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ScienceDirect

Procedia Engineering 00 (2017) 000–000

Procedia Engineering

www.elsevier.com/locate/procedia

The proliferation of ICT and digital technology systems and their influence on the dynamic capabilities of construction firms

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Abstract

Information and Communication Technologies (ICT) are changing the way we work and play. Such changes are evident in the design, construction and operation of large construction projects. Programs such as building information modelling (BIM) and various other innovative digital technologies and engineering systems are changing the way we materialise all aspects of construction projects. This proliferation of ICT and digital technologies facilitated the adoption of various innovative approaches in processes and various ICT systems throughout a project life-cycle and across its supply chain. This has great implication on construction firms providing a new challenge by reconfiguring their resources to rise to the new challenges of large construction projects. ICT is changing three different aspects of large scale projects. As a tool during the build, i.e. BIM, for the ongoing building functionality i.e. BMS and lastly benefiting occupants experience. The integration of these three ICT aspects are forcing firms to rethink their current ICT management systems. Through a case study in a large scale healthcare project, this paper uses a case study to investigate the application of various innovative ICT and digital technology systems on the dynamic capabilities of a construction firm and across the supply chain of a project. The case study presented is the New Royal Adelaide Hospital (nRAH) in South Australia. This is a joint venture project under a Public Private Partnership agreement to design and construct AUS$1.85b hospital. The case study showed that various challenging examples of functional complexity exists that required innovative process management approaches by the construction firm to withstand the test and trial of such a complex project, to successful completion. This has further contributed to the elevation of the dynamic capabilities of the construction firm as well as to its overall reputational assets and branding, nationally as well as internationally.

Peer-review under responsibility of the organizing committee iHBE 2016.

Keywords: ICT; BIM; dynamic capabilities; healthcare project; management systems; smart buildings

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Peer-review under responsibility of the organizing committee iHBE 2016.

1. Introduction

The construction industry is one of the main contributor to the national economy with an annual growth of approximately 10% in Gross Domestic Product. However, the industry is widely being criticised for its lack of innovation with results in low productivity. The proliferation of Information and Communication Technologies (ICT) is influencing today's modern society in all aspects of life. Despite the wider benefits of the adoption of ICT in all industries, specifically construction, it often comes with high costs and disruption to typical management models. The wide uptake of building information modelling and the application of various ICT systems are seen as a way to enhance the productivity of the construction industry. The application of such disruptive technologies has great implications on current construction management models.

Various business models in construction focused on the competitive advantage of firms [1] and resource-based view [2]. The need for convergence of concepts such as knowledge management, organisation learning and reflective practice are stipulated as means for improving the performance of construction firms [3]. More recently the concept of dynamic capabilities has found great prominence in construction to enable firms to respond to a changing environment [4]. It is argued that the uptake of ICT is providing construction firms with great challenges in the way they operate. Construction firms, due to their nature of being project based business, has a distinguished set of competitive advantages. The notion of dynamic capabilities can help firms to reconfigure their resources while acquiring new ones to respond adequately to the change within their environment brought by the development of ICT and the demand of construction of large projects such as hospitals.

It is argued that the construction industry is experiencing a change the industry is being expected to completely adapt their current ways to allow for the management and design of large complex ICT systems within large scale projects. This need for adaption for large scale complex projects has been evident within the new Royal Adelaide Hospital (nRAH) in South Australia. These large scale complex projects can also be referred to as intelligent buildings. Intelligent buildings are buildings 'that integrate technology and processes to create a facility that is safer, more comfortable and productive for its occupants, and more operationally efficient for its owners [5]. Advanced technology combined with improved processes for design, construction and operations provide a superior indoor environment that improves occupant comfort and productivity while reducing energy consumption and operations staffing.' [5,6] Projects are characterized as intelligent buildings mainly due to size, complexity and the relationship between technology systems. These systems are typically undertaken by separate organisations; coming together specifically for the project. This collaboration brings difficulty due to such different work practices and cultures [5].

With regard to the nRAH project, the various adaptations of Public Private Partnerships (PPP) for the procurement of large scale projects has changed the center point, timeframe and working arrangements of many construction contracts and firms. This is mostly due to the change from standard 'product delivery to through-life service support' [7] and with this comes a shift in risk. The complexity and uniqueness of large scale projects like the nRAH raise challenges within management systems in relation to communication, testing of ICT systems and the implications for the life-cycle and ongoing building management. Due to the time length of these projects changes of personal and management structure can be a major problem. In the case of the nRAH the addition of working within the health sector (stakeholder) and with a large amount of involvement from the South Australian Government had a profound impact on established practices and management structures.

Consequently, building a new hospital is a complex undertaking and delivering the project with little to no failure rate, delivering within budget, on time and with the required features and function can be extremely difficult. This is possibly due to the number of unknowns, the incorporation of new complex technologies and the increase in risk of delivering a large scale complex project.

This paper investigates the impact of the adoption of various ICT systems in large and complex projects such as the nRAH using a case study method incorporating various interviews and project document analysis.

2. What is Information Communication Technology (ICT)

Information Communication Technology commonly known as ICT is becoming less of an option and more of a necessity. This is especially evident in the construction industry. ICT is defined as an umbrella term that includes

any communication device or application, encompassing: radio, television, cellular phones, computer and network hardware and software, satellite systems and so on, as well as the various services and applications associated with them, such as videoconferencing and distance learning [8]. ICT is often referred to in conjunction with a particular context, such as in education, healthcare or libraries. Historically ICT within construction has be associated with two aspects of the project, however now construction firms must consider a third use for ICT, especially in large scale projects. These three aspects are:

- As a tool used during the design and build (BIM, Aconex, Revit, hardware);
- For ongoing Building functionality (BMS, security);
- Directly benefitting a user's experience through business process systems (technologies for the user).

ICT as a tool used during the build is one of the most common forms of ICT used in construction. This can be anything from BIM, type of software, to hardware such as iPads. Building Information Modeling (BIM) allows for all data associated with the build, material types, size, function, placement for example, to be added to the design with the intention of keeping a clear and concise overview of the project. BIM is not a single piece of software or model, but a new form of information processing and collaboration, with data embedded within the model. [9] Where BIM is considered more of a philosophy, Revit is considered the tool. Revit is a software application that supports a BIM workflow from concept to construction. Revit is used to model designs with precision, optimise performance and collaborate more effectively.

Aconex is especially useful for large scale projects that typically have multiple companies, thousands of people and even more documents/messages. For these reasons HYLC decided to incorporate this software into their management system in the nRAH. Aconex is regularly used for PPPs and JVs allowing for quicker reviews and approvals of tasks and budgetary issues to keep the project on track with the use of the inbuilt emails system. [10] This can be used in conjunction with general communications via email keeping everyone informed and make individuals accountable for their work and decisions regardless of their companies' individual management system.

HYLC also incorporated the use of iPads for on site use. The iPads were loaded building documentation to allow for easy reference while onsite. The iPads were also used to scan Radio Frequency Identification (RFID) to access information regarding parts of the building, such as, who installed them, when they were installed.

In addition, the venture is employing Building Management System (BMS) as an integrated computer based control system that control and monitor the building electrical and mechanical systems/equipment. Having a fully integrated BMS can have many benefits, such as energy saving, reduction of greenhouse gasses and environmental impact, improved security, building maintenance with the operator conveniently being able to access all building data from any location, at any time.

The third aspect of ICT being used in construction is reasonably new to the industry and consists of technologies that directly affect the user/occupant. Previous projects would see the infrastructure bones of ICT being constructed to allow the client to come in after the projects completion and add in their required technologies. The nRAH project incorporates the installation of the required technologies. This installation must be installed and working before the projects handover. Technically speaking the facility could be functional the next day. Several examples of this can be found throughout the nRAH, such as the way finding systems and nurse call bedside terminal. Such technologies are essential in creating a state-of-the-art health care facility in a world where we have become dependent on ICT.

As documentation remains part of the information set, data can be linked to the elements of the model that it pertains to. Construction firms are constantly being challenged to deliver projects with tighter budgets, quicker finishing dates, limited manpower and information from clients, especially when it comes to large scale projects. Using a combination of ICT tools as part of a management tool can help coordinate outside disciplines, such as architects, facilities managers and engineers, as well as detecting possible future problems before encountering the issues on site.

Fig. 1. (a) first picture; (b) second picture.

3. Case Study: New Royal Adelaide Hospital (nRAH)

3.1. Design

The new Royal Adelaide Hospital (nRAH) has been Planned and designed around a patient centered model of care and reflects international best practices in hospital design [7]. This world class hospital will fulfill todays patient requirements but also has the ability to adapt for future technological and medical innovations creating the optimum patient focused environment. With the patients of tomorrow likely having higher expectations, the adaptability and continuous technological developments are likely to alter opportunities and methods of treatment today. Thus, the facility must do the same. A building with ICT system is no longer a building, it is a service and as such, all planning and construction shall be aligned with the delivery of a working building.

The relationship with the South Australian Health & Medical Research Institute (SAHMRI) will gain South Australia worldwide attention. This combined medical facility will be the leading edge in the design and delivery of South Australian health care using advanced and high quality technology and medical care. The incorporation of a sophisticated and fully integrated ICT system plays a huge part in the success of this world class hospital.
The nRAH will be the State's flagship hospital providing a comprehensive range of tertiary level care to patients, with a focus on privacy and passive surveillance. Care can begin before the patient reaches the hospital, for example, paramedics will conduct onboard assessments while the patient is en-route, sending patient data in advance so staff and services can prepare ahead of their arrival. The nRAH will be one of the most technologically advanced hospitals in Australia, with patient records stored electronically and clinicians able to access test results from monitors within patient rooms. [7]

Utilising technology to assist in providing safe care by reducing time spent on tedious and administrative tasks and increasing clinician-patient time enchasing South Australian Government's model of care.

The ICT Network is being designed with considerable capacity, scalability and expandability both in terms of the cabling and the active devices. It is well positioned to adapt to changes to the hospital in future. This level of integrated ICT will be showcased as part of the nRAH and will establish it as the most technologically advanced health facility in Australia. [8].

However, creating the most technologically advanced hospital in Australia did not come without its challenges.

3.2. Project Bid

In 2006 the South Australian Government proposed to build a new state of the art hospital to compete with the best around the world. The proposal request output drafted during 2010 for the nRAH was an overly ambitious design and specification brief. Specific features in the proposal had been selected from some of the best international hospitals with a lot of the design benchmarks coming from Scandinavian Hospitals. Although these countries had some of the best hospitals in the world there were still no example of hospitals that have an integrated systems to the same extent that the nRAH would be designed to have.

In early 2011 the South Australian Government entered into an agreement with South Australian Health Partnership (SAHP). SAHP would finance and contract out the project. Due to the large scale of the project Hansen Yuncken and Leighton Contractors (HYLC) became a joint venture (JV) to win the design and construct contract. The contract was signed under and Public Private Partnership (PPP) agreement with SAHP financing, HYLC designing and constructing and the provisions of facilities management and non-clinical support services by SAHP subcontractors Spotless and HP. These services being provided under a 35-year term. The nRAH is the first Australian hospital PPP contract to specifically require the Project company to deliver and operate an ICT integration system in conjunction with the State's ICT system.

Hansen Yuncken (HY) is one of Australia's largest privately owned construction company. They focus heavily of health work and in South Australia have completed significant projects at Lyell McEwin, TQEH and Flinders private hospital. They have strong local South Australian partners. Leighton Contractors (now CPB) is a large publicly listed construction company who had no presence in Adelaide. The nRAH opportunity required the financial capacity of Leighton and the local expertise and contacts of HY. The PPP form of delivery also lends itself to partnering to share exposure. Together they formed HYLC and quite successfully have operated as a joint venture without competing interests. HYLC partnered with leading ICT firms to compile a proposal that would be

competitive and contemporary but most importantly was supported by the facility managers and financiers. A scheme design needed to be prepared in order to price the proposal but with very few price comparators existing it was a challenge to create and accurate price for the proposal. The ICT proposal partners were made up of the following companies:

- HP
- Honeywell
- Schneider
- ServicePoint
- Visionstream

These partners eventually became the subcontractors to design and construct the facility.

3.3. Management System

Subcontractors were chosen for many reasons but mainly due to either; previous experience in a similar projects or existing relationships with Hansen Yuncken and/or Leighton Contractors. With these contractors having different levels of maturity it was vital that a clear set of plans and processes where put in place to facilitate the management of one of the largest ICT investments in Australia. The use of an integrated management system helps to facilitate the accurate measurement, ensure clear roles, responsibilities and accountabilities, throughout the ICT subcontractors,

The implementation of the Florey management model was used as a strategy to clearly establish people's roles within the ICT team. Unlike traditional hierarchy management systems, the Florey management model divides people into tasks groups depending on their role within the project. These individual's groups meet specific mangers to report current status of project aspect. The groups are made up of main and subcontractors with the intention of encouraging collaboration throughout the project.

However, these integrated management systems rely on their adherence in order to reap their benefits. HYLC came into difficulties with the alignment of the two industries (construction and ICT) as they both had different approaches. This resulted in subcontractors veering from the already set and agreed management system/plan. With the variable sizes and maturity of the subcontractors having the one management system/plan was a curial element to executing such a large ICT investment.

HYLC found that although the larger, more global companies had greater resources to place on the project they were already set in their ways and were less likely to change, where's the smaller companies we more willing to change most of the time. In similar future projects the mix of small and large companies would still be encouraged with a larger emphasis and possibly monitoring of sticking the developed integrated management system/plan.

4. Adapting to the use of ICT

In organizational theory, dynamic capability is the capability of an organization to purposefully adapt an organization's resource base. The concept is defined by Teece et al as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments [11]. Reasons why organisations may or may not choose to take on the challenge of adapting to the inclusion of ICT may include the following reasons: the sourcing of skill bases (internal and subcontract team) not previously required and extra associated costs and efficiency gains vs time invested. With the ICT component of the facility being a huge part of the nRAH design it was vital that HYLC had the right subcontractors and diversity of skills within the internal ICT team. HYLC subcontracted out the ICT work to the following specialised subcontractors:

- HP - Integration engine
- ServicePoint – Kiosks, Wayfinding, AV
- Honeywell - Security Technology

- VisionStream - Active network, Unified communication, Wireless location
- Schneider - Building Management System (BMS), Nurse call

Incorporating these companies into the ICT team allowed HYLC to gain expert knowledge of the ICT world and allowed them to prepare and/or gain new staff and/or resources to fill in any gaps within their skill set and management systems. While creating a strong team of ICT subcontractors was important, it was equally important to have a strong and diverse ICT internal team. The team was made up of people with all different backgrounds. Some with an ICT background, some with a construction background and others with an engineering background. HYLC was having to source staff not previously sourced before. Such as, BIM managers and ICT test managers. Having such a diverse team allowed for a better understanding of all areas, especially between ICT and construction as there are many similarities and differences. Although creating a diverse team of subcontractors and internal ICT took extra work, due to the number of unknowns, having a collaborative diverse team working together is one of many factors that lead HYLC to successful completion of the ICT contract and would be strongly encouraged for any future large scale complicated projects.

As like most projects, cost can significantly influence a project. HYLC invested and time into research and development to decrease the risk of failure and also to ensure the highest of quality. With the nRAH being a large long term investment for the South Australian State Government it was imperative that the hospitals design features would be current now but also in current years. To ensure the nRAH has the latest in health care technologies HYLC did a study tour of the best international hospitals/facilities. These standout facilities were mainly found in Scandinavian countries, especially Norway. Two of Norway's were the St. Olavs Hospital in Trondheim and the Akershus University Hospital in Oslo. The Scandinavian hospitals gave the nRAH an international bench mark, it also gave an opportunity to learn from many off the fully equipped hospitals within Australia such as, the Fiona Stanley Hospital in Western Australia. Gathering information on the implementation of ICT systems and failures due to the inability to adapt to the inclusion of ICT systems. The use of the integrated test environment (ITE) was an HYLC came up with to reduce the time of testing and commissioning some of the technology. The facility allowed for the testing of the technology's included within the hospital. Having the ability to set up and test the technology's as it would appear in the hospital reduced the risk of malfunctions during installation. Although this strategy of having a ITE created initial extra cost, long term it saved money and time during installation and commissioning.

Although cost can have an effect, the time invested vs efficiency gained can also deter or encourage contractors to include and/or adapt ICT systems. As Hanson Yuncken or Leighton Contractors had not previously been involved with a contract that required the installation of all ICT systems it was necessary for time to be invested in individual training and research into hardware and/or software that would increase the chance of success. As previously explained, the inclusion of BIM and Aconex enhanced the management systems and the use of iPads with the software 'Dome' installed allowed for easy access to plans while onsite. HYLC's willingness to adapt their management systems through the inclusion of ICT infrastructure, allowed for easier management and completion of unknown ICT factors.

Even with all these possible reasons firms may be resisting the opportunity to adapt to this emerging area due to the effect on the risk profile. Inability to price work confidently due to the lack of current price benchmarks for similar projects, increase a projects risk considerably. This lack of benchmarking also causes difficulty in producing a project program and confidence with project handover, especially due to ICT and construction projects current inability to align with each other. With the inclusion of business process systems within the projects contract this changes the liability for the contractor. This inclusion presents long term risk for the contractor especially if the business process systems is the main supporter of the business.

Adapting to the challenges the use of ICT present to construction firms means there must be a leader within the company or the industry that can visualize what may affect them now and in the future and how they must cater for it. Construction firms need to adapt to changing situations by nature construction firms are reactive, reacting to the changing needs of the project. While ICT firms are less adaptive, more structural, but potentially more proactive in their assessment of unknown risks.

5. Lessons Learnt and Future Directions

The absence of a Prime Systems Integrator (SI) made ICT integration difficult. Given there was no one particular organisation responsible for the integration of the entire hospital, it made handling of issues which stemmed over multiple systems difficult and time consuming for all involved. Having a specialist company or body to manage such responsibilities may have reduced mistakes, extra costs and time.

The effort associated with the use of a BIM was greater than HYLC and subcontractors initially planned. The majority of this extra effort was felt in the LOD300, RCP and LOD500 (levels of development within BIM) processes. It was also suggested that more training and design work needed to be done on BIM in the initial stages of development. The lack of initial involvement from subcontractors, especially within ICT, early in the projects development resulted in departments being one step behind each other. When it came to BIM and Revit a lot of people and individual companies were still learning how to use the programs, as many of them had little to no experience using the programs on large scales projects. This realisation showed how crucial it was for there to be more initial involvement to create a more detailed model, focusing strongly on integration with the hope of reducing isolation from other involved industries to create a design that clearly reflected the briefs requirements.

ICT needs to be treated as part of the construction project, in terms of processes, and not as a separate entity. An integrated approach for planning is also important, to facilitate the completion of the project. In regards to Aconex the main issue was the inappropriate use of the inbuilt email system resulting in a significant amount of ‘SPAM’. The use of the iPads worked well, when they worked, as it allowed the access to plans and building information while on site. Like most technology items, such as iPads, they are extremely useful when they work however, if there are any network problems, such as documents loading errors, users still had to revert back to paper plans and documentations. Trade clashes could have been minimalized if all trades participated in the modeling of services, rather than one party creating the BIM model with little to no input from required trades. Mistakes within the modelled services, such as incorrect sizes, which had major impacts during installation with services clashing with each other, resulting in major reworks. The incorporation of a specific organisation to control BIM may reduce the likelihood of such errors.

Although HYLC’s ICT team was made up of a mixture of industry backgrounds there were issues regarding the contracted ICT workforce involved in the actual construction. Simply inserting traditional ICT workforce make up into a construction project presented HYLC with some safety and HR issues. These issues mainly centered around not all ICT workers having the experience to deliver ICT within a construction environment. This meant that HYLC had to significantly increase their training and increased the need for ongoing observance to reduce and prevent errors by the ICT construction workers.

The priority, attention and support given to ICT requirements was initially very low in comparison to the rest of the facility. The ICT systems did not work in isolation and required big efforts in coordination and communication, as well as collaborative participation from all the stakeholders. With the ICT Industry being more rigorous and controlled with their change management, compared to the Construction Industry, it allowed for good traceability of work, but it led to little flexibility to suit the demands of the construction workforce. This meant significant ongoing effort and relationship building was needed to overcome this with trades having to apply as much if not more attention to the ICT requirements as they would to traditional building engineering services.

All stakeholders (State, SAHP, HYLC, individual ICT subcontractors) use a different language, language in construction vs language in ICT, to describe similar tasks. With not all stakeholders being on the same page this lead to miscommunications and several misunderstandings between the two industries. As there were no clear set language definitions, and no one organisation had cross-organisation authority to resolve the language issue, it cost the project time to resolve issues and gather everyone’s understandings. Terminology is also different for these two industries, so having an agreed vocabulary should be used from the beginning to avoid re-work, especially in management. Both construction and ICT have their weaknesses and could learn from each other’s methods. For example, ICT is very regimented when it comes to roles within the project and documentation, sometimes resulting in ‘tunnel vison’.

Knowing the contract and ensuring appropriate resources are on hand to support the understanding of issues is especially import when dealing with ICT. This is mainly due to the number of unknowns of how ICT characteristics

fit within construction aspects. Making sure there is a formal acceptance of requirements and design needs to be sought from the client, assumed to be the State Government in the case of nRAH, but in some PPP's it is unclear if anybody ever accepts. This is something the ICT industry participants struggles to comprehend.

The relationships and collaboration effort were had a substantial impact on the execution of the project. The collaborative effort between HLYC and other subcontractors was greater than expected creating the drive needed to resolve scope gaps, diversions of responsibility and other task where responsibilities were not clearly defined. The co-locating of team members allowed for easy collaborations of specialist contractors, such as architects and engineers, reducing time spent waiting for aspect confirmation.

The use of the integrated test environment (ITE) was excellent for testing and commissioning of ICT elements and played a significant part it HYLC's ability to produce and install the required ICT systems efficiently. The benefits of the ITE defiantly outweighed the cost and would be encouraged to be used for any large scale ICT projects.

6. Conclusions

The incorporation of ICT in large construction projects, such as hospitals, provided construction firms with great challenges. These challenges create a changing operational environment where construction firms are having to reconfigure their companies to meet the demand of large construction projects, such the New Royal Adelaide Hospital in South Australia. This project provided a case study to investigate the implication of the proliferation of ICT on current construction firms. The case study showed that the successful design and construction of large scale buildings with complex ICT systems, requires successful collaboration strategy and plans for ICT and construction professionals, including various other professionals from engineering, design, construction and IT industries. With these industries working together in new ways, many unfamiliar challenges arose with regards to different management styles, testing and commissioning of ICT elements and ongoing building management. Creating an integrated management system, incorporating an integrated test facility that allowed for offsite testing and commissioning as well as allowing team members to co-locate was a key element to HYLC being able to deliver this large complex ICT project. Although there are many capabilities that HYLC would consider incorporating or doing different in future projects, there are many other capabilities such as the adaption of a management system and the innovation of the integrated test facility that HYLC would reconfigure and implement again and share with the wider construction industry as best and common practice.

Acknowledgements

Acknowledgements to all HYLC staff and contractors for their assistance in taking the time to share their project knowledge, without their efforts many of the project aspects would be unsuccessful.

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