Artificial Intelligence Support For Knowledge Management in Construction

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ABSTRACT

The deployment of Artificial Intelligence (AI) tools and techniques to various problem domains in organisation has been steady since their introduction. On the other hand, knowledge management is an innovative approach which is increasingly seen as a source of competitive advantage. This study attempts to investigate the use of established and proven AI tools and techniques in supporting end-users of knowledge management systems through more efficient elicitation and representation of corporate knowledge. Case studies are used to show the situations of knowledge management systems in the construction organisations. From the results of the case studies, this paper attempts to show the usefulness of deploying AI tools and techniques in capturing and representation knowledge in the context of the construction industry.

Keywords

knowledge management, artificial intelligence, construction, knowledge elicitation, knowledge representation.

1.0 INTRODUCTION

1.1 Background

The emphasis on knowledge management reflects the growing realisation that it is a core business concern where the know-how of a company is becoming increasingly important (Drucker, 1993). Generally, knowledge management is more aligned with goals of capturing, sharing and reusing knowledge in an organisation or among organisations. In contrast, knowledge-based systems have, by general consensus, a far technical focus on knowledge (e.g. representation, organisation, reasoning, searching etc.). In other words, techniques developed in knowledge-based systems are analogous to "micro" knowledge strategies, whereas approaches to knowledge management are generally considered as "macro" knowledge strategies for organisations. As such, knowledge management initiatives can proceed without any artificial intelligence efforts (e.g. people-based knowledge management system), but this study proposes that all knowledge management initiatives should embrace some artificial intelligence systems or Web-based business rules execution expertise to provide the value-added services often needed in knowledge processing. Established artificial intelligence tools such as protocol analysis, structured interviews, concept sorting and data mining have made a substantial contribution to various sectors, most notably finance and manufacturing. These artificial intelligence (AI) tools can be fruitfully utilised for knowledge management where the setting up and maintenance of knowledge bases will factor in the usefulness of the system.

1.2 Research Objectives and Methodology

The first step is to review the literature and research reports that review the development of knowledge management, current studies about artificial intelligence and tools and techniques of artificial intelligence. The primary objective of this research is to investigate the use of established and proven artificial intelligence tools and techniques in supporting end-users of knowledge management systems through more efficient elicitation and representation of corporate knowledge in the organisation. Henceforth, this study attempts to examine established and proven AI tools and techniques developed in the other research areas.

The literature review on knowledge management and artificial intelligence provided basis for identifying the issues to be investigated in the context of construction industry. Furthermore, this study will use a descriptive case studies approach that incorporates qualitative comparators with observations made within three construction organisations. The qualitative methods will include comparing characteristics of the knowledge management systems in the organisations. In order to test these propositions, specific units of analysis were developed. The "units of analysis" are as follows: (a) Role of intranet in organisations, (b) Knowledge elicitation, (c) Knowledge representation, (d) Knowledge

validation and, (e) Knowledge updating and maintenance.
While carrying out this study, it was impossible to obtain exactly corporate knowledge management systems because the implementation of knowledge management strategy is not common in the construction industry. This is supported by the study done by Robinson et. al. (2000), "less than 30% of construction organisations have a knowledge management policy document". It was also difficult to obtain documented knowledge management strategies or planning outlines, except for those policies available on the company's report and company's website. The amount of organisation internal strategy documents available was very limited.

1.3 Knowledge Management in Construction

Knowledge management can be defined as the identification, optimisation and active management of intellectual assets to create value, increase productivity, and gain and sustain competitive advantage (Kamara et. al., 2000). Furthermore, KPMG Management Consultant described knowledge management as a systematic and organised attempt to use knowledge within an organisation to transform its ability to store and use knowledge to improve performance (Robinson et. al., 2000). Knowledge is therefore an intellectual asset, which in the new global economy will become more important than traditional capital assets. The awareness of the value of intellectual capital has begun to concentrate management minds on the ways to release this powerful potential (Robinson et. al., 2000)

According to (Kamara et. al., 2000), the factor that has influenced implementation of knowledge management systems in an organisation is the need to manage intellectual assets which arises from the realisation that both content and value of knowledge deteriorate over time. The emergence of the knowledge economy also suggests that what organisations know is becoming more important than the traditional sources of economic power (i.e. capital, plant, land and labour). This is particularly relevant for the construction industry, where the need for innovation and improved business performance requires the effective deployment and utilisation of the intellectual assets of project team members. The nature of the construction process, which will now be briefly discussed, also presents challenges for the integration and management of knowledge within the construction industry.

The construction industry is a project based industry which utilises a variety of separate firms and products in a temporary multi-disciplinary organisation, to produce investment goods (building, roads, bridges, factories) which are usually large, expensive, immovable and custom-built to unique specifications (Kamara et. al., 2000). In recent years, the environment for the construction industry has been changing. Clients are becoming more sophisticated, insisting on better value for money and demanding more units of construction for fewer units of expenditure. Historically, financial indicators were seen by many as the key performance indicator. However, the signs are that there may be a cultural shift. Construction clients are becoming more aware of management principles and the philosophy of a holistic approach to performance through the use of Key Performance Indicators (KPIs) is gaining acceptance.

Knowledge management fits comfortably amongst KPIs being developed. It forms an integral part of "Internal Business" perspective and "Learning and Growth" perspective. It fits into EFQM's Excellence Model criteria for 'People' as well as 'Partnerships and Resources'. Knowledge management also fits in well with the UK Construction Best Practice Programme's KPIs for project performance.

Although the construction industry is responding to these challenges, recent reports (Latham, 1994 and Egan, 1998) suggest that there is much room for improvement, which could be brought about by a renewed focus on: the requirements of construction clients, the development of committed leadership, integrated processes and teams, a quality driven agenda, and commitment to people (Egan, 1998).

Initiatives for improving and managing the construction process have focused on the interrelationship between resources, and the integration, monitoring and control of the contributors to a project and their output. Construction organisations also need to make improvement on their knowledge assets. Construction knowledge is thus both explicit (engineering principles etc.) and implicit (in one's knowledge of organisations, or location). Kamara et.al. (2000) stated that knowledge needs to be managed at different, interrelated levels in the construction organisation including; (a) management of knowledge within projects – across different stages of a project and (b) management of knowledge in individual firms (e.g. consultants, contractors, etc.) in the construction industry to enhance their capability to adequately respond to client requirements.

1.5 Knowledge-Based Systems and Corporate Knowledge-Based Systems

Knowledge-based systems are a part of artificial intelligence families. Maher (1997) defined knowledge-based systems as an interactive computer program incorporating judgement, experience, "rules of thumb", intuition, and other expertise to provide knowledgeable advice about a variety of tasks. Basically, a knowledge-based system is a software system capable of supporting the explicit representation of knowledge in some specific competence domain and of exploiting it through appropriate reasoning mechanisms in order to provide high-level problem solving performance.

The knowledge base stores available knowledge concerning the problem domain hand, represented in an appropriate explicit form and ready to be used by the reasoning mechanism. It may contain knowledge about domain object, their structures and properties, the relations existing among them, the operation that may be executed on objects and relations, the structure of typical problems and the problem solving strategies. The knowledge base is a highly structured, long-term memory, which can store knowledge permanently during the whole lifetime of the knowledge-based system. The reasoning mechanism is constituted by a complex set of programs capable of performing high-level reasoning processes in order to solve problems in the considered domain by exploiting the knowledge stored in the knowledge base. The working memory is used to store all information relevant to a problem solving session of the knowledge-based system, which is: a description of the problem at hand, the intermediate solution steps, and eventually the solution found. The working memory is thus a short-term memory, which is up-dated each time a new problem is considered. Its content lasts as long as the problem solving session does.

For an organisation's knowledge management efforts to be effective, the organisation must build knowledge management systems that crosses all organisational boundaries and elicits knowledge sharing within and beyond the corporate knowledge (Beckett, 2000). The careful organisational implementation of corporate knowledge-based system will give rise to a cross-functional and consolidated corporate data repository, based on open data access standards, that creates new levels of communications, eliminates inefficiencies and is transparent to its users.

There are several important things to be considered before we implement a corporate knowledge management system. These are as follows; (a) KM must cross all factions of the organisation, but to be successful it must target the needs of departments and individuals; (b) KM must engage the largest community which includes management, employees, suppliers, clients and investors; (c) KM must capture and link to the broadbest knowledgebase but it must collect and index only limited assets; (d) KM must improve the organisation's business process

1.7 Artificial Intelligence (AI) Techniques for Knowledge Elicitation

a. Structured Interview

The structured interview is a systematic goal-oriented process. It forces on organised communication between the knowledge engineer and the expert. The structure reduces the interpretation problems inherent in unstructured interviews, and it allows the knowledge engineer to prevent the distortion caused by the subjectivity of the domain expert. A properly planned and structured questionnaire is prepared in advance of the interview, which is used in eliciting the knowledge. These techniques can often be applied to situations where the expert is being interviewed while actually performing task or where the task is simulated or reconstructed by case studies or scenarios or simply from the expert's own past experience.

b. Protocol Analysis

This method asks the experts to "think aloud" while performing a task or solving a problem. Johnson et. al. (1987) defined protocol analysis as the process used by cognitive psychologists to understand human problem solving and decision-making. Protocol analysis, particularly a set of techniques known as verbal protocol analysis, is a common method by which the knowledge engineer acquires detailed knowledge from the expert. A protocol is record or documentation of the expert's step by step information processing and decision-making behaviour.

In this method, which is similar to interviewing but more formal and systematic, the expert is asked to perform a real task and to verbalise his or her thought process. The expert is asked by the knowledge engineer to think aloud while performing the task or solving the problem under observation. Usually, a recording is made as the expert thinks aloud; it describes every aspect of the information processing and decision-making behaviour. This recording then becomes a record, or protocol, of the expert's ongoing behaviour. Later, the recording is transcribed for further analysis and coded by the knowledge engineer.

c. Concept Sorting

Concept sorting techniques are used to help structure the expert's knowledge. As its name implies, it involves having the knowledge engineer writing the names or previous identified objects, experiences and rules on cards which the expert is asked to sort into groups. The expert describes for the knowledge engineer what each group has in common and the groups can then be organised to form a hierarchy. Like multidimensional scaling, some empirical researches suggest that card sorting may be a more efficient elicitation technique than some of the more traditional techniques such as protocol analysis or interviewing. It has been suggested that it is a tool, which could be easily implemented on a computer as an automated knowledge elicitation tool.

d. Data Mining

Data mining can be defined as a method of analysis of large pools of data to find patterns and rules that can be used to guide decision making and predict future behaviour (Laudon & Laudon, 2000). Data mining

software tools find hidden patterns and relationships in large pools of data and infer rules from them that can be used to predict future behaviour and guide decision-making. Data mining helps organisations engage in one-to-one marketing where personalised or individualised messages can be created based on individual performances.

1.8 Artificial Intelligence (AI) Techniques for Knowledge Representation

a. Production Rules

Production rules are general computational models of cognitive processing that assume cognition involving the elicitation and execution of rules governing behaviour. The basic element of this method is 'rules', which consist of a condition and an action. The condition is a state of affairs that must exist for the rule to be applicable. The action is the thing to be done if the rule is applied (rule application is often called rule firing) (Markman, 1999). Basically, in this method knowledge is presented as production rules in the form of condition-action pairs: IF this condition (or premise or antecedent) occurs, THEN some action (or result or conclusion) will occur.

b. Frames

Frames can be defined as structures for representing stereotype knowledge and expectations, which would allow a system to impose coherence on incoming information. Frames were intended to be large enough packets of knowledge to impose structure on a new situation, but small enough to be a flexible and modular part of a large database. Basically, these methods provide a way of grouping information in records made up of slots and values.

c. Semantic Networks

Semantic networks are basically graphical depictions of knowledge composed of nodes and links that show hierarchies between objects. Semantic nets are used basically as a visual representation or relationships and can be combined with other representation methods. Moreover, semantic is the study of the meaning of the individual concepts used in the language. The study of semantics is therefore an attempt to describe word meanings (and the usage of words) where their meaning is ambiguous and the conditions under which such meanings can interact to be compatible with the other aspects of language. Therefore, semantic networks are the networks in which the nodes typically represent objects; concepts or situations and the arcs represent relationships between them.

2.0 RESULTS AND DISCUSSION

These three case studies were done to investigate current practice in construction organisations in managing their knowledge. In the other words, it is a qualitative study involving selected cases. As stated earlier, the "unit of analysis" were analysed to provide the basis of the discussion in the next sections.

2.1 Case Study 1

Company A is a construction based organisation which provides construction operation throughout the UK. This organisation is interested in "best practice" as a priority in managing their knowledge. Secondly, they are interested in lessons learnt and they also manage their knowledge of people.

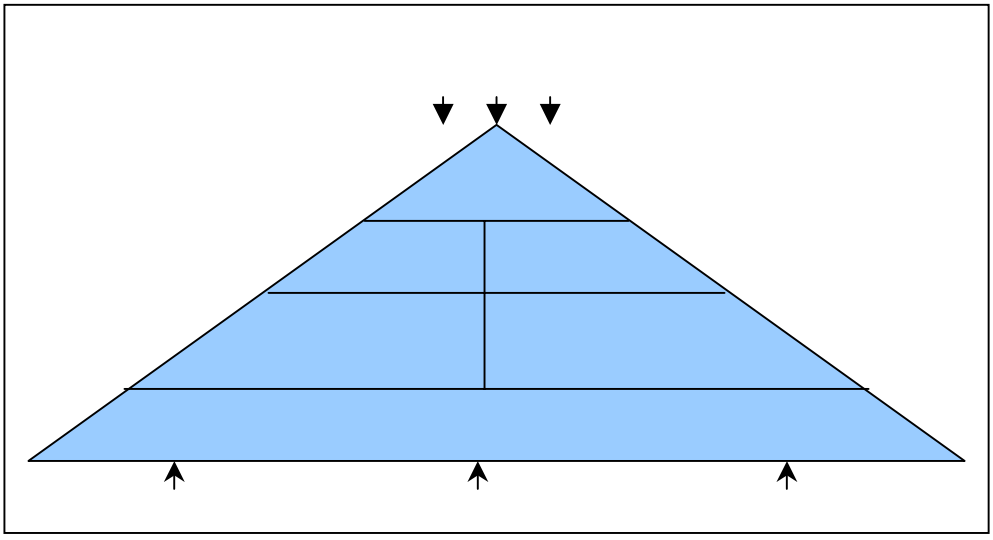

Figure 1.1: Model of Knowledge Life Cycle in Company A

Figure 1.1 provides a graphic description of the knowledge management life cycle in Company A. This figure shows that input of knowledge comes from groups in the organisation, customers and other interested parties. Knowledge also can be captured from each construction project completed by the organisation. In this organisation, they capture knowledge via 3 main vehicles; best practices, knowledge in the document and lessons learnt.

For the knowledge elicitation process, this company uses several vehicles to capture knowledge. These include a knowledge forum, special interest groups, publishing in each department and cross-link the knowledge with other IT systems (e.g. document management systems and expert systems). For the knowledge representation, this organisation uses Microsoft format, Acrobat format and HTML format to represent their knowledge. To retrieve the knowledge on the intranet systems, they use search engine and keyword on the intranet system. Knowledge maintenance and validation are also considered by the organisation. Moderator and sub-units moderator were appointed to control and update the knowledge of the company. It is an essential part of the process to reduce information overloaded in the company.

2.2 Case Study 2

Company B is an international company employing over 13 000 staff with an estimated annual turnover of over £1.4 billion. This company is interested in "lesson learnt" in managing their knowledge. The reason is because the company aims to avoid repeating the same mistakes. In the other words, this company attempts to reduce the cost of maintenance and to ensure the quality of their product.

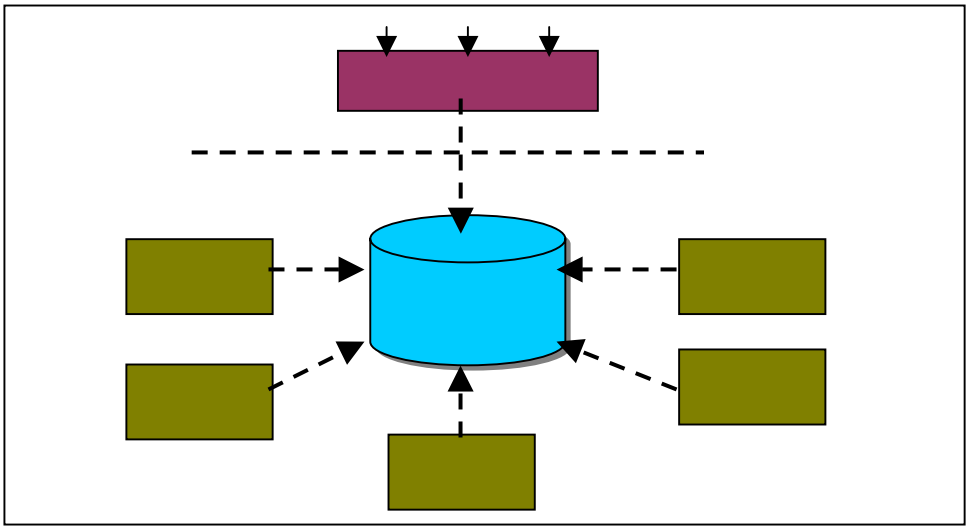

Figure 1.2: Knowledge Management Model for Company B

Figure 1.2 shows how the knowledge management process will be implemented in the organisation. All the captured knowledge is approved by the Technical Director of this company. RBUIC and BUIC are acting as an administrator. In other words, the function of the co-ordinator is as a filtering group for the knowledge capturing process. The captured knowledge is stored in the knowledge bank and the knowledge is disseminated throughout the organisation via intranet system. Lastly, people can retrieve and share the knowledge on the intranet system from different locations and branch offices. Knowledge is captured using several vehicles. The vehicles are RBUIC and BUIC meetings, division reviews, business unit reviews, external auditing, ISO 9001/2000 and quality register. For the knowledge representation, this company uses Microsoft Excel Format and Microsoft PowerPoint presentation and video format to represent the organisation's knowledge. Knowledge can be retrieved in this company using telephone, email systems and search engines. To ensure the validation of knowledge, this organisation has a clear procedure to validate the knowledge. All types of knowledge must be discussed in the business improvement co-ordinator meeting and must be approved by the Technical Director.

Finally, the result shows that this company uses a combination of methods for knowledge elicitation. The proper and tight procedure in validating knowledge is an essential steps of knowledge validity. However, this can reduce the trust level to their staff in the organisation and it also takes a long time to store the knowledge in the knowledge bank.

2.3 Case Study 3

Company C is a professional consulting engineer firm, which spans around the world. Currently operating out of 71 offices in 32 countries, and employing over 6500 members of staff. Over time, the company has developed a number of good knowledge management

practices. These include; (a) Skills networks - the communities of practices that enable the sharing of tacit knowledge in key areas across the firm, (b) Feedback notes - containing "lessons learnt" and "watch-it" notes, and providing a potential route to well defined best practices in the form of explicit knowledge, and (c) Well established intranet and information systems.

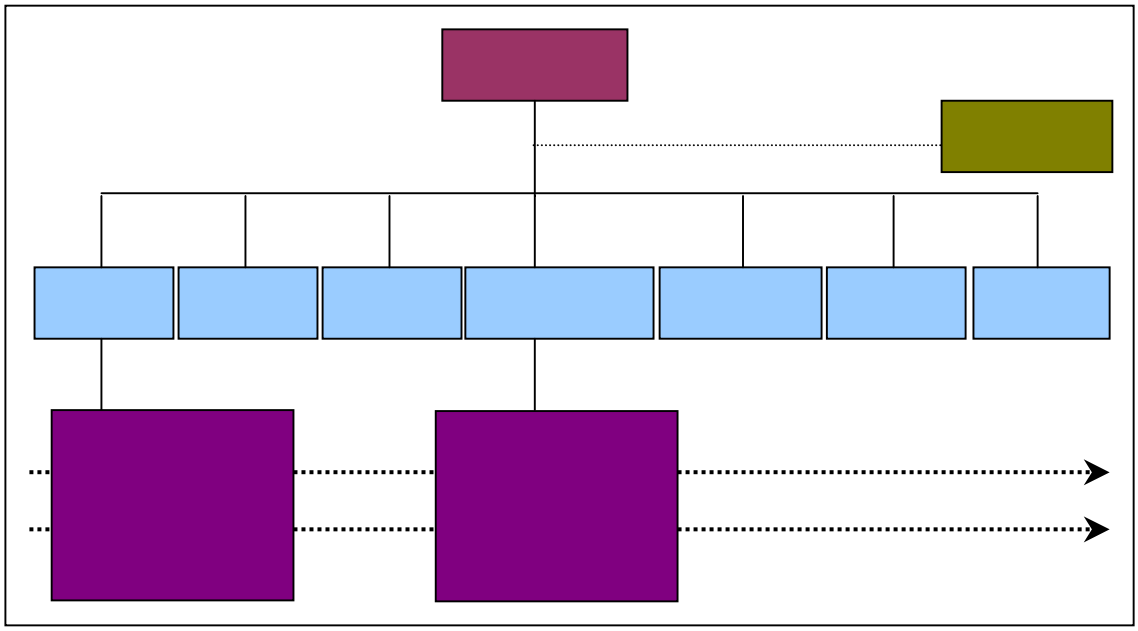

Figure 1.3: Corporate Structure of Company C and the Role of Knowledge Manager

Figure 1.3 shows the corporate structure of Company C and the level of knowledge called "skills networks" in the company. The function of the Knowledge Manager is to understand the knowledge management process in the organisation.

The results of the investigation show that this company is interested in "knowledge in people" for managing their organisation's knowledge. The main reason is because this company is a consultant engineer firm, which delivers a consultation service to the clients. This company is also interested in "lessons learnt" and "best practices". For the knowledge elicitation process, this company uses several vehicles. These include company yellow pages, individual homepages and job numbering systems for each project.

However, this company has a unique approach in validating the organisation's knowledge. They validate the company's knowledge based of trust to the people in the organisation. For knowledge representation, the knowledge is presented using PDF format for document representation and HTML format for corporate yellow pages. Knowledge can also be retrieved using a keyword search engine and free text search.

Finally, it can be concluded that the approach of this company to elicit the knowledge is very easy and it is a part of the company strategy to encourage people use the shared network.

2.4 Knowledge Elicitation and Representation in Construction Organisations

Generally, most of the construction organisations focus on managing "best practice", "lesson learnt" and "knowledge of people". For the knowledge elicitation process, it can be concluded that the construction organisation use two methods to capture the organisation's knowledge. The method can be divided into two categories

- **Volunteer Data Capture -** These include corporate yellow pages, special interest groups, individual homepages, knowledge forums and etc.

- **Formal Data Capture** - These include business co-ordinator meetings, job numbering systems, division reviews, external auditing, ISO 9001/2000 and a quality register.

Furthermore, the knowledge representation process in these construction organisations is presented on the intranet systems using PDF format, Microsoft format and HTML format. The decision to use information technologies tools such as intranet systems has given advantages for the construction organisation in managing their knowledge. For the knowledge retrieval process, it can be concluded that the retrieval process for the knowledge generally uses automatic as well as controlled systems. Most of the companies use keyword and free text search engines. Finally, this investigation shows that construction organisations validate the captured

knowledge via moderator meetings and by the use of formal procedures, which are described earlier.

3.0 AI SUPPORT FOR KNOWLEDGE MANAGEMENT SYSTEMS IN CONSTRUCTION

Based on the above discussions, several possibility areas of research are recommended in this study for the deployment of artificial intelligence (AI) tools in knowledge elicitation and presentation process in the construction industry. For knowledge elicitation tools, the problem complexity may be one determinant of the appropriate knowledge elicitation techniques to chose. From the case studies, it shows that certain knowledge elicitation technique is suitable for certain type of knowledge. For example, knowledge of "lesson learnt" is suggested to be captured by protocol analysis process. This study might propose that protocol analysis might be more efficient than interviewing process. The fact that interviewing is more efficient for simple domains may imply that it is the best used for initial knowledge elicitation sessions, when the problem complexity is not yet developed clearly.

Table 1.1 shows a comparison of knowledge elicitation methods. This comparison was made after the findings from Chapter 4 (Case Studies) were discussed. This study recommends the following methods in which there are possibilities for deployment of knowledge management systems in construction industry with regard in knowledge elicitation and representation.

Table 1.1: Comparison of Knowledge Elicitation Methods

METHOD	APPLICABILITY	ADAPTABILITY	TIME	FEATURES
Protocol Analysis	Tacit knowledge	Lesson learnt	Long	- flexible - structured - little equipment
Structured Interview	Tacit knowledge	Best practices Processes People	Long	- simple structure - deeper knowledge - flexible - portable
Concept Sorting	Tacit knowledge Explicit knowledge	Decision-making	Short	- unbiased - objective - consistent
Data mining (existing knowledge)	Explicit knowledge	Processes Product	Short	- structured - low-cost

There are three methods of representation of knowledge studied (production rules, frames and semantic network). It can be concluded that all the methods are structured representation methods and they contain explicit connections between elements. All the representation methods also have opportunities to be combined by entering them as arguments of other elements. They also permit systematic ways in which higher order relational structures are developed to represent important relation.

Table 1.2: Comparison of Knowledge Representation Methods

METHOD	APPLICABILITY	CLASSIFICATION	USEFUL FEATURES
Production Rules	Explicit knowledge *Documented knowledge *Meta knowledge	Structured representation	can be combined with others activation model
Frames	Tacit knowledge *knowledge of people *knowledge of processes	Structured representation	can be combined with semantic networks model
Semantic Networks	Tacit knowledge *knowledge of processes	Structured representation	using forward and backward chaining inferences

Table 1.2 illustrates the comparison of knowledge representation methods and their applicability to represent knowledge for knowledge management systems. For the knowledge representation parts, it can be concluded that the ideal knowledge representation methods to be deploy in for knowledge management system in construction industry is a combination of frames and semantic networks method. Moreover, these methods are applicable for representing tacit knowledge in the knowledge management system.

In the general context with regard to knowledge elicitation and representation techniques, we can say that artificial intelligence (AI) and knowledge-based systems knowledge management technologies are often purported to deliver the right information to the right person at the right time. However, from the case studies, it shows that construction industry business model is slightly different in terms of approach of business. The factor of many variations of works and different types of construction techniques and procurement are the main obstacle for the implementation of knowledge-based systems.

Moreover, artificial intelligence (AI) and knowledge-based systems are often based upon the assumptions of storing human intelligence and experience. It is true that technology such as databases and GroupWare applications store static bits and pixels of data, but they cannot store the rich schemes that people possess for making dynamic sense of data bits. Hence, storing a static representation of the explicit representation of a person's tacit knowledge in the form of data bits; assuming one has the willingness and the ability to part with it, cannot be considered tantamount to storing human intelligence and experience.

Finally, the precise artificial intelligence techniques and tools used are of less importance than the construction industry needs; corporate knowledge management systems for construction industry can be constructed in many cases using combination of information technologies tools (Intranet, Groupware and Document Management System) with knowledge elicitation and representation tools, due to advancement in Web-based technology and component based development. These opportunities, such as the internet or an intranet can be used to facilitate knowledge elicitations. For example, electronic interviewing can be conducted if the knowledge engineer and the experts are in different locations. Also, experts can validate and maintain knowledge bases from a distance. Documented knowledge can be reached via the Internet.

Nevertheless, such integration between hypermedia technology (such as the web) and knowledge elicitation and representation tools can provide a powerful tool in knowledge management system in construction industry.

4.0 CONCLUSIONS

This paper presents the results of three case studies investigating current situations of knowledge management systems in construction organisations with regard to knowledge elicitation and representations. The results show that the artificial intelligence (AI) tools and techniques can be deployed in the knowledge management system in construction industry contexts. In other words, artificial intelligence tools (protocol analysis, structured interview and concept sorting) for knowledge elicitation and (production rules, frames and semantic networks) for knowledge representation can successfully be used to capture and represent knowledge (people, processes, best practice and lessons learnt) in the construction industry.

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