sometimes are beyond the company's capacity.

The confirmed 11 correlations between the KMP and CC factors (see Figure 3) are further tested with the structural model to identify the directions of relationships.

4.3.2. Structural Model Results

Having confirmed the 11 hypotheses among key KMP and CC factors (see Figure 3), the structural model is further performed to examine the directions of relationships among the KMP and CC factors. The one-headed arrows replace the two-headed arrows, showing the influence of one KMP factor on another. Different directions among five KMP factors are tested in the structural model, and the directions with low path coefficients (low than 0.1) are deleted [112]. MI values may be used to adjust the model fit.

The structural model results recognize model adjustment. Path coefficients between the KA and CC factors and the KD and CC factors are removed from the model as they show low path coefficients (i.e., 0.09 and 0.01). After the model adjustment, the best-fit structural model is achieved (see Figure 4) with the fit indices, as shown in Table 7. The summary of results is presented in Table 8.

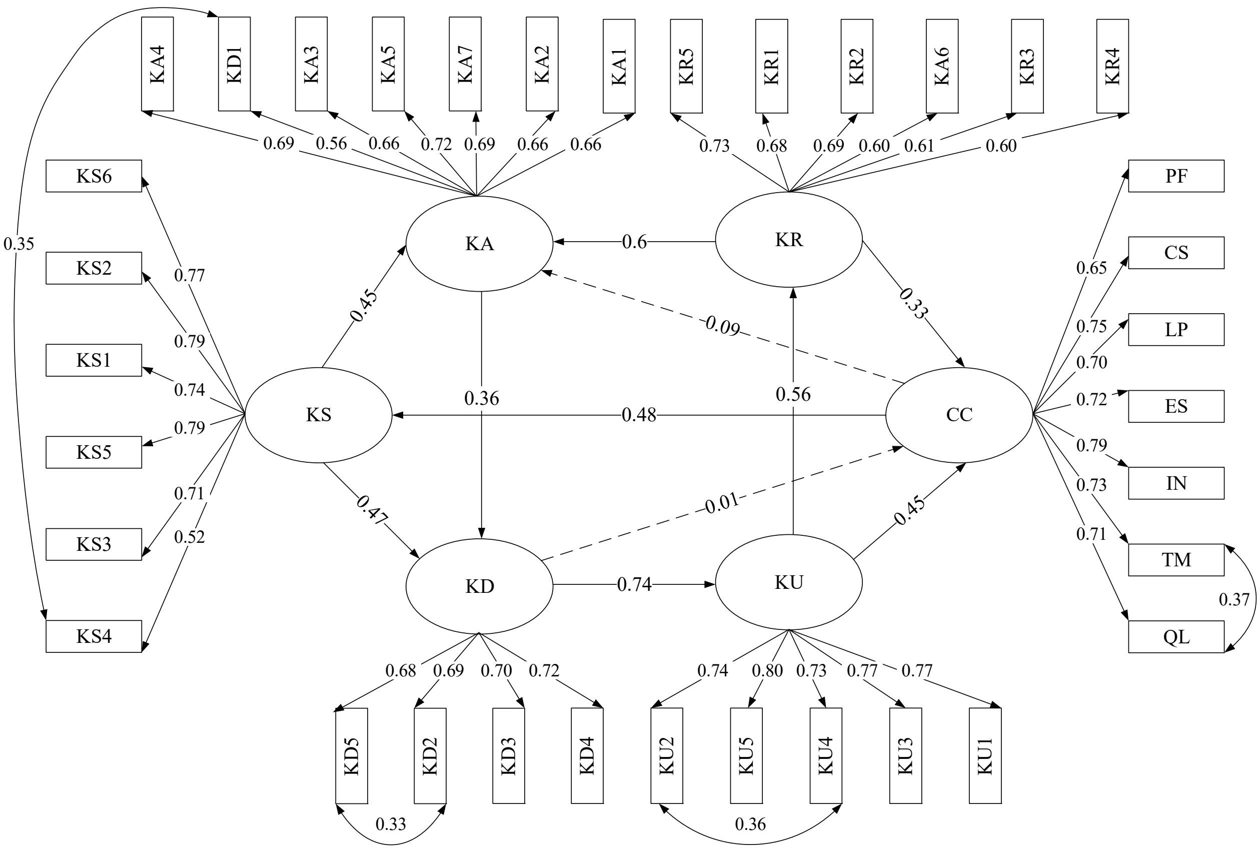

Figure 4. The best-fit structural model.

Table 8. Summary of the SEM results.

Hypothesis	Best-Fit Measurement Model Results		Best-Fit Structural Model Results	
	Correlation Coefficient	Significance	Path Coefficient	Significance
H1	0.77	Yes	0.45 ***	Yes
H2	0.79	Yes	0.47 ***	Yes
H3	0.68	Yes	0.36 **	Yes
H4	0.38	Yes	0.60 ***	Yes
H5	0.30	Yes	0.74 ***	Yes
H6	0.45	Yes	0.56 ***	Yes
H7	0.36	Yes	0.48 ***	Yes
H8	0.39	Yes	0.09	No
H9	0.59	Yes	0.01	No
H10	0.40	Yes	0.33 ***	Yes
H11	0.59	Yes	0.45 ***	Yes

Note: ** $\alpha < 0.01$, *** $\alpha < 0.001$, $n = 272$.

5. Discussion of Results

The best-fit structural model shows relationships among the five key KMP and CC factors, leading to the final model of KMP and CC factors (see Figure 5). The final model indicates that all five KMP factors have direct and indirect influences on each other and the CC factor. Feedback on CC is sent back to the KMP factors through the KS factor to improve KMP and CC in the long term continuously. Among the five KMP factors, the KD factor has the most decisive influence on the KU factor, with a path coefficient of 0.74. Wen and Qiang [86] stated that the company needs to use organizational and individual knowledge to reduce work problems (e.g., repeated mistakes and duplicated work). Strong relationships (with a path coefficient of at least 0.5) are also found between the KU and KR and KA and KR factors. Dang et al. [7] stated that the construction market is a turbulent environment with changes in clients, competitors, and technology. Knowledge acquired from the construction market could be used to deal effectively with these changes [38]. Chen and Fong [37] mentioned that construction companies learn from their clients through a learning mechanism that includes using knowledge to respond to clients, acquiring feedback from them as new knowledge, and integrating and analyzing them once again for new responses in the future.

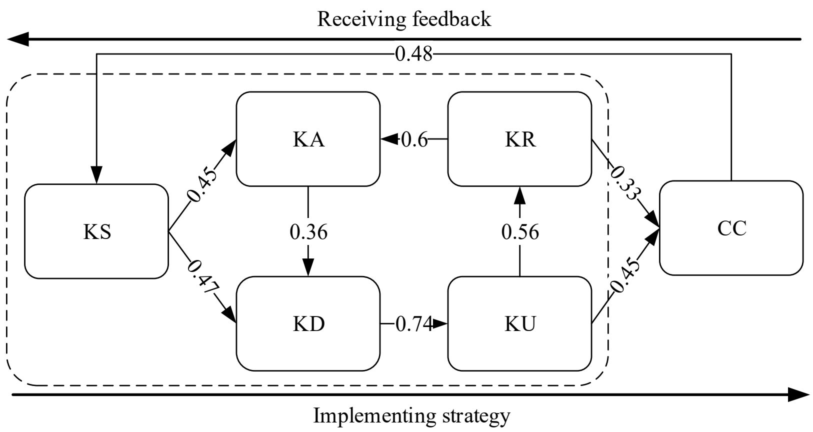

Figure 5. The final model of KMP and CC factors.

The indirect relationships between KMP factors are also crucial. For example, the KS factor has no direct, but indirect, relationship with the KR factor (see Figure 5). This indirect relationship is achieved through the KD and KU factors with the path coefficients of $0.47 \times 0.74 \times 0.56 = 0.19$. For example, Oti et al. [20] mentioned that building information modeling is used as a data storage and sharing knowledge tool, in which construction managers can use updated project information to control effectively changes in projects. The KA factor also has an indirect relationship with the KR factor through the KD and KU factors with a path coefficient of 0.36 × 0.74 × 0.56 = 0.15. Chen and Fong [37] mentioned that KA, KD, KU, and KR factors represent the learning mechanism of an organization in which the intensity of knowledge acquisition increases, leading to an increase in the intensity of knowledge responsiveness. Total relationships (direct and indirect) between the five KMP factors are summed in Table 9.

The final model (see Figure 5) reveals direct and indirect relationships between the five KMP factors and the CC construct. The KU and KR factors are found to have direct relationships with CC (see Table 10). Chen and Fong [37] stated that construction companies should utilize existing and new knowledge to adjust strategic decisions in business processes, solve business problems, and deal with competitors (items in the KU factor) to improve their construction performance. Chen and Mohamed [6] stated that communication and feedback of clients (items in the KR factor) must be carefully investigated to identify the root causes of problems to enhance their satisfaction. The KS, KA, and KD factors, on the other hand, are found to have indirect influences on the CC factor. Activities to store knowledge in the knowledge system (the KS factor items) create favorable conditions for knowledge dissemination among departments in the organization (the KD factor items) and provide accessible information (such as market research, KPIs, and financial reports) for acquiring new information (the KA factor items) [49]. They maintain and update available knowledge capability effectively, initiating utilization and responsiveness. These influence the company's competitiveness.

The performance of the CC factor is sent back to the KMP factors through the KS factor (with a path coefficient of 0.48) for further improvement, see Figure 5. Sang et al. [113] stated that high employee satisfaction raises employee participation in KM practices, such as storing knowledge and sharing lessons learned. Learning from project experiences requires good communication tools to enhance decision-making capability and reinvent knowledge for future projects [114].

Total effects of the KMP factors on the CC factor are summarized in Table 10. The KU factor is the most crucial factor to enhance CC, with the highest total effect of 0.63. To improve CC in the short term, the focus should be on enhancing knowledge utilization by, for example, encouraging team members to brainstorm and use their knowledge learned in previous projects to solve problems and training on how knowledge and technology are used to enhance business processes.

The KD factor is the second most important KMP factor to enhance CC (see Table 10). Though this factor has no direct effect on CC, its indirect effects on CC, through the KU and KR factors, are vital. The data acquired from, for example, market, financial reports, and KPIs should be disseminated through internal communication and staff mentoring (the KD factor) to solve problems and adapt business directions (the KU factor) [39,110]. It assists the companies in effectively responding to clients and defeating competitors (the KR factor). All these lead to a higher CC, showing the relationship of KD→KU→KR→CC.

Although the KS and KA factors do not have substantial effects on CC, they are found necessary in enhancing the KD, KR, and KU factors in the long term. The KS factor is the platform to transfer knowledge to perform activities and accumulate knowledge for long-term use. Time-related issues on site (e.g., technical problems, design changes, and user complaints) should be stored and used to improve project schedules through re-planning, new design and improvement, and monitoring and tracking tools for construction sites [84]. Investing in a storage system helps businesses convert the knowledge of experts and senior engineers into lesson-learned data (e.g., safety, risk, claim and conflict, and contract and law) and use it to build training programs for new employees. Transferring and accumulating knowledge may take time; however, it helps companies reduce long-term losses when their employees leave [115]. Centralized data management also helps the company create a communication environment between projects where information can be shared to enhance knowledge learning.

Table 9. Direct and indirect relationships between the five KMP factors.

	KD			KU			KA			KR		
	Direct	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**
KS	0.47	(0.45 × 0.16) = 0.16	0.63	-	(0.45 × 0.36 × 0.47) + (0.47 × 0.74) = 0.47	0.47	0.45	(0.47 × 0.74 × 0.56 × 0.6) = 0.12	0.57	-	(0.47 × 0.74 × 0.56) = 0.19	0.19
KD	-	-	-	0.74	-	0.74	-	(0.74 × 0.56 × 0.6) = 0.25	0.25	-	(0.74 × 0.56) = 0.41	0.41
KU	-	(0.56 × 0.6 × 0.36) = 0.12	0.12	-	-	-	-	(0.56 × 0.6) = 0.34	0.34	0.56	-	0.56
KA	0.36	-	0.36	-	(0.36 × 0.74) = 0.27	0.27	-	-	-	-	(0.36 × 0.74 × 0.56) = 0.15	0.15
KR	-	(0.6 × 0.36) = 0.22	0.22	-	(0.6 × 0.36 × 0.74) = 0.16	0.16	0.6	-	0.6	-	-	-

Note: Only significant path coefficients of at least 0.1 are used.

Table 10. Summaries the influences five KMP factors have on CC.

Factor	Direct Effect	Indirect Path	Indirect Effect	Total Effect
KU	0.45	KU-KR-CC	0.56 × 0.33 = 0.18	0.63
KD	-	KD-KU-CC	0.74 × 0.45 = 0.33	0.47
		KD-KU-KR-CC	0.74 × 0.56 × 0.33 = 0.14	
KR	0.33	-	-	0.33
KS	-	KS-KD-KU-CC	0.47 × 0.74 × 0.45 = 0.16	0.16
KA	-	KA-KD-KU-CC	0.36 × 0.74 × 0.45 = 0.12	0.12
Sum	0.78		0.93	1.71

Note: Only significant path coefficients of at least 0.1 are used.

6. Self-Assessment Form of CC through KMP Implementation

Based on the SEM results, this study develops a self-assessment form of CC through KMP implementation (see Table 11). The results of the self-assessment form show the current achievement of CC through KMP implementation and suggest key KMP factors for improvement to enhance CC in the long term. The assessment form consists of 35 items under five KMP and CC factors. Each item is assigned, with its importance weight, based on the best-fit structural model in Figure 4. For example, the "storing lesson learned into the database" (KS5) and the "conducting data screening before saving them into the database" (KS2) are the most important items under the KS factor, with their highest loadings of 0.79. In this form, managers and related teams assess each KMP implementation using the 5-point scale, where 1 = no implementation, 2 = randomly implemented, 3 = regularly implemented with supported plans, 4 = regularly implemented and assessed, and 5 = regularly implemented, assessed, and continuously improved. The seven CC items are also evaluated based on the current performance using a 5-point scale, where 1 = the lowest level among competitors, 2 = lower than the average level of competitors, 3 = same as the average level of competitors, 4 = higher than the average level of competitors, and 5 = the highest level among competitors.

Table 11. An example of a self-assessment form of CC through KMP implementation.

Factor	Items	Important Weight	Assessment Score *	Calculated Score
KS	KS2	0.79	3	2.37
	KS5	0.79	3	2.37
	KS6	0.77	3	2.31
	KS1	0.74	4	2.96
	KS3	0.71	4	2.84
	KS4	0.52	2	1.04
Total score of KS				13.89
Adjusted score (KSa) = 13.89 × 5/21.60 = 3.22				
KA	KA5	0.72	3	2.16
	KA4	0.69	3	2.07
	KA7	0.69	2	1.38
	KA3	0.66	3	1.98
	KA2	0.66	4	2.64
	KA1	0.66	3	1.98
	KD1	0.56	2	1.12
Total score of KA (KAs)				13.33
Adjusted score (KAa) = 13.33 × 5/23.20 = 2.87				
KD	KD4	0.72	3	2.16
	KD3	0.70	2	1.40
	KD2	0.69	4	2.76
	KD5	0.68	4	2.72

Table 11. *Cont.*

Factor	Items	Important Weight	Assessment Score *	Calculated Score
Total score of KD (KDs)				9.04
Adjusted score (KDa) = 9.04 × 5/13.95 = 3.24				
KR	KR5	0.73	3	2.19
	KR2	0.69	4	2.76
	KR1	0.68	2	1.36
	KR3	0.61	2	1.22
	KA6	0.60	3	1.80
	KR4	0.60	3	1.80
Total score of KR (KRs)				11.13
Adjusted score (KRa) = 11.13 × 5/19.55 = 2.85				
KU	KU5	0.80	3	2.40
	KU3	0.77	3	2.31
	KU1	0.77	3	2.31
	KU2	0.74	2	1.48
	KU4	0.73	3	2.19
Total score of KU (KUs)				10.69
Adjusted score (KUa) = 10.69 × 5/19.05 = 2.81				
CC	IN	0.79	3	2.37
	CS	0.75	3	2.25
	TM	0.73	3	2.19
	ES	0.72	3	2.16
	QL	0.71	4	2.84
	LP	0.70	4	2.80
	PF	0.65	3	1.95
Total score of CC (CCs)				16.56
Adjusted score (CCa) = 16.56 × 5/25.25 = 3.28				
	KMP factor	Total effect	Adjusted score	Influential score
The influences of KMP factors on CC	KS	0.16	3.22	0.52
	KA	0.12	2.87	0.34
	KD	0.47	3.24	1.52
	KR	0.33	2.85	0.94
	KU	0.63	2.81	1.77
Influential score of KMP factors on CC (KMPf) = 0.52 + 0.34 + 1.52 + 0.94 + 1.77 = 5.09				
Final score of CC through KMP implementation (CCKMP) = (CCa + KMPf) × 5/13.55 = (3.28 + 5.09) × 5/13.55 = 3.09				

Note: * The assessment scores are the assumed scores and do not reflect the actual status of the Vietnamese construction industry.

The assessment of the CC through KMP implementation combines the current CC performance and the influences the KMP factors have on CC. The final score is separated into five levels.

- 1—No KMP in place: KMP activities are performed randomly, and CC is achieved without KMP implementation.
- 2—Beginner level: KMP activities are recognized but not performed regularly. No standard practices are conducted.
- 3—Medium level: KMP activities are performed under a standard process. The KMP practices are assessed on a regular basis.
- 4—High level: KMP activities are acknowledged as a tool to enhance the CC and are well-managed with supporting tools.

- 5—Excellent level: KMP activities are comprehensively and continuously improved and performed in an optimized manner. A long-term KMP improvement plan is established, implemented, and regularly updated to enhance CC.

The steps of the CC assessment through KMP implementation are as follows:

- Step 1: Each item of KMP and CC factors is assessed using a 5-point scale. The assessment score of each item is multiplied by its importance weight, and all items' scores are summed to achieve the total score of each KMP and CC factor, (see Table 7). Please note that the assessment scores used in Table 11 are the assumed scores and do not reflect the actual status of the Vietnamese construction industry. They are used as examples for the calculation steps only. The total score of the KS factor (KSs) is (0.79 × 3) + (0.79 × 3) + (0.77 × 3) + (0.74 × 4) + (0.71 × 4) + (0.52 × 2) = 13.89 points (see Table 11). The total score is then adjusted to a maximum adjusted score of 5 points. For example, the maximum total score of the KS factor is (0.79 + 0.79 + 0.77 + 0.74 + 0.71 + 0.52) × 5 = 21.6 points when all six KS items receive 5 points in the assessment. The adjusted score of the KS factor (KSa) is then 13.89 × 5/21.6 = 3.22 points (see Table 11).
- Step 2: The influences the five KMP factors have on CC are reflected by the influential score of KMP factors on CC (KMPf). It is calculated by multiplying the adjusted scores of five KMP factors by their influential weights (see Table 10). It is summed to achieve a maximum influential score of 8.55 points (i.e., when five KMP factors receive the adjusted scores of 5 points). For example, the total effect the KS factor has on CC is 0.16 (see Table 10); this results in the influential score of the KS factor on CC of 0.16 × 3.22 = 0.52 (when the adjusted score of the KS factor is 3.22), see Table 11.
- Step 3: The final score of CC through KMP implementation (CCKMP) is finally calculated by summing the adjusted score of CC (CCa) with the influential score of KMP factors on CC (KMPf). It is then adjusted to a maximum score of 5 points by multiplying by 5 and dividing by 13.55 (which is the maximum score of CCa and KMPf, i.e., 5 + 8.55 = 13.55 points). In Table 11, the CCKMP is (3.28 + 5.09) × 5/13.55 = 3.09.

The assessment results in Table 11 show the CCKMP score of 3.09 points. This represents a medium level of KMP implementation in the companies, where KMP activities are performed and regularly assessed under standard processes. To further improve the KMP implementation and enhance CC in the short term, the companies may focus on enhancing the KU and KR factors as they receive low scores of 2.81 and 2.85, respectively (see Table 11). In the long term, the companies may focus on the KA factor by, for example, retrieving international benchmarking systems to be used to improve the KMP implementation and adding the KMP implementation in the KPI system (i.e., the KA7 and KA3 items under the KA factor).

7. Implications for the Construction Industry

Successful KMP implementation to enhance CC depends on various aspects, such as budget availability, the company's size, and the number of ongoing projects [116]. Different strategies may be implemented in different circumstances. It is, therefore, suggested that the implication of KMP to enhance CC is separated into short-term and long-term plans. The short-term plan should focus on the KU, KR, and KD factors by utilizing the limited budget and resources to enhance KM implementation. Project engineers and team members should have regular meetings to share experiences, solve common construction defects, reduce rework, conflicts, and costs, and avoid other risks [4,12,44,93]. Real case studies and previous project problems must be discussed to achieve lessons learned that are understood and acknowledged by all members. Project managers should create an enabling environment to promote project knowledge utilization to project members to reduce missing information, increase coordination among members, and focus on the overall goal of project success [83].

Close-out meetings should be set with team members, suppliers, competitors, subcontractors, and clients, as possible, to discuss success and areas for improvement. Critical failures must be discussed, and solutions, based on all parties, should be disseminated to related functions using traditional (e.g., hard copy and personal communication) and new technology (e.g., online meetings, database system) means. The meeting reports should be generated as a hard copy to be used and referred to in the following projects.

Long-term plans should focus on human and knowledge systems [4,13,83]. Though having a high cost, investment in IT systems eases and enhances KM implementation by, for example, storing data and records in a database, retrieving and sorting data to be used with specific projects, and authorizing permission for data access to ensure data security. Building information modeling (BIM) is a construction tool that assists KM implementation throughout the project lifecycle to achieve better KM [14]. It operates like a central data platform that stores construction information. It illustrates the project via a 3D model, which is easier for those who are not construction engineers, with some essential information (e.g., cost, schedule, and other resources) for users (e.g., engineers, managers, and clients) to communicate effectively with each other. Thus, the project information may be utilized accurately by stakeholders. In addition, the long-term plan should also focus on the relationships among parties in the construction market to represent the social network among contractors, designers, supervisors, suppliers, and clients (owners) [117]. In particular, by building long-term relationships with clients and suppliers, the contractor's reputation may be increased over time with activities, such as exchanging and acquiring data and technology for improvement and keeping in touch with suppliers and clients. These could be performed through meetings with customers and suppliers to provide service updates and new project plans.

Knowledge acquisition and responsiveness should be implemented continuously in the construction market in terms of the product, price, place, promotion, and people [118]. Product-related activities may include seeking client satisfaction and training for interpersonal skills, while price-related activities may include providing free preliminary estimates and training estimators. Place-related activities include seeking new geographical locations, while promotion-related activities include using professional marketers, maintaining websites, and participating in trade shows. People-related activities include providing client entertainment, setting up scholarships, and hosting social events. Effective KMP implementation results in the trust of clients and stakeholders to build sustainable relationships to achieve construction competitiveness in terms of productivity, work quality, and profit.

The above-suggested plans may be applied, adjusted, and implemented in the construction industries in developed and developing countries as they are not limited to the Vietnamese context. For example, standard or local communication tools, such as Line Chat, Zalo, and Discord, may be selected and used among team members to respond to requests and problems immediately. Lessons learned from the parent companies may be shared with their subsidiaries to avoid similar mistakes.

In summary, activities related to short- and long-term KMP implementation plans to enhance CC are summarized.

- In the short term, project managers may organize a weekly meeting on sites to discuss problems and challenges with workers. Workers with good examples are invited to give a short talk on their performance, and their stories are posted on the company website. Social communication channels are encouraged to promptly manage and solve problems on sites. The new technology as building information modeling (BIM) and 3D model, is utilized in client discussions, and the discussion summaries are recorded for future reference.
- In the long term, the company should invest in data warehousing to effectively record, analyze, and use the data to minimize possible human errors. Skill training in data warehousing is required for effective utilization. The BIM is encouraged to be used to closely monitor the work progress, manage problems, and record solutions for future uses.

8. Conclusions and Recommendations

Knowledge becomes an asset in a highly competitive environment that helps increase construction companies' adaptability and competitive advantages. This study explores KMP constructs, interrelationships among KMP factors, and the effects of KMP factors on CC. KMP, which comprises 28 activities relating to knowledge management, is confirmed by five key factors: KA, KD, KR, KS, and KU. The analysis results show that five KMP factors influence each other and CC directly and indirectly. Moreover, the CC result is fed back to urge KMP improvement, generating continuous improvement in companies. The cyclical pattern between the KMP and CC factors implies the dynamic relationships that require continuous improvement to enhance competitiveness in the long term.

The analysis results suggest the construction companies focus on the KU, KD, and KR implementation to quickly improve the CC in the short term. Companies must attempt to fully utilize their current resources, especially the workforce, in sharing data, information, and experiences in solving work problems. Additionally, with the KS factor being a connection point between the CC and other KMP factors, it is suggested that work solutions should be documented and used in future projects. Investing in database systems may also help manage, access, sort, summarize, and utilize knowledge to enhance CC in the long term effects.

For practitioners in the construction industry, this study proposes a self-assessment form to be used to assess current CC and identify the improvement to enhance KPM implementation and CC in the long term. The assessment form may be used with other industries with some weight adjustments to suit each industry.

This study has some limitations. This study is a cross-sectional study of constructors providing building project types in one geographical region (Vietnam). Future research studies in different geographical areas may be performed to provide insights and contributions to construction engineering and management. Different datasets may result in different directions of relationships between the KMP and CC factors, leading to different strategies and implementation plans. Moreover, focuses on profit, schedule, and quality may be adjusted in companies in each region to best explain their construction competitiveness. The generalizability of the study results may also be improved by increasing the sample sizes and characteristics (sample diversities). The self-assessment form is developed based on the SEM results. Future studies may be conducted to assess the factors' weights using various methods, such as the analytic hierarchy process and multiple regression methods to suit the actual practices of the companies [119]. To further examine the dynamic relationships among the KMP and CC factors, further analysis using, for example, the system dynamics modeling approach may be performed to establish a long-term implementation plan.

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