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Knowledge Management Model for Construction Design Consulting Companies

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Abstract: An optimum design is critical for improving a construction project efficiency in its implementation phase. However, it is observed in Vietnam that in many construction projects, the design optimization process has not attracted reasonable attention; this process is often carried out in a perfunctory manner without a systematic approach, then the projects' designs are often not optimized, leading to a reduction in their performance efficiency. This study presents a knowledge-based approach with knowledge management model developed to aid in the management of a construction project's design process, based on the intelligent use of accessible corporate data and experience knowledge. Semi-structured interviews were conducted in three construction consulting companies with the goal of learning how the selected design solution process was executed in practice and gaining necessary knowledge for system identification and design of the suggested model. A Construction Design Knowledge Model was created, operated, and validated with consultancy construction experts. The developed Construction Design Knowledge Model was deemed an advanced tool for building design selection as a result of its ability to assist consulting firms in creating corporate information, making decision-making in a less subjective manner, and lowering reliance on personal knowledge. The system's indicated advantages helped to increase construction design performance.

Keywords: Selection of construction project designs, Construction Consulting Company (CCC), Knowledge Management (KM)

1. Introduction

To increase productivity and value of a construction project, the design company, which in Vietnam is categorized as a construction consulting company (CCC), must perform a design optimization process (Knotten, Svalestuen, Hansen, & Lædre, 2015). According to the European Construction Institute (ECI), design is considered one of the four off-site aspects that have potential effect on on-site productivity loss, if there are changes in design and scope of work during the project implementation (ECI European Construction Institute, 1994). However, in order to generate design alternatives and select an optimum solution for the design, lots of expertise needs to be mobilized and a number of bodies of knowledge should be utilized. Therefore, the job of managing sources of knowledge is essential for project management in general and project design in particular. In the construction sector, this job is particularly important for construction consulting companies, which mainly use knowledge resources for their services (Carrillo & Chinowsky, 2006). The proper use of knowledge can help improve the performance and innovation processes of organizations (Al-Ghassani, Kamara, Anumba, & Carrillo, 2004; Hayles et al., 2004). The effectiveness of the decision-making process is affected by a combination of careful analysis and management of clear information and available knowledge (Sommerville & Craig, 2006). However, CCCs have difficulty in knowledge management (KM) because they do not have any useful tools to

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capture, store, share, and reuse knowledge generated during the design of previous construction projects (Cooper et al., 2008). As the nature of the construction industry, after each project, the team may disbanded then lessons learnt are often lost, leading to a lot of repeated prior mistakes (Anumba, Egbu, & Carrillo, 2008), not to say time consuming in re-inventing the good solutions. Furthermore, CCSs may not have a chance to take advantages of valuable knowledge from external sources because the knowledge generated in this construction sector is largely empirical and often less shared (Al-Ghassani, Kamara, Anumba, & Carrillo, 2006). Therefore, an intelligent model is needed to support the decision-making process in project design in the CCCs, especially in Vietnam.

This research study aims at developing a KM model to be used in CCCs which helps them to capture, store, share, and reuse knowledge generated during the design of previous construction projects. This paper presents the development of this KM model, called Construction Design Knowledge Model (CDKM), which is based on the typical design process in construction projects and an e-management tool. The paper consists of the following sections, apart from the introduction and conclusion: (i) reviewing the literature background of the design selection process; (ii) research methodology; (iii) developing a concept and main features of the proposed knowledge management model; (iv) validating the model; and (v) discussions on the application of the proposed KM.

2. Literature and Background

2.1. Construction Design

According to Tunstall (2006), "design" can be a noun and also a verb. When it is in the verb form, it means to plan or to arrange. When it is in the noun form, it represents the product that has been "designed" and is often "new". When designing any product, attention must be placed at its core elements, which include materials, processes, forms and appearance (Tunstall, 2006). Alternatives of design, therefore, are different in one or some of those elements.

Construction designs are developed to express the client's requirements on project functions. There are several phases of construction designs in a typical project life cycle, their classification may differ from country to country. In the United Kingdom, designs include Concept Design, Spatial Coordination, and Technical Design (RIBA, 2020). Other countries perceive schematic design, design development and construction document as key stages of design (MasterClass, 2021). Design development documents are similar to schematic design documents, but they include greater detail in the drawings and requirements, as well as an updated cost estimate, depending on the contract. However, with the recent evolution of digital construction, these phases have become more muddled as a result of technological advancements (AIA, 2013b). All of the construction designs must comply with technical standards and codes while ensure that the projects can be built in an optimum and economical way (Dieter & Schmidt, 1963; Knotten et al., 2015). In CCCs, the design process requires engineers to search for a variety of data sources to use together with the reuse of their own experience and knowledge to come up with a set of advantages solutions for each of the design phases. Also, when selecting a design solution, not only time, cost and the use of resources need to be considered (Fischer & Aalami, 1996), but also the availability of data for the designing job should be taken into account. Literature shows that when making decision for a problem has more than one criterion to assess, the problem should be analyzed as a multi-criteria decision system (Ferrada, Serpell, & Skibniewski, 2013). In this case, the efficiency and effectiveness of the knowledge management approach, therefore, should be considered important for the design services provided by CCCs.

Typical teams to perform the design job include architectural, structural, MEP (mechanical - electrical - plumbing) (Metha, Scarborough, & Armpriest, 2009); some projects require additional teams for special works. However, in the design development stage, AIA (2013b) differentiate between essential designs, which include architectural, structural, HVAC, electrical, plumbing, and fire protection systems and specialized designs such as acoustic and vibration, lighting, landscaping and others. In addition to these teams, in the construction documents stage, there can be an involvement of the interior designers in building projects (AIA, 2013a). Therefore, in addition to their own discipline, the manager of a design process must have a clear understanding of the full project scope, as well as of the responsibilities and contributions of each team member. A good KM model can be helpful for such type of people.

2.2. Knowledge Management in Construction Consulting Companies

According to Anumba et al. (2008) in their book entitled "Knowledge management in construction", any organization wishing to advance knowledge management should consider the tacit information held in people's heads as well as the explicit knowledge included in papers and intranets. This is specifically true for CCCs as this type of firm mainly use knowledge resources for their services (Carrillo & Chinowsky, 2006). Though there are different perceptions between the design firms and construction firms, these key players in the construction industry in several countries such as Spain, Malaysia, United Kingdom, etc. are all aware of the benefits that KM could bring to them (Duryan & Smyth, 2019; Forcada, Fuertes, Gangolells, Casals, & Macarulla, 2013; Yap & Lock, 2017).

There are two options that a CCC can adopt for knowledge management. It can seek to capture construction in available documents, databases, intranets, etc. This 'explicit knowledge' approach works well for conventional problems, but it hinders the sharing of fresh ideas. In another approach, it can also consider focusing on people and developing

mechanisms for them to share their "tacit knowledge" in order to foster creativity (Anumba et al., 2008). Yap and Lock (2017) reported that in Malaysia, the most preferred techniques for sharing knowledge include “face-to-face interaction”, “mentoring” and “documents and reports” while the important tools for this purpose are “groupware” and “telephone”. These lessons learnt clarify that the identification of essential knowledge management attributes serves as a foundation for project managers to develop effectively and efficiently knowledge management methods (Yap & Lock, 2017).

KM application may face many challenges in firms in the construction industry in general and in CCCs in particular. The construction industry is characterized by its fragmentation with many companies providing different specialized services in a construction project (Metha et al., 2009). The most significant organizational challenge impeding knowledge management practice adoption is "lack of motivation," while the main cultural issue is "bureaucracy and hierarchical" and the critical people issue is "lack of trust" (Yap & Lock, 2017). There is a lack of dedication and cultural leadership, as a result of which individuals are overly reliant on them to share and apply knowledge (Duryan & Smyth, 2019). Furthermore, each construction project is a unique structure built to last for hundreds of years and no project is exactly the same as another project. Therefore, individual experience and corporate knowledge are critical factors in construction tasks. As discussed before, there is little chance for CCSs to take advantages of valuable knowledge from external sources (Al-Ghassani et al., 2006); this is considered as an important challenge for reusing knowledge from the projects that they were not involved in. As such, KM has become a vital concern for CCCs to improve efficient performance (Rasli, Majid, & Rahman, 2009).

The construction industry worldwide recently observes the emergence of Building Information Modelling (BIM). As a BIM model can store intelligent data for future uses, BIM-based KM has been proposed (Wang & Meng, 2018). In developing countries like Vietnam, BIM are more widely adopted in design firms than in other players (Nguyen, Luu, & Ngo, 2020). It is noted that only basic uses of BIM have been widely implemented in construction projects (Dao & Nguyen, 2021), therefore, CCCs in Vietnam may not be able to overcome their barriers (Nguyen & Nguyen, 2021) for this more advanced use of BIM for KM.

3. Research Methodology

This research study aims at developing a Construction Design Knowledge Model (CDKM) for CCCs to manage knowledge for their design services. It applies a mixed research approach with a theoretical model development method, trials and errors and a validation process with experts recruited from CCCs. The KM model was developed based on the process of construction design, which shows the needs for taking advantages of available knowledge in each of the stages. Then, available e-management solutions were screened and reviewed to select the best application to support the KM in the stages. The proposed KM was then put into trial in two large construction consulting companies and feedback was collected to revise it. The final model then was validated with a group of seven experts to verify its effectiveness and applicability in practice, and also identify the challenges for a wider application. The research process, then, is illustrated in Figure 1.

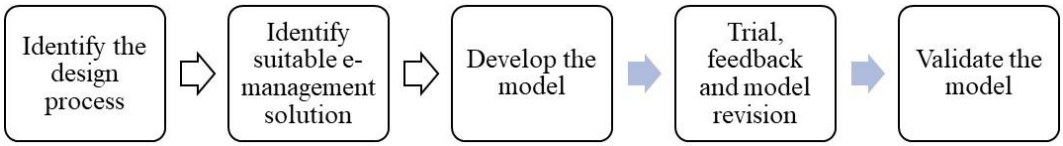

Fig. 1 - The research process

4. Developing a Knowledge Management Model for Construction Design Consulting Companies

4.1 Identifying the Construction Design Process

According to Marzouk, Bakry, and El-Said (2010), a typical design process in construction consists of three phases, including initiation, core design, and finalizing and closing of the project (see Figure 2). The Initiation design phase is deployed when a client places an order showing their requirements in project functions, scope, scale and technical standards. Receiving the order, the design team in the CCC will do their research to collect necessary data and information and develop initial design alternatives in conceptual form. This job is often done by a small team together with the design manager. The design alternatives are then proposed to the client for them to select what they prefer mostly considering their own priorities and perception of project value. The Core design phase is started after the initial project design has been approved by the client to proceed. This is the part of the design process where the project is delegated to different divisions for them to work together on developing a full design item for the project. The teams to be mobilized in the phase may differ from project to project due to the types of the construction works and also the work volume. In the

Finalizing and Closing phase, after the design teams have completed the design drawings and documents, the design manager will check the compatibility of the entire design to ensure the quality before submitting it for approval.

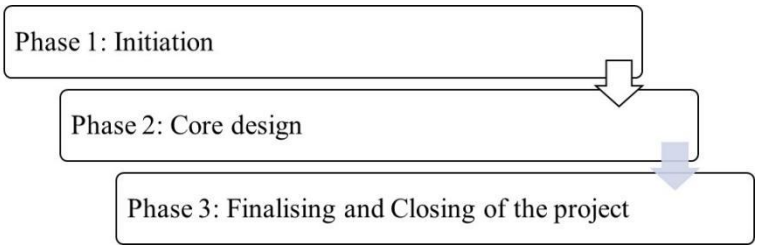

Fig. 2 - A flow chart of three phases of the construction design project

The three phases of the construction design will be used for developing a KM model, since they show the general design process with different level of information development in the design. Different types of lessons learnt and best practices can be identified for reusing in each phase. Historical data can also be captured from each phase with different levels of detail to be shared to succeeding design duties. The phases will be used to design the knowledge storing means for reusing and sharing later.

4.2 Developing Construction Design Knowledge Model

According to Whitten and Bentley (2007), when developing a model, both the functional and non-functional requirements need to be considered.

• Functional requirements identify the inputs, processes, stored data, and outputs needed to satisfy the model operation. In this case, the model must be able to easily store, update and extract design solutions and lessons learnt, as well as necessary data and information. Therefore, the model must consist of a database with different sheets for the ease to store, modify and delete knowledge documentation when necessary. Also, for the accessibility, especially in this era of internet and digitalization, also considering the multidisciplinary nature of the design work, the model should have a functionality that allows it to be accessible via the internet for uploading and downloading files and storing data in cloud computing.

• Non-functional requirements address other features, characteristics and the definition of the constraints of the system. For a CDKM, they include the decentralization of the model's users, the ability to upload files in the form of docx, dwg, sap…. or pdf format, optionally exporting construction design documentary to boards and cards in e-management applications, the easy interact interface.

After defining the required functions of the system, the next step of this study began with the finding of applications available on the internet that supports the four principal CDKM components: (1) capturing knowledge, (2) storing knowledge, (3) reuse knowledge, and (4) sharing knowledge (Figure 3). The suitable application that must well-support the operation of the model's functions to reduce setting work or start all settings from scratch, if necessary, finally, the Trello application was chosen that composes.

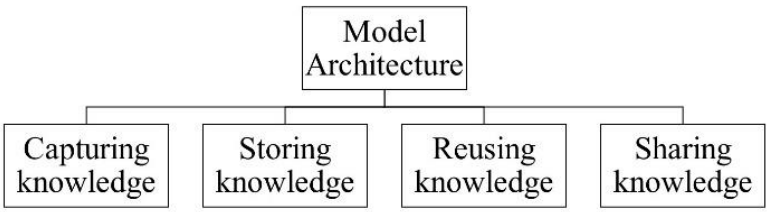

Fig. 3 - Components of the model

Trello is a project management tool. It divides projects into boards and cards to make them easier to manage. You may use the cards to arrange all of your projects and day-to-day tasks so that you can keep track of their progress. The app may unite your complete team on a single platform, making it easier to collaborate in real time (Trello, 2020) (Figure 4). Trello is provided free of charge, therefore, is good for testing new ideas.

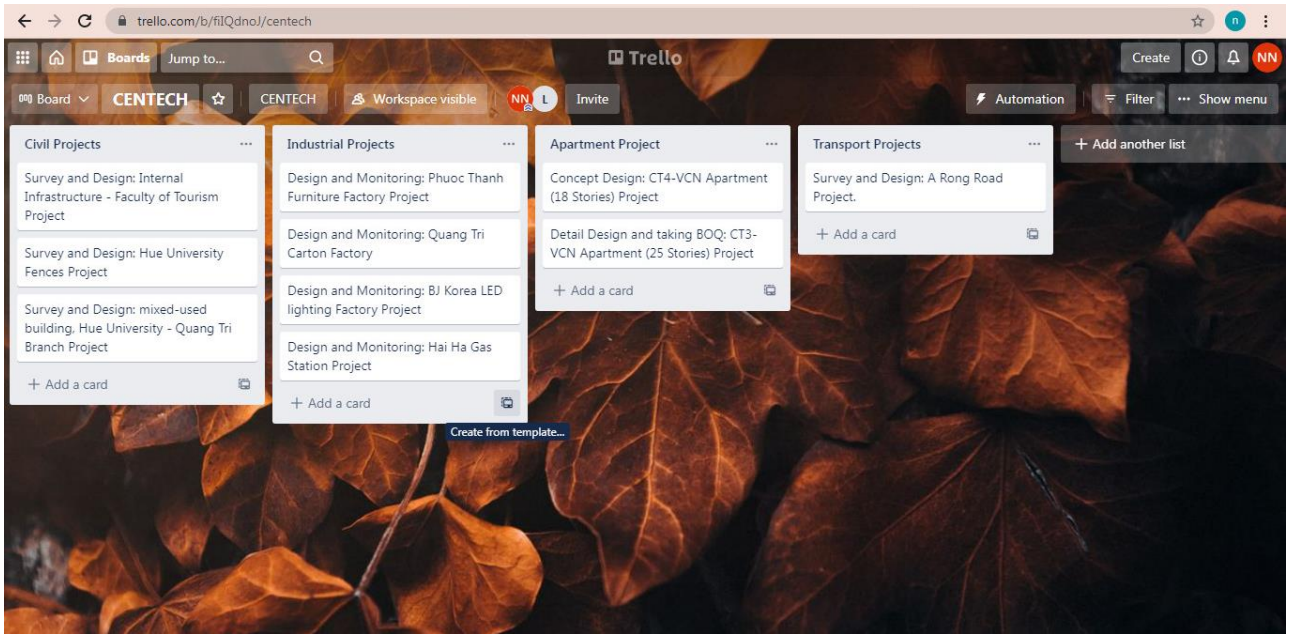

Fig. 4 - A screenshot of The Trello application to support knowledge management

The components of CDKM are integrated into Trello e-management when configuring the application of Trello for design jobs. Logging-in via their own email account (google mail can be used), users can access the app with their own role as a manager, a technical team leader, a design engineer, an architect or a draftsman. Depending on the role, they can access different functions of the app, their access rights are determined based on a set of criteria which define the decentralization of the system's user and the levels of confidentiality of corporate knowledge. Using the app, users can access different menu options: (a) Dashboard: Organization or consultancy services; (b) Board: Types of projects (public project, industrial project, residential projects); (c) List: Classification of knowledge or documentation types; (d) Card: Detail of data.

The application-based KM model operates as follows: when a design project is initiated, a technical team leader will be assigned for it. The technical leader will have a dashboard manager role. When a requirement for design data arises for a new design project, the manager can go to the board of the types of projects to browse the available lists and cards to find what he/she needs. The data to be searched from the CDKM for using in a new construction design can be of three types: (i) documents on design standards, design guidelines, material guidelines for the design; (ii) design drawings and calculation notes for the old project; or (iii) a list of experts and their experience in designing all types of works. Data will be collected from previous and current design projects and uploaded onto the system, linking with one of the menu options based on the data classification.

5. Construction Design Knowledge Model Testing and Validation

During the definition and development of the model, the CDKM development team was supported by two experts from two large construction consulting companies, who tested and reviewed three times the application of the model to optimize the construction design selection process. The feedback is used to modify some aspects of the system's content and the aesthetics of the interface and improve its user hierarchically decentralization. The post-test model was then trialed by providing to a wider range of experienced engineers in CCCs; those designers have applied the model in their construction designs. The aim of this activity is to verify the effectiveness of the system and evaluate its applicability in practice, and also identifies the challenges of bringing the system to the application in design work daily.

The model revised after the trials was validated with seven experts from three consulting organizations, who have at least five years of experience in managing designs in construction projects and are aware of KM in construction. These experts work in the following roles: design manager, Quantity Surveying Manager, Project Manager. All of them tried out the CDKM to apply the work management daily, and fully understand the model process to support decision-making. After leaving them enough time testing the model, each expert was interviewed to collect their assessment on the model's performance. Respondents considered the proposed CDKM as an intelligent tool to support the decision-making process to optimize construction design selection because of its ability to locate necessary information and provide all necessary data quickly and conveniently. In addition, they all agreed that the model is a suitable means of capturing knowledge for

organizations, using individual knowledge effectively. They suggested that CCCs should apply the model to have a useful tool for managing knowledge asset of the organizations. Table 1 shows the perceived advantages of the model.

Table 1 - Perceived advantages of the CDKM

Advantages	Frequency
Advanced design with more knowledge mobilized	6
All the data in just one place	4
Increasing organizational knowledge	7
Knowledge sharing	4

The validation experts also evaluated a close connection with the benefits of applying the CDKM model in CCCs. Most of the interviewees emphasized the benefits of capturing and classifying knowledge regarding design data, reduced duration in the search for suitable construction designs data, supported for the development of knowledge-oriented culture within organization, improve CCC's competitiveness. In addition, it is considered a suitable tool to minimize the mistakes in the design process. Table 2 shows the key benefits of adopting CDKM in construction consulting companies.

Table 2 - Key benefits when adopting CDKM in construction consulting companies

Benefits	Frequency
Shortening for construction design duration	5
Possibility to manage and classify companies' knowledge	6
Enhance competitiveness of the company	5
Reduce the number of redesigns and wrong designs	4
Development of a knowledge-oriented culture within the organization	5

Regarding the trial operation of the CDKM model in practical work, all the interviewees clearly agreed that it assisted an increase in their productivity by saving time in searching for suitable designs of construction and easily gathering useful information. The model was also highly appreciated for its user-friendly interfaces and ease of operation. In addition, it was indicated as an intelligent tool to guide the construction design selection process, support innovations within the CCCs. These results are presented in Table 3.

Table 3 - Practical values of CDKM

Practical Values	Frequency
Increase productivity	7
Easy access to information	5
Guide material and solution design selection	4
Support innovations within the organization	6
Saving cost, man-hour, and completed work duration	5

6. Discussion

During the interviews for models' validation, the interviewees had stimulation comments about the adoption of the CDKM model in the future. Firstly, the willingness of the engineers to integrate the model into work processes in CCCs, it is believed that based on the information technology capacity of engineers. Young engineers will be easier to apply this model than older engineers because of their better ability to use proficiently software applications and the internet. Secondly, they addressed the challenge of integrating the model due to the inherent organic culture in each CCCs. In order to integrate the real KM model in an organization, it is important to set up an organization's knowledge culture, realize the benefits of managing knowledge to facilitate tasks daily within companies. Thirdly, for engineers to actively participate in the adoption of KM systems, the CCCs have to enhance them with the necessary capabilities, especially, having knowledge and using fluently information technology, and social networks, and software applications. Finally, all of them considered that the role of applied KM through e-management has great potential for development in construction consulting companies.

7. Conclusions

Engineers' empirical experience in the construction field is useful knowledge to support the decision-making process of selecting optimal construction designs and that it is reused in other similar construction designs. Thus, CCCs need to promote a model suitable to capture, store, reuse, and share knowledge, including explicit knowledge and tacit knowledge. The model can become a valuable tool to enhance the search performance of construction design solutions that saving time and optimizing resources. The result of the research has developed the proposed CDKM to provide a

suitable way to capture, share, and reuse knowledge for optimizing the selection of construction designs within CCCs. Furthermore, the study showed that to accomplish this, in the age of technology 4.0, CCCs need to promote the application of information technology, cloud storage, and e-management through online applications to support the selection of construction designs and improve the effectiveness of performance works based-KM.

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