Exploratory Study on Cognitive Style in a BIM environment in the Australian Construction Industry

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ABSTRACT

Building Information Modelling (BIM) has been introduced to the construction industry to improve productivity. However, BIM has a limitation to accommodate the cognitive functions of construction
professionals to make proper decisions because BIM requires encompassed digital workflows over a project life cycle that inundate design and construction professionals with a plethora of construction information. Subsequently, construction professionals are not able to have a sufficient time for applying their intuitions and tacit knowledge properly. In order to understand the cognitive styles of construction professionals to make a better decision, this research adopted a mixed method approach comprised of a questionnaire survey and a follow-up interview. Total 105 construction professionals participated in a questionnaire survey, and 15 interviews were conducted. Consequently, the Planning and Knowing styles are the most frequently used cognitive skills for a decision making, and the Creating style is the less frequently used ability for a daily based task. The knowledge and insights of construction professionals are recognised as an essence of better decision making, and BIM is recognised as a knowledge management platform to capture and share the valuable intuitions of construction professionals. Furthermore, proper trainings are required for construction professionals to increase their innovative and creative cognitive skills for their tasks. This research will serve as a stepping stone to further investigate a human aspect in a BIM system, and to provide insights for an organisation or a project team how to adopt BIM for better decision making based on the cognitive styles.

**Keywords:** Cognitive Function, Decision Making, BIM, Australian Construction Industry

**INTRODUCTION**

Recent design requirements of a building have become more irregular and bespoke, and sustainable aspects in a building such
as high energy performance and low carbon footprints have become one of the major considerations in the construction industry. Essential construction information has become more specialized and larger in its volume, and consequently, effective management and integration of the massive amount of construction information have become vital than ever. As a response to the increasing complexity of construction projects, Building Information Modelling (BIM) has been introduced to the construction industry as an enabler to facilitate collaborative efforts among project participants, and to improve fragmented construction practice and productivity (Eastman et al, 2011). BIM is being increasingly adopted in the construction industry due to various benefits including a) Design Quality Improvement; b) Productivity Improvement (Effective and Efficient Project Information Management); and c) Sustainability Enhancement that can be utilized for productivity improvement (Park and Kim, 2017; Eastman et al, 2011). Furthermore, BIM has become a mandate for the public construction projects in various countries including the US, UK, and Australia, and South Korea (Kim et al, 2016).

COGNITIVE FUNCTIONS IN A BIM ENVIRONMENT

Although BIM provides various benefits, there are numerous researches pointing out that BIM has a limited capability to accommodate the cognitive functions of construction professionals to make proper decisions. Decision making process is carried out based on a human’s cognitive style, which is described as human’s ability to think, learn and solve problems (Esa et al., 2014). According to Jul and Furnas (1997), the cognitive function is highly required to understand a special information and locate proper information about a design and construction. More importantly, the decisions on design alternatives made at the early design stage
such as building orientation, shape, and structural system, mainly rely on the cognitive functions of designers and engineers as they use their intuitions and insights learned from their experience (Gervásio et al., 2014; Granadeiro et al., 2013). Cognitive styles are the ability for individuals to be able to critically think, and resolve problems, and archive the lessons learned from an event (Granadeiro et al., 2013). According to Cools and Van Den Broeck (2007), the cognitive styles are categorised into three major styles – Knowing, Planning and Creating – as shown in Table 1. Akin (2014) asserted that daily tasks are carried out via a combination of tacit knowledge and intuitive skills, but a BIM environment is not fully capable of accommodating these cognitive functions as design and construction professionals cannot have a sufficient time to utilise their intuitions properly.

<table>
<thead>
<tr>
<th>Style</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowing</td>
<td>Facts, Logical, Rational, Precision with Tasks</td>
</tr>
<tr>
<td>Planning</td>
<td>Conventional, Structures, Routine</td>
</tr>
<tr>
<td>Creating</td>
<td>Innovative, Open-ended, Creative</td>
</tr>
</tbody>
</table>

Although researchers emphasise the importance of cognitive abilities in a BIM system, BIM is still blamed for its encompassed digital workflows over a project life cycle because design and construction professionals are inundated with a plethora of construction information. Indeed, Foqué (2011) emphasised that intuition and rational thinking should be utilised simultaneously to make proper decisions, and pointed out that the digital workflows in a BIM environment should acknowledge the current limitations and improve the current decision making processes in a BIM environment.
Kopper et al. (2006) recognised that exploring a 3D BIM model often renders a tedious experience to find out accurate and necessary construction information. Dodiya and Alexandrov (2008) elaborated that design and construction professionals, who are not familiar with a BIM environment, experience frustration due to inaccurate spatial cognition as they have been oriented based on 2D drawings. The negative experiences have led the design and construction professionals to resist to adopt new technology and processes (Joo and Lee, 2006; Chai and Chai, 2007). Indeed, the cognitive style is commonly recognised as an important aspect for employers to consider for better work performance as an individual and a team. (Cools and Van Den Broeck, 2007). Esa et al. (2014) highlighted that it is important to appreciate the connection between the construction professionals’ cognitive styles and its impacts on decision makings. A better understanding of design and construction professionals’ cognitive decision making styles will improve construction professionals’ decision making in a BIM environment (Pinch et al. 2010; Carmel-Gilfilen and Portillo, 2010).

However, the cognitive styles of the construction professionals have not been clearly identified. Thus, this research aims to investigate the cognitive styles of construction professionals to make a proper decision. In addition, this research is expected to provide insights for construction professionals how to make proper decisions in a BIM environment based on different cognitive styles

RESEARCH METHODOLOGY

This research adopts a mixed method that is comprised of a paper-based questionnaire survey and follow-up semi-structured interviews because this research is designed to obtain specific
viewpoints and in-depth insights regarding ‘what is the cognitive style of construction professionals’ and ‘how can cognitive styles affect the decision makings’ in the Australian construction industry in real life context (Creswell et al., 2004). The questions adopted a 5 point Likert scale as it is the most popular method among researchers and easy to communicate with respondents (Knight and Ruddock, 2008).

In order to obtain valid and relevant research findings, 105 prequalified construction professionals, who have experience in a BIM-enabled construction project, and have an authority to make a decision, and employed in a nation-wide construction company are selected. The paper-based questionnaire was personally hand-delivered to surveyees to achieve maximum response rate, and the research adopts the Cognitive Style Indicator questionnaire developed by Cools and Van den Broek (2007), which is a widely adopted structured questionnaire to measure the three cognitive styles (See Appendix 1). The questionnaire is comprised of 18 questions designed to measure the following three major cognitive styles; a) Knowing, b) Planning, and c) Creating. A pilot questionnaire survey was conducted prior to the main questionnaire survey to eliminate misleading questions, ambiguity and any difficulty in responding (Polit et al., 2001). After the completion of questionnaire surveys, follow-up semi-structured interviews were conducted with 15 construction professionals, who indicated their willingness.

RESULTS AND DISCUSSION

Total 105 prequalified professionals were responded to the survey. As shown in Table 2, the profile of respondents indicates three major roles – Quantity Surveyor, Project/Construction
Manager, Site Manager – and the portions of respondents are evenly distributed. The profile has been confined to a manager level with decision making authority since this research aim at identifying the cognitive styles for decision making. The average experience of respondents is 9 years, and 20% of respondents (20 respondents) indicate that they have more than 15 years of experience.

Table 2. Profile of Respondents (Total 105 Respondents)

<table>
<thead>
<tr>
<th>Role</th>
<th>Number of Respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity Surveyor</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td>Project/Construction Manager</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td>Site Manager</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
<td>100</td>
</tr>
</tbody>
</table>

Overall Cognitive Styles of Construction Professionals

The collected data is analysed based on the calculation of Mean value using the 5-point scale such as 1 point for Strongly Disagree and 5 points for Strongly Agree (See Appendix 1).

Table 3. Overall Cognitive Styles of Construction Professionals

<table>
<thead>
<tr>
<th>Cognitive Style</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowing</td>
<td>4.15</td>
</tr>
<tr>
<td>Creating</td>
<td>4.01</td>
</tr>
<tr>
<td>Planning</td>
<td>4.22</td>
</tr>
</tbody>
</table>

The overall cognitive style does not present a wide range of variation in its value as shown in Table 3. In the follow-up interviews, interviewees stated that personal preference cannot
overrule the given processes based on their preferences since they have to consider all the possible angles using all three cognitive abilities before they make a decision although they have their own preferred cognitive styles. Based on the comment, the result can be explained that construction professionals utilise three cognitive styles related to analytical knowledge and intuitions for construction projects simultaneously.

**Cognitive Styles based on Experience**

The cognitive styles of respondents have been further investigated based on their years of experience because knowledge and intuitions are mainly obtained from past experience. As shown in Figure 1, a certain pattern has been presented. As construction professionals have many years of experience, the Knowing such as Facts, Details, Rational, Logical, and Precision about a project have increased. It is obvious that more people experience, more lessons learned and tacit knowledge are accumulated. In contrast, the Planning style such as Planned, Organised, Systematic and Routine present a pattern of continuous decrease. According to interviewees, as construction professionals are located in a higher position over the time, many daily project tasks related to planning and organising are delegated to the professionals located in a lower position while they get involved in more authoring or final decision making processes. Thus, the level of involvement into a project planning based on a position or a rank is reflected on the pattern.

Interestingly, the Creating style related to creative and innovative approaches to a problem or an issue of a project indicates the highest Mean value at the entry level of construction professionals while the most experienced construction professionals indicate a balanced level of cognitive styles in Planning and Creating.
One respondent pointed out that the Creating styles such as innovative thinking are the most important skill required for a construction professional who strives to become from being 'good' to 'great'. The respondent was a recruiter, and he mentioned that the creative or innovative thinking is a factor in the recruitment process for graduates. Thus, it is evident that the entry-level professionals indicate more Creating styles. Respondents unanimously agreed that the Creating style might be the most important cognitive thinking style.

Respondents emphasised that the need for a construction professional to be innovative including learning advanced construction technologies including BIM and other ICTs will be a key competence in the construction industry. Furthermore, construction companies continuously invest in reinventing and training employees to improve productivity. In terms of highly experienced professionals, they can adopt a balanced perspective between the Planning and Creating styles based on their
knowledge (the Knowing style) as they are highly experienced in various construction projects.

**Cognitive Styles based on Roles**

The cognitive styles based on the roles of respondents have been investigated to identify if there are any differences in the cognitive styles based on duties of each role. As shown in Figure 2, the site manager indicates the highest level of Knowing style, and the project manager indicates the highest level of Creating style among three roles. The Planning style is indicated higher level at the project manager and the quantity surveyor compared to the site manager.

![Figure 2. Cognitive Styles based on Roles,](image)

**Project Manager**

Three cognitive styles are presented in a balance for a project manager, while a site manager and a quantity surveyor indicate relatively large differences. The Creating style indicates the
highest level, and an interviewee elaborates that more experienced project manager can resolve issues and problems in a creative way, and motivate project team members to develop innovative ideas.

Furthermore, an interviewee, who is a project manager, commented that the duty of a project manager is required to plan and organise a project, and delegate tasks, and monitor work performances of project team members over a project life cycle. Consequently, well-balanced cognitive skills are required to carry out the given tasks, and this is why three cognitive styles are evenly indicated high and balanced for a project manager.

**Site Manager**

The site manager indicates predominance in the Knowing style, which is mainly related to insights and intuitions based on their experience and knowledge. As a site manager mainly works at the construction site, various site works require their immediate attention and decisions, which might be related to risks.

Furthermore, there may not be sufficient time for them to analyse the entire situations and possible options, which is relevant to the construction site. One interviewee stated that the level of education or a type of education might impact on the cognitive style of a site manager since a typical site manager started his/her carrier from a tradesman while a project manager and a quantity surveyor typically complete a university degree course. Thus, it is identified that more intuitive and prompt response is required for a site manager to carry out the tasks.

**Quantity Surveyor**

The quantity surveyor heavily relies on the Planning style as they are responsible to analyse and estimate costs and develop a cost management plan. Interviewees commonly stated that a standard for developing a bill of quality such as the Australian
Standard Method of Measurement has already been well established. The standard is currently used across the supply chain of the construction industry to estimate all the construction works. Thus, a quantity surveyor presents a tendency to reply in the Planning style. One interviewee pointed that most of a quantity surveyors’ work related to costs and risks, i.e. numbers, and it is why using a commonly accepted standard is important compared to inventing a new way of measuring and planning costs. Based on this comment, it can be extrapolated why the Planning style is indicated high for a quantity surveyor.

Reflections on Cognitive Styles and BIM

The Planning style is recognised as the most preferred and frequently used cognitive style for each profession regardless of the number of years of experience. As BIM is capable of organising and planning diverse construction information over the life cycle, it can be considered that BIM can accommodate the Planning style, and even enhance the cognitive abilities (Akin, 2014). For project managers and quantity surveyors, the Planning abilities can be improved by adopting a BIM capability for time and cost estimation, which is named as 4D and 5D BIM capabilities. Effective coordination of design alternatives and informed decision making and instant updates on costs based on design alternatives throughout a project life cycle is the most important capabilities of 4D and 5D BIM. These BIM capabilities are equivalent to the Planning cognitive abilities that are required the most for a project manager and a quantity surveyor to carry out their tasks. Thus, 4D and 5D BIM capabilities would be the best way to utilise BIM for enhancing cognitive decision making processes and improve project productivity (Kim and Park, 2016).

In contrast, the Knowing style is the most frequently used cognitive style for a site manager. Interviewees commonly stated
that site managers take their roles based on their varying amounts of experience from the construction field as a tradesman. In addition, the majority of site managers have a trade background, and the trading based experience is highly valuable for the job since they should be able to fully understand the requirements as an onsite supervisor daily basis. Thus, it is evident that site managers indicate the Knowing styles as their preferred cognitive skills as it utilise their experience and intuitions.

In alignment with the importance of knowledge from the past experience, there have been recent researches focusing on the knowledge management using BIM for construction tasks, safety and risk management (Ding et al., 2016; Deshpande et al., 2014; Pishdad and Beliveau, 2010). The studies assert that tacit knowledge from construction personnel should be captured and shared for better decision making and improved safety and risk management. More importantly, the essence of the knowledge management framework based on a BIM system is a 'human being', not a software or technical skills. Based on the studies, the construction industry should archive the insights and intuitions of a site manager, and share it with project team members via a BIM system to facilitate the Knowing cognitive skills. All the interviewees agreed that creativity is required more than ever in the construction industry, while they also argued that typical day to day tasks are not necessarily required innovative approach, which requires a learning curve or extra efforts to make it works.

Consequently, the Creating cognitive skills are often considered as less important compared to other two Knowing and Planning cognitive abilities under the tight construction schedule. However, many construction companies are keen on investing their capital in advanced technologies and relevant trainings for employees, and the creative and innovative approach to a new technology and new workflows are essential to achieve a competitive advantage against
other companies. Indeed, BIM is a new methodology and an ICT technology to deliver a project outcome to a client with agreed quality, cost and time, and interviewees also agreed that proper and timely training for BIM and any other relevant new ICT technology would help them to increase the Creating cognitive abilities as well as other cognitive abilities.

CONCLUSION

This research investigates three major cognitive styles – Knowing, Planning and Creating skills of construction professionals – to make a proper decision in a BIM environment. A mixed method comprised of a questionnaire survey and an interview was adopted to identify the most frequently used cognitive styles based on the number of years of experience and the roles of respondents including a project manager, a site manager, and a quantity surveyor. As a result, the Planning and Knowing styles are the most frequently used cognitive skills for a decision making, and the Creating style is the relatively less frequently used ability to make a decision for a daily based task.

This study recognised that the 4D and 5D BIM capability to manage time and cost of a construction project can be an enabling tool to enhance the Planning and Knowing cognitive abilities of project managers and quantity surveyors. A knowledge management capability of a BIM system can be potentially used to capture and share the knowledge and intuitions of construction professionals and eventually can enhance the Knowing styles, which is the most preferred cognitive style for a site manager.

It is also revealed that the construction industry increasingly requires a creative and innovative idea, which is the Creating cognitive ability, to improve productivity and make a better decision. Furthermore, proper trainings are required for
construction professionals to increase their innovative and creative cognitive skills for their tasks. The research findings are expected to serve as a stepping stone to further investigate human cognitive abilities in a BIM environment, and to provide insights for an organisation or a project team how to adopt BIM for better decision making based on the cognitive styles.

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REFERENCES


Appendix 1 – Cognitive Style Indicator Questionnaire

Please indicate to what extent the following statements specify you.
1- Strongly Disagree
2- Disagree
3- Neutral
4- Agree
5- Strongly Agree

1. I like much variety in my life.  
2. I study each problem until I have understood the underlying logic.  
3. I prefer well-prepared meetings with a clear agenda and strict time management.  
4. I like to contribute to innovative solutions.  
5. New ideas attract me more than existing solutions.  
6. I make definite engagements which I follow-up meticulously.  
7. I try to avoid routine.
8. I want to have a full understanding of all problems.
   1 2 3 4 5

9. Developing a clear planning is very important to me.
   1 2 3 4 5

10. A good task is a well-prepared task.
    1 2 3 4 5

11. I prefer to look for creative solutions.
    1 2 3 4 5

12. I always want to know what should be done when.
    1 2 3 4 5

13. I like to analyse problems.
    1 2 3 4 5

14. I like to extend the boundaries.
    1 2 3 4 5

15. I make detailed analyses.
    1 2 3 4 5

16. I prefer clear structures to do my job.
    1 2 3 4 5

17. I am motivated by ongoing innovation.
    1 2 3 4 5

18. I like detailed action plans.
    1 2 3 4 5