Mitigating Environmental Characteristics with Integrated Design and Automated Construction Approaches for AQH Development

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ABSTRACT

Industrialised Building Systems (IBS) implementation requires a systemic operational approach from conceptual design to implementation. In doing so, ensuring the movement of knowledge amongst the team members for a timely and within the budget implementation is a major concern because it impacts the long-term sustainability of the completed project. This study attempts to relate recent international findings to the Malaysian context, which recommended the need to look at the life span of property projects and proposing the development of tools and methodologies that could mitigate the knowledge-loss phenomenon. It found some similarities between housing development projects in USA with those of the local public projects. At the conclusion of this paper, it supports the recommendation for a systemic review of the local IBS delivery process by integrating 3D-CAD modelling during the housing development design process. The systemic IBS process is expected to promote a seamless transition towards 4D technology in the building phase.

Keywords: Industrialised Building Systems, Integrated Design, Housing Development

1. INTRODUCTION

Industrialised Building System (IBS) implementation requires a systemic operational approach from conceptual design to implementation for the housing developer to take advantage of its financial benefits. In promoting IBS, the housing developer could also take advantage of ensuring the movement of knowledge amongst the team members for a timely and within the budget implementation. This building approach has been promoted by the government of Malaysia for the purpose of providing quality-controlled end products through controlled prefabrication process and simplified installations. It is a construction process that utilizes techniques, products, components, or building systems, which involve prefabricated components and on-site installation (Zuhairi and Sarhar, 2003).

Another benefit as mentioned by the IBS Roadmap 2003-2010 states that IBS could provide faster completion of construction when builders use standardised prefabricated components and having the installation process simplified. The Construction Industry Master Plan 2006-2015 by the Construction Industry Development Board (CIDB) has a strategic plan to improve the effectiveness and productivity of the construction industry in Malaysia by facilitating the integration of ICT into the local construction industry (Zuhairi and Sarhar, 2003). Among the proposed priority areas for the strategic plan include electronic commerce of the design and fabrication processes, 4D (3D plus schedule) in architectural/engineering design, improved data sharing with flexible product model schemas, transaction performance measurements and project websites, and other project communication systems for remote teams (ibid.).

There are 5 priority areas for the local construction industry to innovate as outlined by the IBS Roadmap 2003-2010 (which eventually were adopted by the Construction Industry Master Plan 2006-2010). Firstly, is the adoption of new construction techniques and technology. Secondly, the development of manpower to support adoption of IBS/MC. Thirdly, continuous development of materials (components and machines) to support adoption of IBS. Fourthly, continuous enhance ment of management processes and methods to encourage adoption of IBS. Finally, provision of monetary (economic and financial) support to encourage IBS adoption. The purpose of this study is focused on continuing the enhancement of management processes and methodologies to encourage the adoption of IBS for housing development in Malaysia. In this paper, we are supporting a systemic review of the current design procedure in order for the design team to implement 4D technology during construction. Rather than attacking the problem at one phase (i.e., at the construction phase), a system review is called for where designers (such as architects and engineers) would use 3D-CAD in enhancing the management processes during the pre-construction phases. The 3D-CAD modelling design protocol would eventually encourage the adoption of IBS later.

This is a theoretical paper supporting an earlier work by Ibrahim (2006) whereby, first it presents the current knowledge about the housing development's operating environment as its background literature. Then, it also highlights challenging issues in global projects. The study makes simultaneous comparisons between the American housing development process and that of Malaysian in both sections. At the conclusion, the study would like to propose how local construction stakeholders can fit the ICT technology into the methodologies and processes throughout the housing development life cycle in a systemic manner that will eventually support the implementation of 4D technology during construction.

2. HOUSING DEVELOPMENT ENVIRONMENTAL CHARACTERISTICS

In this section, we present an overview of the background of housing development and discuss what current diagnostic organisation theory says about the operating environment that housing development organisations are into. The background literature is based on several recently completed studies at Stanford University (Ibrahim, et al. 2005a; Ibrahim, et al. (2005b); Ibrahim and Paulson (2005); Ibrahim and Nissen (2007)). Ibrahim and Paulson (2005) present unique environmental characteristics obtained through an ethnographic study that Malaysian housing projects also experienced. Another two studies involved computational organisational simulation studies (Ibrahim, et al. (2005a); Ibrahim, et al. (2005b)) that describe the different knowledge types involved in the workflow process and how the dynamic formation of the project team affects the efficiency of knowledge movements amongst the team members. These recent studies were motivated by the fact that knowledge loss (K-loss) continues to recur despite the advancement of knowledge management technologies. Hence, it is integral for all stakeholders in the Malaysian construction industry to understand the underlying forces of the housing development process; besides understanding the peculiarities of working in a "global" project that forces the use of ICT for communications and exchanges of information on top of their individual industry's background. The four environmental characteristics are multiple sequential and concurrent workflows, discontinuous memberships, interdependent tasks, and different knowledge types.

2.1 Multiple Sequential and Concurrent Workflows

The housing development life cycle process consists of several sequential and concurrent phases. These phases are unique because each life-cycle phase has a different workflow process that requires different skill sets for the team to complete the tasks (Ibrahim and Paulson, 2005). Ibrahim (2006) had earlier divided the sequential phases of the housing development life cycle process into feasibility (equivalent to Malaysian schematic design phase), entitlements (equivalent to Malaysian design development phase), building permit (equivalent to Malaysian contract documentation phase), construction, and property management phases. The most critical is during the integrated feasibility and entitlements phases, which Ibrahim and Paulson (2005) later combined into the feasibility-entitlements phase—this phase is equivalent to Malaysian conceptual stage until the receipt of development order from the local authority. This early phase starts when a parcel of land becomes available for consideration, and continues until the development proposal receives its permit for development. Ibrahim and Paulson (2005) also found that property developers have two additional life-cycle phases that run concurrently with other four sequential life-cycle phases—i.e., finance and asset management. The finance phase is handled mainly by non-design and non-construction team members. In organisations with larger property portfolios, the asset management phase is distinct from the finance phase.

2.2 Discontinuous Memberships

The ethnographic study by Ibrahim and Paulson (2005) provides rich insights into the cultural and operating environment of housing development teams from a project manager's perspective. It reveals a dynamic project team organisation that varies across different housing development life-cycle phases. The evolving organisation is caused by the need for different skill sets among its team members in order to complete the tasks in one life-cycle phase within the multiple phases of a housing development life cycle. The study found that some team members remained in several life-cycle phases while some only served in one. For example, the environmental engineer only served in the feasibility-entitlements (or Malaysian schematic) phase while the architect was involved in three phases involving design and construction tasks. The study found similar discontinuous character in the Malaysian housing development sector.

Ibrahim and Paulson (2005) describe the members of the evolving organisation as having discontinuous membership. They claimed that discontinuity in an organisation is a source for knowledge losses in the housing development projects. Discontinuity in an organisation occurs when a position in an organisational structure is added or deleted while the process is on-going. It differs from turnover, which occurs when the incumbent of a position in an organisational structure is replaced with another incumbent to fulfill the same position's role during the on-going process. Ibrahim, et al. (2005a) supported these earlier results. They found that a new member could cause the task he or she was handling to incur higher functional risk, and in the long run could put the whole project at risk. The incomplete knowledge of prior history of a task or project can trigger an escalation of schedule delays and cost overruns with potential individual failure as mentioned by Ibrahim and Nissen (2007). It is unfortunate that any missing knowledge during the pre-construction phases in the housing development may force development project sponsors to decide not to proceed with the project. A project development's cancellation would mean the lost of future income to designers and builders. This is true in the Malaysian context.

Despite the discontinuity character in housing development organisations, the Ibrahim, et al.'s (2005a) study observes that regularities in the organisation—as highlighted by Grant (1996) and Kogut and Zander (1992)—do help an organisation to overcome this organisational dynamism. A housing development project could still move forward despite having engaged a new civil engineer, or omitted the landscape architect's position. This is evidenced by the lack of significant changes to the overall total work volume and the duration of project for two test cases in Ibrahim, et al.'s (2005a) study. More importantly, their intellective computational model reflects how a subtly incomplete task can cause a major failure in the total process if it is not addressed diligently. As in many cases, the project managers are too overloaded to catch an apparently minor error. Unfortunately, the minor error tends to be discovered after a major breakdown in the total process, and usually evidenced in the form of financial or schedule losses. These incidences are common in Malaysian context.

2.3 Interdependent Tasks

We note another key finding from Ibrahim and Paulson (2005) study that is the workflow in each phase can have multiple interdependent tasks. These tasks are distributed in both sequential and concurrent workflows. They cite instances where property developers require building permits before starting construction, but they need to close the construction loan before issuing the site hand-over for the general contractor to start construction. Obtaining the building permit to start construction is in a sequential workflow, but obtaining a building permit to close the construction loan to start construction involves tasks in two concurrent workflows. Similarly in Malaysia, no developer will award a contractor prior to obtaining any end-financing loan or major capital commitment for the development project. Despite the risky outcome that a property project may not eventually see its implementation, Ibrahim and Paulson (2005) surprisingly found the project managers were not concerned with the uncertainties and complexity of the housing development lifecycle process. In fact, these experienced project managers exhibited substantial tacit knowledge of their operating environment that enabled them to comfortably maneuver socially, politically and financially throughout the complex process.

2.4 Different Knowledge Types

With the above-mentioned observations, Ibrahim and Paulson (2005) concluded that different characteristics of knowledge movements do occur during different facility development's life-cycle phases. Tacit knowledge dominates during the feasibility-entitlements phase. Project managers articulate and share knowledge through their actions, commitments and involvement in a specific context (Nonaka, 1994). They obtain tacit knowledge by socialising and internalising the actions and comments of the local elected officials and the public that supports them. Unlike tacit knowledge, explicit knowledge is transmittable in formal, systematic language. It can be articulated and shared via plans, drawings, documents and databases, which are the dominant forms of communication among the architectural-engineering-construction team members. The study found similar instances where the exchanges of knowledge do occur by socialising and internalising the actions and comments of public officials especially during the early phase of a housing development project. Malaysian projects exhibited substantial similar cross-socialisation and internalisation processes especially during the earlier phases. Subsequent studies by Ibrahim, et al. (2005a) and Ibrahim, et al. (2005b) cross-validated Ibrahim's and Paulson's (2005) assumption.

Ibrahim, et al. (2005b) study illustrates that knowledge movements are also impacted by the continuous vs. discontinuous participation characteristics of team members. Firstly, an individual team member would retrieve information from more expert members of the group. However, while expert members would tend to wait for lesser expert members to retrieve knowledge from them, they would also tend to seek information from other members. Secondly, an individual team member would allocate information to more expert members of the group. However, again their study found an interesting additional knowledge allocation pattern. Experts in this discontinuous organisation also tended to allocate information to a greater number of others than their less expert counterparts. Thirdly, in a discontinuous membership organisation, team members will turn to continuous members to augment their knowledge by referring to "who knows what." An individual continuous team member also has a higher tendency for both knowledge retrievals and knowledge allocations. Both the knowledge retrieval and allocation behaviours show that both continuous and expert members do turn to other members in their network to augment their knowledge by referring to "who knows what" when their cognitive knowledge networks are incomplete. Further study is recommended to understand if the Malaysian project team members would behave similarly although this study believes that the above-mentioned situations do exist.

3. SCENARIOS FROM LOCAL PUBLIC PROJECTS

Property developers and builders will have more complex issues to deal with in addition to the inherent typical housing development projects this paper have discussed if they decide to embark on international projects. Preliminary observations show that some operational issues that occur when managing Malaysian projects are similar to issues experienced on international projects. They are spatial, professional, cultural and technology differences (Fruchter, 2003). It is our proposition that Malaysian projects can benefit through the use of ICT-supported collaborative work at the local context as per their counterparts involving in global projects. The paper explains in details the four identified issues below:

3.1 Spatial Distribution

It is common that a global project entails participation from a combination of multiple professional individuals and organisations that are located in many places. For example, a high-rise residential project is planned in Dubai, U.A.E., by a Malaysian property developer. The property developer will hire a Malaysian concept architect, but the Malaysian architect will need to work with a local project architect who will eventually submit the documentation requirements for the residential project to the Dubai authorities for development and building approvals. The developer may hire a structural engineer who already has some experience working in that area or a Malaysian engineer who is an affiliate of a multi-national consultancy group. This list will grow because, as much as the developer would like his Malaysian team to go along with him on this project, he is concerned about the implementation of various aspects of the residential project. The risk to the developer is very high indeed and he is not in Dubai all the time to supervise the development operations. Additionally, when the team is divided over several geographical locations, the global team must work along with the time differences that may span over more than two continents. The team must continue having coordination meetings, document their decisions and share information amongst the team members effectively. Comparatively, the headquarters of a housing development organisation is located in Kuala Lumpur with several building consultants distributed either in Kuala Lumpur or in the state where the project will be built. Representatives of the development organisation are located in the respective state to oversee the site project management and market the project. Despite having no time differences within the Malaysian context, some states do have different working days and communications are consequently limited during those days only.

3.2 Multiple Professional Mix

Having multiple professional mix are common in both global and Malaysian project teams. Both engage multiple professional mix, which include professionals in architecture, structural engineering, mechanical engineering, electrical engineering, interior design, landscape architecture, construction management and several specialised experts needed for the project's design and building purposes. Another set of professionals will also be appointed (if the property developer does not have its own in-house teams) to provide financial services, asset management services, property management and sales. On many occasions, the design-building team does not work closely with the financing-asset management team. Due to this circumstance, the project manager tends to become the mediator between the two professional groups (Ibrahim and Paulson, 2005). Ibrahim and Paulson (2005) recommend that all team members of a project must work very hard to understand the different professional requirements in order for the project team to work efficiently and effectively.

3.3 Cultural Differences

In addition to the different professional requirements, a global project team must also have an open mind in the different work methodologies of getting the tasks completed. In a study by Tamaki, et al. (2004), they found that culture could play a role in determining the organisational performance of project teams. Most Asian cultures tend to work through some level of consensus building, while most European and American cultures tend to work with strong independent leadership. Moreover, religious and cultural differences may influence the outcome of many decisions. In many Asian cultures, statements tend to have many underlying meanings. If their western counterparts—who are used to straight and direct statements—do not understand their multiple meanings, we can expect an unfortunate clash between cultures especially when the situations are not in favor of certain decisions that were made earlier by either parties. This study believes that project teams should be able to observe cultural differences amongst their team members and make appropriate decisions. Hence, more studies are recommended to understand these subtle differences that could affect teamwork.

3.4 Technological Differences

Regardless of any spatial differences amongst members of an international project, the team must deliver their professional services in order to complete the project. The construction industry is grateful that ICT technologies have advanced enough and enable team members to continue delivering their services despite the geographical and time differences. Fruchter (2003) points that for a global team to function, it requires some minimum facilities. Among these facilities are having a network infrastructure (eg., LAN/WAN, Internet2 and the wireless zones), utilising mobile devices (eg., interactive wireless and wired devices to enable mobile team members to stay connected with their peers such as PDAs and pen-based laptops), and having the capability for collaborative synchronous review and decision support (eg., web cameras, SmartBoards® and iRoom). It is very important that an international project team chooses the appropriate collaboration applications that address the need for synchronous and asynchronous communication; interaction and feedback; direct manipulation, knowledge capture, sharing and re-use; and data collection and analysis. Nevertheless, the building industry is aware that there exist technological differences amongst different professionals, and the most critical is the technical differences between the participating countries. One can expect that the more developed counterparts would have already engaged in ICT-assisted collaborations, while the less developed counterparts would have just started testing the technology and tools. Both parties will need to work towards developing a work process that is comfortable and convenient to everyone (Fruchter, 2003). In this subject matter, more studies are recommended to understand and gauge to what extend do Malaysian building professionals and local authorities could use these facilities comfortably in the local context or when overseeing global projects.

4. USING ICT FOR ENHANCING IBS DESIGN PROCEDURES

The key problem during fabrication of an IBS component or system is that design professionals require 3D visualisation skill to integrate their professional requirements into the building components' design (Osman, 2006). Furthermore, if a builder wants to create a 4D-CAD model to monitor his project, he will need a 3D-CAD model of the design documents plus his implementation schedule. On the contrary, structural, mechanical or electrical professionals produce engineering requirements in 2D-CAD format, which are based also on 2D-CAD architectural documents. Due to this situation, the building industry in Malaysia needs to close the gap to reach the 4D level of delivery. A concern to the industry is that a newly graduated project manager will need at least 3 years to acquire some understanding about the different professional disciplines within the design team, while the project engineers will need to acquire industrial skills in order to coordinate various building elements on site. It is in this light that we believe that these necessary acquired skills could be enhanced earlier through 3D visualisation.

In an earlier case study, Ibrahim (2006) proposes the following to close this gap. She believes that the architect can provide the IBS flexibility to the clients by providing a 3D-CAD modular coordinated design that could ensure the successful manufacturing of IBS components downstream. The proposal is expected to reduce errors due to uncoordinated work processes which are prone to occur during current design integration process. These errors are costly because when they emerge at the later construction stage, they will cause schedule delays and incur additional costs when the project team has to rework the components. In such a case, an IBS component manufacturer would ideally like to work with the architect as early as possible to minimize these errors. However, this is not always possible because the client is not willing to commit to one IBS system very early.

4D technology will assist construction managers in project planning and monitoring, procurement deliveries and building trades' coordination on the site. Besides those benefits, the 3D-CAD model can be used later by the property management team for facility maintenance and management purposes. These are the end goals highlighted by Ibrahim (2006) when utilising 4D technology in the IBS Roadmap 2003-2010. Hence, the proposal shall start at the end first where 4D technology is being used, i.e., the building phase. The proposal can minimise the conversion problem if designers would consider working as early as possible during the design phases in a 3D format. We support Ibrahim (2006)'s hypothesis that a 3D-CAD model can facilitate the coordination of different aspects of a building design since every team member can visualize all the different professional requirements synchronously or asynchronously, and each profession can annotate additional comments or make revisions for others to know. Ibrahim (2006) proposes the integration of ICT (via visualisation of 3D-CAD coordination collaboration) into the Malaysian housing development procedures.

Referring to Figure 1, Ibrahim (2006) proposes a three-prong consideration based on 3D-CAD modeling. She proposes to 1) develop a 3D-CAD modular coordinated design documentation protocol that will be used for 2) 3D-CAD e-submission that 3) facilitates the integration of IBS components from a 3D-CAD modular coordinated database into a 3D-CAD model. The end product of the three focused steps is a 3D-CAD model that the builder can use for 4D construction. In all the steps that she proposes for review, it requires the design team to work in an embedded design methodology that is termed as the IBS design mode (Ibrahim and Azmeer, 2006). The IBS design mode refers to the automatic subconscious reference to IBS systems during the design process including its modular coordinated dimensioning system and the various implementation strategies that different industrialised building systems use. The IBS design mode is a design skill above the conventional architectural and engineering design process.

Two of the auxiliary steps also rely on the availability of the third step that is an IBS database in 3D-CAD format. At the moment, many IBS manufacturers have some kind or other database of their IBS components as reference to for the design teams. Therefore, the initial step is developing a 3D database for IBS components. One key issue when developing this 3D database is that all IBS components must be able to optimize their usability with minimal cross-jointing systems for selective component types such as concrete panels or masonry panels. While the IBS manufacturers and experts work on developing several ubiquitous jointing systems, the design team can develop a design protocol that will encourage the use of IBS components during construction.

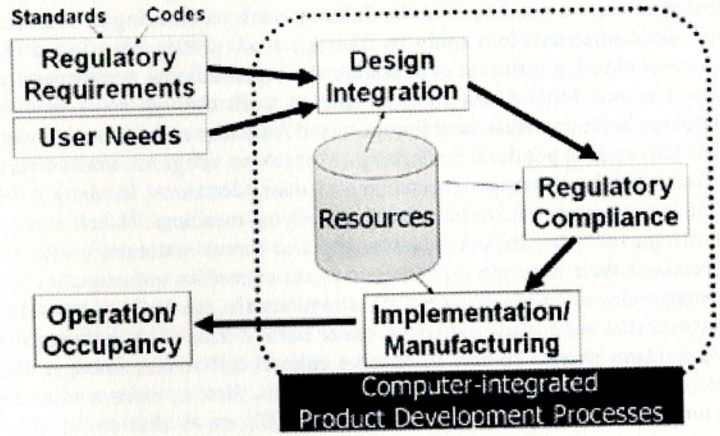

Figure 1: Proposal for streamlining the design-construction process of IBS housing project. (Adapted from Ibrahim (2006)).

A key problem in IBS component design and manufacturing is actually visualising the different professional requirements during coordination meetings and an IBS design protocol can help. Currently, the IBS manufacturer representative can be considered the project manager during these design coordination sessions since he or she has the global picture of the different professional requirements besides already knowing the related IBS manufacturing process. The design protocol in 3D-CAD allows visualisation of all the professional requirements for producing the IBS components during coordination meetings. It considers the modular coordination dimensioning systems. Therefore, we are recommending further studies to develop a 3D modular coordinated design protocol among the professional team members in the housing industry.

The next step is to enhance the e-submission procedure that will allow 3D-CAD submission to housing authorities. We believe such 3D-CAD submission can reduce or eliminate the number of documents architects and engineers have to submit to the local authorities when applying for development and building permits. Local authorities can learn how to manipulate the 3D-CAD model and confidently decide to issue the appropriate approvals. We believe the 3D-

CAD models will help them visualise the development project long before it is being built. The 3D-CAD e-submission also allows local authorities to ensure how well the regulatory requirements are complied with by the clients. However, further studies are needed to gauge and facilitate the capacity building of local authorities and building professionals to embrace new IT-based procedures.

Nevertheless, the proposal will cause some changes to the current approach local building professionals are providing their services to their clients. Readers will have quietly noted by now that clients may have to fork out more finance upfront in the housing development process. This is something that project sponsors may not be willing to undertake although the study shows that the additional undertaking can help control escalating financial losses later especially when the project has already reached construction phase. Given the tendency for any project to incur about 20% or 30% of cost increment from conceptual phase to construction completion, the small increment during the design phase is a small amount compared to the potential savings in the future.

In addition, should the construction industry stakeholders agree to this proposal, the professional bodies will need to review their service agreements to facilitate the additional services and their corresponding financial compensation. The reason is that the current professional compensation schemes do not support any 3D form of delivery. The faster designers complete the 2D documents, the faster they can claim their fees. Therefore, the study would like to suggest that the professional bodies review some approaches that could be incorporated within their professional services agreements. In conclusion, enabling 4D technology application during constructions will and have already raised more issues in the housing development process. A systemic review of the housing development life cycle process will facilitate the transition, but the industry will require the support of every stakeholder including project sponsors, local authorities and professionals. Since the Malaysian housing development practise examples that the study cited are not as comprehensive and exhaustive, we would like to recommend further studies to identify, innovate, and integrate ICT-based processes within the Malaysian practise.

5. CONCLUSION

The complexity of the housing development process is caused by the multiple sequential and concurrent processes, discontinuous membership, multiple interdependent tasks and different knowledge types. Already operating in the complex housing development process, a housing development project team must also work in a situation where professional, cultural, spatial and technology differences would add to the complexity. This paper proposes a systemic review of the process that could integrate ICT integration by developing 3D-CAD modeling into the design process. Since the nation is moving towards 4D technology in construction, the adoption of 3D CAD within an IBS design mode is one approach in continuing enhancement of current management processes and methods to encourage adoption of IBS among the design professionals.

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