RE-USE OF DOMAIN KNOWLEDGE TO PROVIDE CONFIDENCE FOR ADOPTION OF OFF-SITE MANUFACTURING FOR CONSTRUCTION IN AUSTRALIA

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ABSTRACT

Many construction industry decision-makers believe there is a lack of off-site manufacture (OSM) adoption for non-residential construction in Australia. Identification of construction business process was considered imperative in order to assist decision-makers to increase OSM utilisation. The premise that domain knowledge can be re-used to provide an intervention point in the construction process led a team of researchers to construct simple base-line process models for the complete construction process, segmented into six phases. Sixteen domain knowledge industry experts were asked to review the construction phase base-line models to answer the question "Where in the process illustrated by this base-line model phase is an OSM task?". Through an iterative and generative process a number of off-site manufacture intervention points were identified and integrated into the process models. The re-use of industry expert domain knowledge provided suggestions for new ways to do basic tasks thus facilitating changes to current practice. It is expected that implementation of the new processes will lead to systemic industry change and thus a growth in productivity due to increased adoption of OSM.

Key words: adoption confidence, Australia, domain knowledge reuse, OSM.

INTRODUCTION

Off-site manufacturing (OSM), off-site assembly, off-site fabrication and prefabrication are modern methods of construction. For simplicity in this paper OSM is used to indicate a number of different process types that take place distant from the construction site. There are a numbers of factors that foster the adoption of OSM according to the extensive literature (Nadim and Goulding 2011; Blismas and

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Wakefield 2009; Goodier and Gibb 2007). OSM offers better waste control through coordination and use of a controlled environment. In times of skills shortages, OSM can solve the problems of a limited on-site workforce because most of the jobs are production is located in a factory. In addition, repetitive standardised processes, such as constructing door frames, can be controlled for quality more effectively using a single manufacturing facility. However, OSM adoption is still limited outside of the residential housing sector (Nadim and Goulding 2011; Blismas and Wakefield 2009. Rodriguez-Melo and Mansouri (2011) suggest that stakeholders, including clients, architects, engineers, project managers, builders, contractors and suppliers are unable to make decisions to utilise OSM due to the lack of understanding OSM processes.

Smith (2010) however, suggests that some construction stakeholders do have specific domain process knowledge concerning OSM, but do not effectively share this knowledge with other project stakeholders. It could be argued that the product design sector provides a model for domain knowledge sharing (Ogawa and Piller 2006). For example, empirical product development studies show that product knowledge shared among suppliers and consumers leads to a widely accepted outcome. This is because knowledge sharing can facilitate problem-solving and decision-making that enables cost trade-offs thus improving manufacturability and increased product quality (Lawson, et al. 2009). Thus one mechanism of providing support for increasing adoption of OSM could be linking specific domain knowledge about off-site manufacture for construction projects to current construction processes.

Domain knowledge is defined as a concept in a number of disciplines such as education, psychology, engineering, and information technology (Vitharana et al. 2012). The concept is widely used with multiple meanings: cognition, language acquisition, professional practices, institutional processes and information systems. The common thread for application of the concept is that individuals, groups, organisations and construction projects can create, store, disseminate or re-use specific knowledge. Many studies have shown that individuals, teams and organisations become ‘experts’ about specific tasks and processes, often with limited ability or desire to re-use that knowledge for change (Kanjanabootra 2011). The difficulty appears to be that individual domain knowledge cannot be re-used and applied outside of the individual’s construction process framework unless specific mechanisms are in place to facilitate that domain knowledge re-use.

RESEARCH DESIGN

The aim of the study is to develop a mechanism to facilitate domain knowledge re-use through domain knowledge sharing about OSM for construction projects. Specifically the research focuses on development of construction business process models, based on the re-use of construction stakeholder domain knowledge for intervention points supporting the adoption of OSM (Demian and Fruchter 2006).

Business Process Management

Business process management (BPM) provides organisations with the ability to save money and time by systematically documenting, managing, automating and optimising their business processes (Weske, 2007). This is achieved by promoting a process-centric view of an organisation through end-to-end management of business processes. When an organisation takes on the BPM initiative, it goes through the different phases of the BPM lifecycle. A business process management lifecycle typically have a number of distinct and iterative phases; namely, design, implementation, enactment and diagnosis (Dumas et. al 2005). During the design phase, the process requirements are gathered from the stakeholders and an initial set of business process models are designed based on the requirements. The resulting business process models are used as a basis for communication with stakeholders and as input for later phases (e.g., to design IT systems and to identify process improvement opportunities.)

A business process model can be depicted using a number of different process modelling languages, each with their own advantages and disadvantages. In this study we use Business Process Modelling Notation (BPMN) which provides a graphical representation of the order of activities carried out within business processes together with the people who carry out these activities and the data required for these activities (White and Miers 2008). Its purpose is to provide a process modelling language that can be readily understood by business users as well as technical users. The BPMN notation has been widely adopted by many organisations.

The Three Stage Research Design

In Stage one, a value chain of the construction process is developed based on the literature review of construction project processes in a range of professional knowledge-based literatures. This construction value-chain provides a high-level overview of the various phases involved in delivering a construction project as shown in Figure 1. . These sixphases, namely Arrange Project Team, Develop Detail Design, Prepare Tenders, Tendering and Award Contract, Build and Handover and Operation, provide an overview of a construction project. This value chain enables researchers to identify key activities/resources/data involved in each of the six phases and process models are developed to capture the domain knowledge behind these phases. During stage one, the personal construction domain knowledge (Mechanical Engineering, Project Management, Quantity Surveying, and Building) of the research team assisted in expanding each phase into base-line process models.

Figure 1: Construction Value Chain

Stage two of the research design involved iterative and generative engagement with construction industry professionals. An opportunistic industry network sample consisting of 16 construction industry experts as listed in table 1 analysed the base-line process models. Individuals and teams were asked the question “Where in the

process illustrated by this base-line model is an OSM task?" to encourage specific domain knowledge discourse.

Table 1: Domain Knowledge Experts for Knowledge Re-use

Domain Knowledge	**Number =16**	**Type of Organisation**
Architect	2	Australian-based International Architectural Organisation
CEO	1	Australian-based Consultant for BIM and Precision Instruments
Government Client	4	Government Buildings and Works (Finance)
Project Manager	5	Australian-based International Infrastructure Contractors
Site Manager	3	Australian-based International Infrastructure Contractors
Service Supervisor	1	Australian-based International Asset Management

The interviews were recorded and the data analysed using and iterative method (Holliday 2007) of hermeneutics, checking and rechecking the usability of the construction business process models. Each model was modified as requested with each modification forming eight iterations. Task and sequence modifications were important in relation to identification of possible OSM intervention points in each of the construction phase process models (Vitharana 2012).

Based on the outcomes of the interviews, base-line construction processes modelled in stage 1 are modified in two ways: 1) the process models are updated to reflect the practices of industry participants and 2) the OSM intervention points are incorporated in these process models. The main outcome of stage 2 is a collection of six construction processes which not only depict typical activities carried out during a construction project but also explicitly model the changes required to enable OSM. Figure 2 illustrates the first section of the resulting process model, developed in BPMN, for the Arrange Team phase. For instance, the first activity of the process "Identify Requirements" has been recognised as an activity with OSM implications (depicted using dash-line) which is carried out by a client and requires the strategic asset management framework as the data input. Similarly, the "Business Case/Feasibility Study" and "Budget Investigation" activities are also identified that require OSM considerations. A checklist for OSM is proposed as input and a business case/plan as output with OSM.

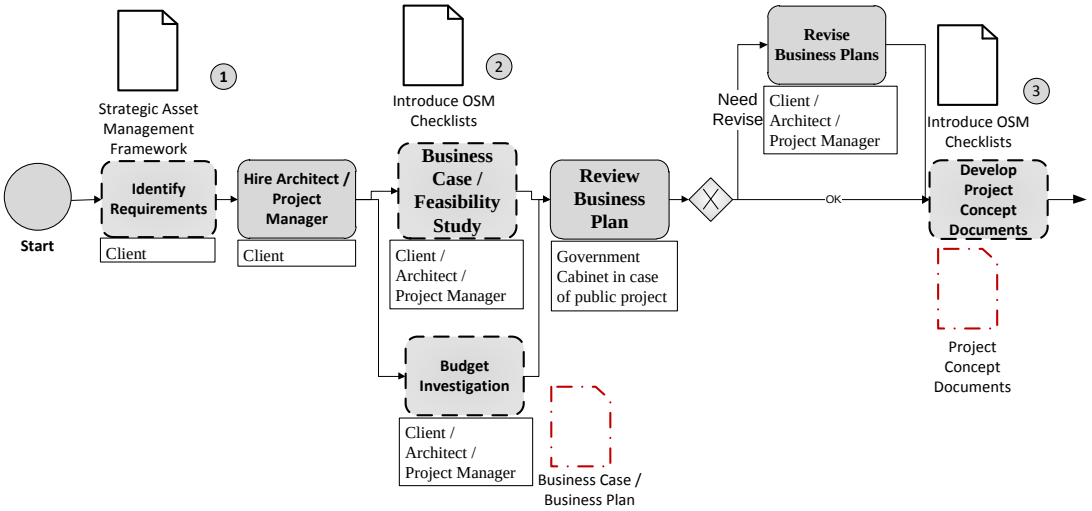

Figure 2: Example of Baseline Model in "Arrange Team" Phase

DOMAIN KNOWLEDGE RE-USE

The definition of knowledge re-use is when domain knowledge is re-used to carry out the same task. For example in Figure 2 Identify Requirements, Business Case/Feasibility Study and Develop Project Concept Documents are tasks that have been identified in the literatures. But the data collected from the research domain knowledge experts reviewed these tasks by answering the question "Where in the process illustrated by this base-line model is an OSM task?" Table 2 shows both the experts' answers to the question and the three specific OSM Intervention Points related to re-use of personal knowledge by domain experts interviewed.

Table 2: Changing the business process by adding the OSM option

Domain Knowledge Re-use Interview Data	OSM Intervention (number in Figure 2)
It is often the OSM concept has not been initiated during the "Identify Requirements" and the project has been carried away into the design phase and the project is trapped in the non-OSM concept which is difficult to change	1 Organisational Strategic Asset Management Framework review has been added to the task of developing the project requirements to ensure that the option of OSM is included as per the SAMF
There is a lack of OSM option analysis guidelines to help governments make decisions during the "Business Case/ Feasibility Study", as a result the project team cannot see overall benefits of adopting OSM.	2 OSM checklist to assist project teams evaluate the OSM options in order to make a business case

"Ideally, it would be useful if we have some input or comments regarding to production process and transportation aspects from suppliers/contractors during "Develop Concept Documents".	3 OSM checklist to assist with project logistics for OSM options along the supply chain

The re-use of individual domain knowledge has provided a new process and it is expected to be a more effective way of doing the same task (Kanjanabootra 2011). Thus, re-use of domain knowledge has facilitated change in construction processes which is expected to lead to changes for the OSM sector and the industry in general.

Stage three of this study will involve the development of a prototypical workflow application based on the construction processes identified in Stage 2. These BPMN models are used as a starting point to develop executable process models (i.e., workflows). Customised user interfaces will be provided in some of the activities to enable the interaction between an end user and the workflow system. A pilot application using process/workflow technology based on the knowledge captured in the construction process models is expected to facilitate knowledge sharing among stakeholders and to provide automated support for construction processes. The workflow system will also have the ability to integrate with other technologies within the construction industry such as BIM systems thus becoming a champion for change: increasing OSM adoption.

CONCLUSIONS

This study provides a good example of how two different types of knowledge are transferred; human and IT. Both have been used to re-locate OSM information in a place that is more accessible for construction industry stakeholders. Development of the base-line process models assisted industry domain experts to expand their areas of expertise as it shifts through the workflows of the construction project process. This paper has been able to provide only three examples of OSM intervention points being created through domain knowledge re-use. However, it is clear that even these small process interventions have the possibility of a large effect. The domain knowledge was usually from a specific field such as design, engineering or construction. However, the re-use of individual knowledge for innovation is evident in the requests to change the process as illustrated in the "Arrange Team" phase. The effect of the expert domain knowledge is that other industry stakeholders will now be able to have earlier points in the construction process for making OSM decisions. Thus, the modified processes are expected to increase stakeholder confidence in perceiving opportunities for productivity gains through OSM adoption.

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