A PRELIMINARY INVESTIGATION OF KNOWLEDGE MANAGEMENT TOOLS FOR THE CONSTRUCTION SECTOR

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ABSTRACT: *Knowledge management (KM) is used by construction firms to establish organizational memory (OM) and consequently improve their performance by learning from past mistakes and best practices. Knowledge is the input to innovation; thus, the industry must adopt better ways of managing knowledge for advancement in the construction processes. Knowledge management consists of locating, modifying, and sharing knowledge to meet the needs of the current fast-paced sector. Various tools have been developed to support KM and OM in construction companies, however, it is very important to adequately address the needs of the sector for successful implementations. The aim of this study is to analyze the existing KM tools and evaluate their compatibility with the necessities of today's sector. First, knowledge types in the construction industry were outlined, and existing KM tools were evaluated. Then, expert interviews were performed with two representatives from a prominent construction and a prominent consulting firm to delineate the contemporaneous KM practices as well as the KM needs in the construction industry. Finally, current practice in KM in the construction sector is evaluated, and a vision is developed for a more effective KM approach that could support OM in construction firms.*

KEYWORDS: *Knowledge Management, Organizational Memory, Construction Firms, Software Tools*

1. INTRODUCTION

Intellectual assets are the primary capital in knowledge-intensive industries. For companies looking to thrive in knowledge-based work environments, in-house procedures should be created to accumulate, explore, and exploit corporate and individual knowledge. The term "knowledge management (KM)" was used in Western countries for the first time during the late 20th century in books, academic research, consulting, and organizational adaptation processes. Nevertheless, the management of organizational knowledge did not truly start until the mid-1990s. Implementations of KM mechanisms were somehow present in companies long before these concepts emerged, such as knowledge-sharing activities. In the early 1990s, sector leaders such as BP, Shell, and Chevron used KM initiatives before any academic publication (Quintas, 2005). This shows that KM techniques were naturally used as a part of cooperative incentives to gain a competitive advantage and improve business performance. Today, KM is at the center of any modern business as rapid developments in information and communication technologies influence a profound shift from tangible assets to intangible assets focusing on people and knowledge. Even though many sectors with such needs have adapted ways of managing knowledge today, it is only in the last ten years that companies in the construction sector have started familiarizing themselves with the KM concept (Rezgui & Miles, 2011).

In order to benefit from KM as a pursuit of enriching organizational memory (OM) and achieving productivity, the types of knowledge encountered must be analyzed. There is a popular attempt to categorize types of knowledge in order to ease comprehending, storing, and sharing it. Each categorization considers different aspects of knowledge that guide the analysis in the specific field. The most applicable and renowned categorization for the knowledge management field belongs to Polanyi (Polanyi, 1966), which divides knowledge into tacit and explicit knowledge. Explicit knowledge is the recordable or documented information that can be written, coded, or saved with the intention to transmit knowledge. Tacit knowledge is the knowledge an individual owns, gathered from their insights, personal experience, and observations.

The construction sector is a knowledge-based industry comprising different project participants such as designers, engineers, contractors, and clients that generate overwhelming amounts of data in each project. Effective KM is crucial to organize and benefit from this data overflow. In the past decade, much research has focused on KM for various other sectors, such as consulting, finance, or computer science. Despite the evident need, the construction sector is still lacking effective KM tools to foster organizational memory in a project-based environment. The aim of this study is to explore the KM tools used for gathering, sharing, and storing tacit and explicit knowledge in construction companies. Since KM is effectively used in only a few initiator companies, the authors investigated the steps taken by these pioneers to delineate KM best practices for the construction sector.

This paper reports the results of the two pilot interviews done with the senior managers of two multinational firms.

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The first firm is a consulting firm operating in 50 countries with more than 55 years of experience in the consulting sector. The interview was performed with a senior project director who has 10 years of experience in the sector. The second firm was chosen among the few contractors that use KM effectively, which operates in 50 countries with 107 years of experience in the construction sector. They are among the sector leaders with more than 80,000 employees. The interview was performed with a country manager who has 20 years of experience in the sector. Both experts were asked the same set of 12 questions under three main categories, which were: Data Collection, Data Accessibility and Usage, and Knowledge Management (See Appendix for the Questionnaire Form). The interviews with the company representatives took approximately one and a half hours each, during which the experts were guided by the questions and expressed their views on the topics driven from, but not limited to, the questionnaire.

2. EXPLICIT & TACIT KNOWLEDGE

Resources and competencies are critical factors for companies to survive in an evolving and fiercely competitive atmosphere in the knowledge-based economy (Subramaniam & Youndt, 2005). Thus, one of the biggest challenges is to be able to distinguish characteristics of knowledge from information. Knowledge can be either explicit or tacit. It is also important to distinguish tacit and explicit knowledge in order to comprehend the notion of organizational knowledge

Explicit knowledge is founded on widely recognized and objective standards. It is archived in the form of written procedures or documents. Therefore, it can be codified and communicated with relative ease. It encompasses the majority of knowledge exchange inside companies. Since explicit knowledge can be easily documented, formalized, and expressed, processes of sharing knowledge tend to be more widely used in the workplace. Several management tools are used to increase the willingness of employees to share their explicit knowledge, such as handbooks and information technology systems (Coakes, 2006). Since this knowledge can be codified, it may be reused repeatedly and is, hence, simpler to convey. Design codes of practice, performance requirements, paper-based or electronic drawings, and building methods are a few examples of explicit knowledge in the construction industry (Charles & Robinson, 2011). Other instances of explicit information include design sketches and photographs, 3-D models, and textbooks. Explicit knowledge is the data that can be interpreted by others once it has been codified. People with supplementary knowledge who are able to understand the "codes" and derive meaning from them may be able to understand the presented knowledge. Even this process of comprehending or deriving meaning from knowledge requires the application of implicit interpretational, evaluative, and generalizing skills.

The foundation of tacit knowledge sharing is human experience (Nonaka & Takeuchi, 1995). Polanyi (1966) described tacit knowledge as instinctive knowledge that cannot be expressed coherently by means of words; it is acquired via collective involvement and can be challenging to describe, systematize, and transmit. The informal adoption of taught behavior and methods obtains the uncodified and disembodied know-how. Furthermore, tacit knowledge cannot be directly conveyed to someone since knowledge and task performance have distinctive personal qualities, requiring the acquirer to adjust their mindset. Hence, the degree to which it is conveyed varies. Tacit knowledge can be maintained by individuals or as a team in the form of collective experiences and assessments of events. Employee objectives, capabilities, routines, and intangible information are sources of individual tacit knowledge. On the other hand, collective tacit knowledge may arise from various notions, including top management strategies, organizational agreement on previous shared experiences, company procedures, company culture, and professional customs (Lyles & Schwenk, 1992). Tacit knowledge can also be described as knowledge that has been converted into a habit and possesses a personal quality, as well as being very context-specific. The reality of tacit knowledge is that the less clear and codified the tacit know-how, the more difficult it is for individuals and businesses to internalize. Academics and managers have overlooked the notion of tacit knowledge until recently, although it now plays a major role in corporate growth and economic competitiveness (Howells, 1996). Transmitting tacit knowledge is frequently done primarily through direct conversation. Some tacit knowledge transfers are official as a result of training programs or seminars, while others are more informal as a consequence of interdepartmental work teams, unofficial social networks, and personnel interactions. The desire and ability of individuals to share their knowledge and apply it in practice are crucial to the formal and informal transmission of tacit knowledge (Holste & Fields, 2010). On the other hand, explicit knowledge is able to be formalized and communicated through structured and methodical means, such as in the form of rules and procedures (Nonaka & Takeuchi, 1995).

The difference between individual and collective explicit knowledge is that individual explicit knowledge consists

of expertise and abilities that are easily teachable or writable, whereas collective explicit knowledge lies in standard operating procedures, record keeping, IT systems, and policies (Brown & Duguid, 1991). Regarding innovation speed and financial success, tacit knowledge sharing is more influential than explicit knowledge sharing, whereas innovation quality and operational efficiency are influenced more by explicit knowledge sharing (Wang &Wang, 2012). Thus, companies must learn to share and store both knowledge practices to unlock their potential benefits fully. The following statement explains the criticality of harmonizing explicit knowledge with tacit knowledge; *"If Nasa wanted to go to the moon again, it would have to start from scratch, having lost not the data, but the human expertise that took it there last time"* (Brown & Duguid, 2000,p.122).

3. KNOWLEDGE MANAGEMENT

In a knowledge economy, conducting business has opportunities as well as drawbacks. The opportunities include the potential for expanding market share, enhancing productivity, and increasing profitability through innovation and efficient knowledge asset management. The key difficulties are dealing with rising global competitiveness, shifting levels and patterns of client, customer, and societal demands, and the speed as well as effects of change in information and communication technologies (ICT) (Charles & Robinson, 2011). In order to gain a competitive edge, one must be able to use knowledge efficiently. A common question is whether organizations store knowledge in memory similarly to how people do. The answer is that there is a rising notion that organizations do have frameworks, practices, structures, and other tangible artifacts that demonstrate the existence of knowledge encoded in the organizational culture.

The formation of an organizational memory (OM) within an organization is a critical knowledge management activity that promotes the organizational learning (OL) processes (Ozorhon, Dikmen & Birgonul, 2005). OM can be defined as the means by which knowledge from the past is brought to bear on present activities; thus, it helps to learn from previous experiences (Stein & Zwass, 1995). OM becomes a corporate asset by sharing, organizing, storing, and reusing the knowledge created previously. The knowledge management activities within organizations should aim to enhance the OM.

OM requires continuous improvement and growth of organizational knowledge, which means that both the organizations and the individuals within them must be constant learners. One important aspect of KM is its need to reinvent your organization through learning constantly. Experience-based knowledge is incorporated into procedures and is embedded in technologies and systems. Organizational routines and a culture that encourages the creation, assimilation, and abandonment of outdated information and practices must be developed in order to promote continuous change. Organizations must accomplish two goals that may be in conflict with one another: first, they must build their knowledge bases over time and draw lessons from their past experiences; second, they must make sure that they are learning outside of their core competencies and develop the capacity to assimilate new knowledge in order to be able to respond to change (Quintas, 2005). The generation of knowledge is frequently seen as somehow more significant than knowledge reuse, more challenging to manage, and less dependent on information technology support. However, perhaps a more common organizational concern—and one that is unmistakably tied to organizational effectiveness—is the efficient reuse of knowledge (Markus, 2001). The reuse of knowledge in various decision-making mechanisms and circumstances is expected to result in the generation of new remarks that automatically update the organizational memory when stored back into the system. A cycle should be made where organizational memory is referred to on knowledge transactions, and outcomes are reflected back to enhance the organizational memory.

Construction companies must implement knowledge management mechanisms in their daily routines to improve effectiveness and thrive in an overly competitive sector. In order to meet this objective, first, the sources of knowledge generation need to be analyzed, as well as the type of knowledge they generate. As explained in the previous section, the possible tools for regulating and sharing tacit and explicit knowledge differ due to the nature of the knowledge.

4. KNOWLEDGE MANAGEMENT TOOLS

There are a variety of knowledge management tools available to choose from thus, it is vital to select the appropriate tool that addresses the goals of the organization adequately. The KM tools can be categorized as IT and non-IT-based tools that are used to support the essential aspects of KM such as sharing, reusing, and locating knowledge. In order to distinguish between the two categories, experts suggest naming IT-based tools as KM technologies and non-IT-based as KM techniques (Al-Ghassani, Anumba, Carrillo, & Robinson, 2005).

KM techniques do not require IT tools to execute the sub-processes of KM, such as knowledge sharing. It is clear that the scope and nature of human knowledge are much broader than what can be encoded by IT tools. Some of these tools are; seminars, post-project reviews, communes of practice, project feedback mechanisms, mentor programs, and training programs. Knowledge has a social aspect thus, seminars, communes of practice (where different professions meet to interact), and training programs are great opportunities for employees from different backgrounds to meet and share knowledge. Whereas post-project reviews, project feedback mechanisms, and mentor programs promise a similar scenario to a master-apprentice model where junior individuals get to be criticized and influenced directly by a senior colleague, which is an extremely effective knowledge-sharing mechanism. These tools may seem simpler to implement when compared to IT-based KM tools, however, they hold a much greater value for the initialization of tacit knowledge when compared to IT-based tools. Often the highly skilled members of the working environment are unaware of their tacit knowledge, such as their problem-solving skills or the resources they use. For this reason, knowledge sharing becomes highly dependent on communication within the working environment. Tacit knowledge is personal, linked to experience and learning, and cannot be coded. This results in tacit knowledge being shared within groups with common learning experiences and understandings rooted in common practice via non-codified pathways (Brown & Duguid, 1998).

The IT-based KM tools mainly focus on capturing codifiable knowledge. These tools act as a great OM archive that eases how organizations create an organizational learning and knowledge management culture. The data stored in software and hardware systems can be referred to and reused whenever necessary, making monitoring the data much simpler. Today, there is a variety of software-based programs on the market that offer diversified approaches to KM.

Using Artificial Intelligence (AI) and Machine Learning (ML) based software for KM is one of the leading trends in the knowledge industry. The classification, labeling, and retrieval of data are only a few examples of knowledge management tasks that can automated with the help of AI. Large volumes of unstructured data may be analyzed by these technologies, making it simpler to find insightful patterns and trends in a company's knowledge base. According to Forrester Consulting's principal analyst, Gualtieri (2016), between 60% to 73% of all the collected data within an enterprise goes unused for analytics. With the help of AI-driven KM tools, advanced data structuring could be done for an insight-driven data presentation for the knowledge seeker. The outcome is similar to a personal intelligent assistant that can revolutionize how knowledge workers consume meaningful information and increase their cognitive capacity by providing them with more efficient tools for processing, filtering, sorting, and navigating information sources (Jarrahi, Askay, Eshraghi & Smith, 2022). Thus, organizations can improve their search capabilities, use time more efficiently for knowledge management operations, and provide employees with more individualized content suggestions by implementing AI-powered algorithms.

Another current KM-IT tool is the ontology-based KM system and its application. A knowledge management system based on an ontology is more capable of encouraging the integration of linked resources, identifying precise knowledge rapidly, and steering away a significant amount of unnecessary knowledge. The procedure transforms disorganized knowledge data into structured knowledge by transferring all the necessary information. Storage of knowledge is the process by which the metadata is extracted from the knowledge sources acquired, and knowledge objects are marked in the implication of ontology and metadata standards, with the aim of transforming semi-structured and unstructured knowledge into structured knowledge and storing it in the knowledge base (Zhang, Zhao, Wie & Chen, 2015).

Whether it is a more futuristic approach to KM, such as AI-based tools or more simple cloud-based archive programs, these IT tools share distinct key functions to cover the majority of the needs of KM. Firstly, a "Document Management" function must be present to act as an archive with a correct taxonomy for material and track document changes when they occur. The second one is a "Knowledge Archive". Knowledge bases store structured and unstructured information in the system. These could be not only documents but also tutorials, videos, etc. The third key functionality is the "Security System". This feature limits accessibility for predetermined employees that determines which data is available to obtain. The fourth feature is a strong "Search Function". This function aims to save time when searching for past documents. The final feature should be "Communication Tools". Communication channels can make the systems much more efficient, especially when one has further questions on the uploaded material and can directly reach the author.

5. CONSTRUCTION SECTOR & KM

The activities of today's construction industry demand an increased level of knowledge, skills, and learning, as the sector is a multilayered knowledge-based environment that has knowledge input from different project parties

(Ferrada, Núñez, Neyem, Serpell, & Sepúlveda, 2016). Explicit and tacit knowledge come together to form organizational knowledge. In every individual's thought lies an accumulation of tacit knowledge. It is a collection of experiences, observations, and intuition that can be either cognitive or technical. Examples of tacit knowledge in the context of construction may include estimating and tendering prices that have been prepared over time through practical experience in preparing bids, encountering the construction processes, interaction with clients/customers and project team members in the construction supply chain, as well as an understanding of markets. Experience-based, judgmental, and context-specific knowledge makes it challenging to codify and share this type of knowledge.

Explicit knowledge in construction is generally the data obtained from site activities. This could be man-hours, machine hours, periodical reports, unit prices, and anything generated from real-life implementations. As a result, better ways of knowledge management should be the primary target to comprehend the overflow of data in the construction sector. However, this might be unfavorable at first for some managers due to the general nature of the lack of human resources or timely pressure on on-site activities. Thus, the general outcome and long-term benefits of adopting such an ideology must be made clear to decision-makers for the right resource allocation. Every employee in a construction organization must embrace a culture that values knowledge capture and sharing of knowledge.

However, there are a set of socio-technical barriers defined by Rezgui & Miles (2011) that limit the progress of KM in the construction industry. Firstly, employees do not perceive any immediate benefits from sharing knowledge and experiences. In fact, this is seen as a possible threat to their status as "experts" since there is usually no encouragement for a supportive knowledge-sharing culture focused on all employees. (e.g., by implementing creative ways for rewards and recognition). Next, shelf solutions do not work, and there is a weak culture of software adoption. In order to perform their duties and access software, employees are frequently limited to a specific place, which is usually their office. However, access to information from construction sites is frequently constrained by network availability. Another obstacle is that the industry is divided and organized into numerous disciplines, each of which has its own rules and specialized terminology. There is not a particular language that captures a shared comprehension of construction principles utilized across disciplines. All these aforementioned challenges limit effective communication and the sharing of experiences.

By actively participating in projects over an extended length of time, one can gain valuable construction knowledge. However, this is usually not the case, as employee turnover is radically high. The specific needs of the employees who will use the project data may not always be understood by those in charge of gathering and archiving it. Furthermore, data is gathered and archived at the end of the construction phase rather than being handled while it is being created. By now, it is likely that those who were aware of the project have moved on to other projects. Again, due to high turnover, many businesses keep archives projects however, it is challenging to get in touch with the original report authors. These projects should be available to be used with little (or no) consultation, this past data should have a rich representation of the data context. Lastly, decision-making objectives are frequently not noted or documented. The millions of spontaneous messages, phone calls, emails, and discussions that comprise much project-related information require complex methods to track and document.

In order to understand the reflections of these limitations on current construction sector knowledge management practices, two interviews were conducted. The first interview is held with the country manager of a 100-year-old multi-national construction firm, which is among the top 20 highest-grossing international contractors according to ENR magazine 2023. The second interview is made with a senior consultant in one of the top global strategy consultancy firms by revenue, who has one of her expertise in KM. The reason for the second interview being made with a representative from the consultancy sector is due to the factor that they were one of the earliest adaptors of KM tools in their organizations. From the early stages of the introduction of the KM concept, the major consulting firms took advantage of the immense potential of information technology as the driving force in the business world. The ideology has always been similar to the one today, which combines well-known IT tools like databases to make it easier to gather, share, store, retrieve, and use knowledge (Easterby-Smith & Lyles, 2015). For this reason, comparing the approaches to KM of a successful construction firm to one of the best knowledge-managing sectors in business would outline the necessities to be implemented by the construction industry, which is the aim of this study.

6. FINDINGS OF THE EXPERT INTERVIEWS

The interview questions were categorized under three headlines: Data Collection, Data Accessibility/ Usage and Updates, and Knowledge Management. The results are explained with the participants being referred to as

"Consultancy (Firm) Representative" and "Construction (Firm) Representative". On the first question of the Data Collection section, participants were asked if there is a department in their organization dedicated to collecting and storing data from past projects. It was revealed by the construction representative that there was no such dedicated department, but all the departments in the headquarters (such as Procurement, Legal Matters, HR, etc.) would collect their own data from the sites. The consultancy representative revealed that they did have a special team dedicated to knowledge management for every specific field of activity. Next, participants were asked if their organizations had a digital database and a predetermined taxonomy for storing this data and what type of data was chosen to be stored in this system. The construction representative explained that they do have a digital database to store this knowledge, but only the specific departments have a taxonomy to obtain worldwide uniformity, such as the finance department, cost control department, and HSEQ department. It was added that they try and store most of the explicit data generated from the site, such as the man-hours, machine hours, accident rates, etc. Similarly, the consultancy representative stated that they do have a company-wide digital database to store project data. It was revealed that the uploaded material usually is in project analysis reports that have some identifiers that make it easy to find it in the future, such as keywords, date, location of the project, project team, a summary page, etc.

The next section was about Data Accessibility/Usage and Updates, where the first question inquired if the stored data from the previous projects could be accessible anytime when needed and who could access this data. The construction representative stated that this data is only accessible to the related departments at the headquarters, and site employees could only access it via headquarters. On the other hand, the consultant representative made clear that this data could be accessible to anyone at any time. The second question on this topic examined if the ongoing projects referred to the stored data, how often they referred to it, and what type of data was most frequently requested. The answers to this question were quite different, as the construction representative stated that even though there are times when the site refers to the stored data, it is not too regularly requested. He added that the most requested data from the headquarters is the sub-contractor-related data (such as their prices, if they have worked with them before, and their references). On the contrary, the consultant representative stated that it is referred to at the beginning of each project. The last question was asked to determine how frequently the system was updated with the knowledge currently produced. The construction representative stated that it was every month unless there was a special reason to make it more frequent, and the consultancy representative stated that the sanitized version (a version that prevents the disclosure of the client) was uploaded at the end of each project.

The final section consisted of questions regarding the KM policies. The first question of this section was to determine the explicit knowledge-sharing methods used in their company. The construction representative stated that they have an e-learning platform for employees to work on themselves and that some of the end project reports and analyses are available for every employee to view. The major explicit knowledge sharing on the consulting firm is stated to be their online tool, where the majority of the project data is imported into. The last question was about the knowledge-sharing mechanisms of tacit knowledge. The construction representative stated that there are regular voluntary webinars and seminars made, but most employees are expected to obtain this knowledge from working with one another, similar to the master-apprentice model. The consultant representative stated that they too, have seminars on general business matters and seminars on expertise fields. However, it was explained that although these seminars are voluntary, they have a reward system, such as being awarded a certificate or conference invitation. Additionally, it was explained that they, too aim to convey the tacit knowledge by the mater-apprentice model but in a more structured way. Firstly, a pairing system is used within project groups where seniors and juniors are matched. Next, throughout a project, the juniors get to work with their seniors to understand the business approaches they take in action. Then, after the end of the project, there is a feedback mechanism that monitors the desired performance of individuals, which is a great way to restructure the knowledge learned from the project.

7. DISCUSSION AND CONCLUSION

The review performed on the requirements of the construction sector revealed that knowledge management tools need to (1) collect the contextual details in a structured, continuous and real-time manner, (2) overcome difficulties in the extraction of knowledge from text-based data, (3) encourage a knowledge sharing culture, (4) combat the limits of the fragmented industry in effective communication and the sharing of experiences, (5) meet the specific needs of the employees who will use the project data, not those in charge of gathering and archiving it, and (6) facilitate efficient reuse of knowledge and learning outside of core competencies.

The findings from the expert interview show similarities as well as major differences. For example, even though each department is set to collect data from the site in the construction firm, it is ambiguous how much the

employees are involved in the real site activity when compared to knowledge management teams in consulting firms who act as part of the project for a period of time. Another major difference is seen with the KM software these companies use. The accessibility and usability of the KM tool of the construction firm seem considerably constrained in terms of creating a knowledge-sharing culture compared to the KM tool used in the consulting firm. Even though the diversity of data is richer in construction, due to a lack of accessibility from key players and site personnel, there are significant limits to embracing the concept as a company culture. Finally, the biggest gap between their KM ideologies is related to their approach to sharing tacit knowledge. We can see a clear company culture inside the consultancy firm that motivates and provokes both the knowledge owner and knowledge seeker to interact in a knowledge-sharing activity. This is either done by rewarding systems for participation in seminars or compulsory feedback mechanisms post-project. On the other hand, an environment is set for this knowledge-sharing interaction in the construction firm, however, it is left to the employee will and enthusiasm to engage in it.

The interview results reveal that most of the determined KM requirements of the construction industry have not been incorporated into the current tools and practices. Whether it is due to the natural barriers of the construction firms, which is explained in the previous section, or being the latecomer to the KM concept, one thing is for sure; which is that are many areas of improvement for enhancing the engagement in KM within the construction firms. The sector has a huge advantage in generating enormous amounts of knowledge, which, if and when interpreted correctly, could result in a much more efficient, resilient, and technologically advanced sector.

These challenges faced by construction companies can only be overcome by establishing and maintaining a knowledge culture where knowledge is valued and generated, shared, and utilized as an instinctive aspect of corporate activities. Organizations and the individuals within them must be constant learners, and this demands a clear vision, strong leadership, and solid processes from the corporation. If the construction industry is to build and maintain the capability in a knowledge economy, it must shift its adversarial culture to a sharing culture. Furthermore, it has to learn from each project and then transfer knowledge from projects to organizational bases to improve OM. A cycle should be made where organizational memory is referred to on knowledge transactions, and outcomes are reflected back to enhance the organizational memory. For future studies, this research that acts as a pilot study will be broadened with more interviews from the construction sector to understand the in-depth usage of KM tools within organizations.

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REFERENCES

Al-Ghassani, A. M., Anumba, C. J., Carrillo, P. M., & Robinson, H. S. (2005). Tools and Techniques for Knowledge Management. In C. J. Anumba, C. Egbu, & P. Carrillo (Eds.), *Knowledge Management in Construction* (pp. 10–30). London, UK: Blackwell Publishing.

Brown, J. S., & Duguid, P. (1991). Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation. *Organization Science, 2*(1), 40–57. https://doi.org/10.1287/orsc.2.1.40

Brown, J. S., & Duguid, P. (1998). Organizing Knowledge. *California Management Review, 40*(3), 90–111. https://doi.org/10.2307/41165945

Brown, J. S., & Duguid, P. (2000). *The Social Life of Information*. Boston, MA: Harvard Business School Press.

Coakes, E. (2006). Storing and sharing knowledge: Supporting the management of knowledge made explicit in transnational organisations. *The Learning Organization, 13*(6), 579–593.

Easterby-Smith, M., & Lyles, A. M. (2012). The Evolving Field of Organisational Learning and Knowledge Management. In M. Easterby-Smith, & A. M. Lyles (Eds.), *Handbook of Organisational Learning and Knowledge Management* (pp. 1–20). New York, NY: J. Wiley & Sons.

Egbu, O. C., & Robinson, S. H. (2005). Construction as a Knowledge-Based Industry. In C. J. Anumba, C. Egbu, & P. Carrillo (Eds.), *Knowledge Management in Construction* (pp. 31–49). London, UK: Blackwell Publishing.

Ferrada, X., Núñez, D., Neyem, A., Serpell, A., & Sepúlveda, M. (2016). A lessons-learned system for construction project management: A preliminary application. *Procedia - Social and Behavioral Sciences, 226*, 302–309. https://doi.org/10.1016/j.sbspro.2016.06.192

Gualtieri, M. (2016). Hadoop is data's darling for a reason. Forrester. Available at https://go.forrester.com/blogs/hadoop-is-datas-darling-for-a-reason/

Holste, J.S., & Fields, D. (2010). Trust and tacit knowledge sharing and use. Journal of Knowledge Management, 14(1), 128–140. doi: 10.1108/13673271011015615

Howells, J. (1996). Tacit knowledge, innovation and technology transfer. Technology Analysis and Strategic Management, 8(2), 91-106

Jarrahi, M.H., Askay, D., Eshraghi, A., & Smith, P. (2022). Artificial intelligence and knowledge management: A partnership between human and AI. Business Horizons 66(1), 87–99

Lyles, M. A., & Schwenk, C. (1992). Top management, strategy and organizational knowledge structure, Journal of Management Studies, 29(2), 155-74.

Markus, L. M. (2001). Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success. Journal of Management Information Systems, 18(1), 57-93. doi:10.1080/07421222.2001.11045671

Nonaka, I., & Takeuchi, H. (1995). The knowledge-creating company: How Japanese companies create the dynamics of innovation. Oxford University Press.

Ozorhon, B., Dikmen, I., & Birgonul, M.T. (2005) . *A case-based reasoning model as an organizational learning tool*, Paper presented at CIB 2005 Helsinki Joint Symposium, Helsinki, Finland. Retrieved from https://www.irbnet.de/daten/iconda/CIB6822.pdf

Polanyi, M. (1966). *Human knowledge*. Chicago, IL: The University of Chicago Press.

Quintas, P. (2005). The Nature and Dimensions of Knowledge Management. In C. J. Anumba, C. Egbu, & P. Carrillo (Eds.), *Knowledge Management in Construction* (pp. 10–30). London, UK: Blackwell Publishing.

Rezgui, Y., & Miles, J. (2011). Harvesting and Managing Knowledge in Construction. New York, NY: Spon Press.

Stein, E. W., & Zwass, V. (1995). Actualizing Organizational Memory with Information Systems. *Information Systems Research, 6*(2), 85–117. Retrieved from http://www.jstor.org/stable/23011005

Subramaniam, M., & Youndt, M. A. (2005). The Influence of Intellectual Capital on the Types of Innovative Capabilities. The Academy of Management Journal, 48(3), 450–463.

Wang, Z., & Wang, N. (2012). Knowledge sharing, innovation and firm performance. Expert Systems with Applications, 39(10), 8899–8908.

Zhang, J., Zhao, W., Xie, G., & Chen, H. (2011). Ontology-Based Knowledge Management System and Application, Procedia Engineering, 1021–1029.

8. APPENDIX: QUESTIONNAIRE FORM

This questionnaire form is part of the MSc thesis study of Bartu Kologlu at Istanbul Technical University Construction Management Program. The aim of the thesis is to understand the current knowledge management practices and the tools that construction companies use to maintain and enhance their organizational memory. The answers will only be used for academic purposes, and the answers will be evaluated anonymously without the identity of the participant/organization.

1) Data Collection: One of the main capital of knowledge-intensive sectors such as construction/consulting is intellectual assets. Most of the processes are generated toward exploration, accumulation, and exploitation of individual and firm knowledge. Your company has been in the construction/consulting sector for many years and has completed many projects.
   1.1) Is there a department/process in your company that collects and stores the knowledge data acquired from

the projects?

1.2) What kind of data is collected/stored from the previous projects (financials, man-hours, machine hours, financials, reports, etc.)?

1.3) How often is this data collected?

1.4) How is this data stored? Is there a digital database for this purpose? If yes, is there a predetermined taxonomy or a uniform filing system that is used to store the data?

2) Data Accessibility and Usage

2.1) Is the stored data from the previous projects accessible when needed?

2.2) If yes, do the ongoing projects use this data? How often is the previous data used for ongoing projects?

2.3) What type of data is used? Please list the specific information/data items used most frequently.

2.4) Is there an IT program to access this data? If yes, what is the most critical aspect of this program to operate correctly?

3) Knowledge Management: We can divide knowledge into two categories: Explicit and Tacit. Explicit Knowledge is the documented or recorded information that is written or saved. Tacit knowledge is the knowledge that an individual owns that is gathered from their personal experience, insights, and observations.

3.1) What are the knowledge-sharing methods in your company for explicit knowledge (seminars, shared monthly reports, etc.)?

3.2) Skilled members of a community of practitioners are often unaware of the tacit knowledge they possess, e.g., their problem recognition and problem-solving behavior, the rules that they follow, and the knowledge sources that they draw on. What are the methods in your company that convey tacit knowledge transactions?

3.3) The sector operates in a project-based environment. How can you ensure that individual knowledge becomes a company asset and does not disappear when that person is no longer part of the company?

3.4) Are there any other Organizational Learning practices your company performs?