DESIGN, PROCESS, AND SERVICE INNOVATIONS TO ACHIEVE SUSTAINABILITY

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Abstract
Climate change has led to the global recognition of the need to reduce the carbon footprint of buildings. In the UK increasingly demanding building regulations require contractors to use innovative products and processes in their construction processes in order to deliver the specified environmental sustainability performance levels. Cost effective innovative solutions for achieving sustainability in construction requires considerable effort and commitment. As a fragmented and project-based industry, much construction innovation is co-developed at the project level. The major objective of this study is to analyse a construction project by exploring the role of design, process, and service innovations in achieving sustainability. In this respect, the eco-friendly accommodation at Lancaster University has been investigated as a case study. The project presents a case of client-driven innovation where building regulations on sustainability were taken into account in developing design and planning the construction process. The paper discusses the leading role of the university client as well as the role of partnering approach and community engagement in the innovation process. Finally, some recommendations are provided based on the lessons learned in this project.

Keywords: Sustainability, client-driven innovation, design innovation, community engagement.

INTRODUCTION

There have been a number of changes and challenges such as globalization of the business environment; demographic change; environmental sustainability and climate change; new materials and technologies; ICT; and governance and regulation that continue to have a significant impact on the construction industry (e.g., Hampson and Brandon, 2004; Boddy and Abbott, 2010). Foremost among these drivers, sustainability has become an increasing concern for the construction industry due to the fact that construction activities significantly impact on waste, energy use and greenhouse gas emissions. As a response to climate change and its effects on the environment and energy academics, practitioners and governmental bodies have been involved in many discussions and applications to create a low-carbon economy. There has been a growing emphasis on corporate sustainability, which is also reflected by pressure being exerted by clients, government and other stakeholders for the industry to be more accountable for its environmental impacts (Thorpe et al., 2008). Recently issued building regulations such as the Code for Sustainable Homes (CfSH) (DCLG, 2006) in the UK require the contractors to use innovative products and processes in their construction processes in order to deliver the specified environmental sustainability performance levels.

Developing cost effective solutions for achieving sustainability in construction requires considerable effort and commitment to innovation. As a fragmented and project-based industry, much construction innovation is co-developed at the project level. The link between firm level processes and innovation at the project level should be explored to enable a better understanding of how different firms contribute to the innovation process by developing/implementing strategies, assigning resources to create ideas and diffusing them. The major objective of this study is to analyse a construction project by exploring the role of design, process, and service innovations in achieving sustainability. The project analysed is the eco-friendly accommodation at Lancaster University. This student residences scheme was the first replicable scalable model of its kind and was designed to create a social space for the students that would encourage ‘good habits’ in terms of sustainable living. The main innovations observed in the project were within the residences’ bespoke design that adopted the ‘sustainable by design’ concept using offsite manufacture (OSM) driven and enabled through a lean construction approach and community engagement. The project presents a case of client-driven innovation where building regulations on sustainability and user perspectives were taken into account in developing design and planning the construction process.

INNOVATION IN THE BUILT ENVIRONMENT

Innovation may be defined as creation and adoption of new knowledge to improve the value of products, processes, and services (Ozorhon et al., 2010). The construction industry can benefit from the diverse benefits offered by innovation particularly by adoption of new methods to improve processes and organisational effectiveness. According to Lansley (1996), the occurrence of innovation within the construction industry is often characterised by the widespread adoption of new practices as a result of advances in technological and business processes and much of construction innovation is process and organisation-based (Slaughter, 1993). Innovation in construction is co-developed at the project level (NESTA, 2007).

The construction sector is viewed as a system involving clients, contractors, sub-contractors suppliers, consultants, and designers. Clients are seen by many as having a leading role in driving innovation in construction (Brandon and Lu, 2008) although this viewpoint is contested in for example Ivory (2005). Clients can act as a catalyst to foster innovation by exerting pressure on the supply chain partners to improve overall performance and by helping them to devise strategies to cope with unforeseen changes (Gann and Salter, 2000), by demanding high standards of work (Barlow, 2000), and by identifying specific novel requirements for a project (Seaden and Manseau, 2001). Contractors, on the other hand, play a mediator role in the interface between the institutions that develop many of the new products and processes (materials and components suppliers, specialist consultants and trade contractors) and those which adopt these innovations (clients, regulators and professional institutions) (Winch, 1998). Manufacturing firms invest far more in R&D than contractors and are subsequently more likely to develop technology driven product and process innovations (Gann, 1997), whereas in construction successful innovation often requires effective cooperation, coordination and working relationships between the different parties in construction projects (Gann and Salter, 2000; Ling, 2003).

Management of innovation is complicated by the discontinuous nature of project-based production in which, often, there are broken learning and feedback loops (Barlow, 2000). Gann (2001) suggests that project-based construction firms often struggle to learn between projects, and often have weak internal business processes. Measurement of the dimensions and elements of construction innovation at the project level is key to improving the innovation performance of companies. An organisation employ a number of tools, techniques and strategies throughout the whole process and external factors such as drivers, barriers and enablers determine the effectiveness of creation and diffusion of innovation. The link between the processes at organizational level and innovation at the project level should be investigated to gain a full understanding of the drivers and underlying factors of innovation in a project setting.

A research project was carried out by Ozorhon et al. (2010) to investigate the ways in which innovation occurs in a project setting and the dynamics between project and firm level innovation. The research team collaborated with the Centre for Construction Innovation (CCI) Northwest to survey the applicants of the 2009 North West Regional Construction Awards. The awards entrants were chosen as they all believe that they are at the leading edge of construction in the region and were willing to share their innovations, and so the sample should provide an insight into perceived ‘best practice’. The findings of this survey were used to guide the next stage of the research that involved the production of a series of case studies and interviews with key parties in selected projects. The particular case study presented in this paper describes the eco-friendly student accommodation at a UK University that has demonstrated numerous examples of innovation.

CASE STUDY: ECO-RESIDENCES

The eco-friendly student accommodation at Lancaster University is the first replicable scalable model of its kind and was designed as an environment that would encourage ‘good habits’ in terms of sustainable living. It is a successful example of collaborative partnership that achieved affordable sustainability through a series of technical and organisational innovations.

Client and regulations as the drivers of innovation

The project was very notable for the pro-active role of the client, whose drive for sustainable practices were the main drivers of innovative activities. This drive was itself reinforced through energy performance regulation such as the CfSH and specific guidance by Higher Education Funding Council for England (HEFCE). The UK Government’s initiative to create sustainable homes is specified in the CfSH (DCLG, 2006). The code requires contractors to use innovative products in their construction processes in order to deliver the specified sustainable performance levels. Similarly, HEFCE guidance on universities’ environmental performance provides an important benchmark. HEFCE has confirmed that from 2011, all HEFCE capital funding will be subject to Institutional Carbon Management Plans and further, that pursuant to the Climate Change Act, the Higher Education Sector is likely to be set a target of reducing carbon emissions by 80% by 2050.

In addition to the requirements of CfSH and HEFCE guidance, the University's own desire for the adoption of sustainable practices was a major driver for the success of this project. The University recognises the significant environmental impacts associated with its operations and also its responsibility to address these impacts in all areas of its activities through its Environmental Policy and Environmental Management System (EMS). The environmental impact of new or refurbished buildings is very carefully evaluated from conception, through design and construction to operation.

Another key ingredient of successful delivery of this project was the innovative partnership between the University and the developer. The University selected a residential developer as partner to design, build, fund, and manage its eco-friendly accommodation under a unique 48-year contract. This partnership firmly places the emphasis on the use phase of the building and opened the way to the adoption of the 'sustainable by design' concept (Friedman, 2007) in the bespoke design by the architect of the project, which in turn was the result of a more formal collaboration to ensure that the best ideas from around the world are brought into the organisation.

Another business partnership, 'GreenLancaster', was established between Lancaster University Student's Union, the University's Estate Management department, and the residential developer, the aim of which was to help departments across campus promote and deliver environmental initiatives. This has helped increase recycling rates, reduce toxic waste, reduce energy consumption and green the University's supply chain.

Design innovation

The design criteria focused on environmental sustainability, reduced construction and rental costs, enhanced social space, and improved design quality and specification. The key success was to achieve a highly sustainable development at an affordable cost. Affordability has been achieved by looking at the construction process and how the detail design may incorporate features which facilitate construction. The design was mainly based on the work of Professor Friedman (from McGill University, Canada), who is recognised as a world authority on the subject of affordable housing. The key features of this 'sustainable by design' concept focused on a simple design delivering high energy efficiency and heat recovery. The residences have been configured as 4-storey townhouses providing semi-independent, un-serviced accommodation for either 6 or 12 students with a large shared kitchen/dining/lounge space. The key features of this 'sustainable by design' concept are as follows:

- ***Plan:*** The designs are based on the use of modular dimensions which allow the use of building components to their manufactured sizes, such as plasterboard or ply sheets. This speeds the construction process as there is minimum requirement for cutting or fitting of components, and significantly reduced waste generation.
- ***Energy and resource efficiency:*** The design of the building, comprising terraced units is very efficient in terms of site utilisation (good floor to wall ratio), minimization of external surfaces (high levels of energy efficiency), and minimisation of material use. Designed allows the maximum use of natural light, minimising lighting requirements. Low energy fluorescent light fittings are used throughout the buildings with Passive Infra Red (PIR) detectors in communal areas. Water use is minimised by low flow rate fittings and dual flush fittings on toilets.
- ***Sustainability and renewable materials:*** The reduction of waste is central to the concept and the choice of construction materials related to carbon footprint reduction. The BRE 'Green Guide to Specification' is used to inform the choice of materials, and benign

natural materials are used wherever possible to ensure a healthy internal environment. By using timber sourced from sustainable, managed forests for the building's superstructure, the carbon footprint was reduced by one third. Timber frames were also manufactured offsite in order to minimise waste. Recycled construction materials have been used as far as possible in underlying hard-paved areas and floor-pads. Internal fittings such as showers, basins and lavatories are assembled offsite as complete 'pods' improving construction speed and reducing construction impact further.

- ***Heat recovery:*** A passive approach is used to create a very highly insulated, airtight building envelope which requires very little energy for space heating, the major energy load being to generate hot water and this is supplemented by solar thermal panels which are effective and have a relatively short payback period. A heat recovery system operates on the extract ventilation serving the shower/bathrooms, providing warm air into the internal circulation areas; while each room is equipped with a small radiator, controlled by a thermostatic radiator valve and linked to a high efficiency, gas-condensing boiler. Ventilation with heat recovery is primarily whole house mechanical ventilation with heat recovery (re-claiming 70%). Trickle vents and windows that can be opened to provide additional user controllable ventilation. The kitchen cooker extractors switch on and off automatically.
- ***Utility monitoring:*** The eco-residences have a Building Management System (BMS) which constantly communicates utility use to enable the students to monitor their carbon footprint for their townhouse which is calculated from its water, gas and electricity usage. The University also seeks to develop future university estates on the basis of sustainable principles.

Process innovation

In terms of the construction method, closed panel timber frame was the chosen solution to speed up the process and achieve sustainability. Although the systems or products used in the scheme have been used before, the main innovation in this project is that all the various design and construction approaches are brought together in a coherent, holistic housing concept that was both sustainable and affordable. Prefabrication is a major factor in keeping costs and waste to a minimum. Both the structural timber frames and bathroom pods are built off-site and delivered ready for quick installation and connection.

- ***Modern methods of construction:*** Timber frame is a tried and tested structural system. It is widely believed to be the most environmentally friendly form of construction available that conforms to MMC and OSM principles. BRE reported that that modern timber frame construction produces near zero carbon emissions (Reynolds and Enjily, 2005). Timber frame is also renowned for its excellence in energy efficiency terms. As the structures are assembled from components made to manufacturing tolerances, the better fit achieved improves air tightness and hence positively effects energy efficiency. The closed timber frames were used as the structural elements of the superstructure in the project among the many forms to choose from, including advanced and closed panel, volumetric, and hybrid systems.

  To gain the potential benefits of MMC required tighter, more reliable processes which lead to the adoption of lean principles. The lean approach meant that construction could be completed well ahead of schedule due to the unexpectedly quick insallations of the timber frames. Just in time (JIT) deliveries were fundamental to maintaining the construction programme. Lean construction is "the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and the pursuit of perfection in the execution of a constructed project" (Design for Manufacture Competition, 2005). The adoption of MMC through a lean approach required more time in the design and planning phases, but this attention to detail minimised conflicts that can dramatically change budgets and schedules. Standardisation of the finishing processes brought benefit to the supply chain, reducing wastage of materials on site as well as wasted operations.

MMC and lean construction involved different mindsets and operations that were initially threatening to members of the supply chain. Seminars and project meetings were held at an early stage with regard to the process approach and construction technology involved both to give confidence and exchange knowledge. 'Toolbox talks' were initiated with the workforce of the various supply chain partners to ensure requirements were properly implemented on site. Many detail design or construction issues incorporated in the scheme have been adopted by supply chain members as general practice moving forward.

Service innovation

The project was also notable for its use of a 'user-driven' approach to successfully deliver the environmental performance levels. The university aimed to create a social space for the students that would encourage 'good habits' in terms of sustainable living. The end user requirements were an important component of the scheme and so engagement with students began at an early stage in the design process. This aspect is considerably strengthened by the measures that are in place to monitor and provide information on energy use as a means of directly involving the students with the ongoing operation of the building. Following completion, further engagement on obtaining and addressing initial feedback from new residents was also critical. Initial resident feedback has been very positive. General comments of the students have included: 'probably the best accommodation you will live in as a student', 'light, airy and clean', 'very sociable', 'good space for a family'. This stakeholder participation model will also be used in future student residence developments.

GreenLancaster had a central role in the environmental initiative of the University. They have generated jobs for students, as well as raising the profile of environmental issues amongst staff and students. A carbon competition was launched in the University's eco-residences to motivate the students to be more environmentally conscious. This was set-up in conjunction with GreenLancaster to promote and incentivise reduced energy and utilities use, and reward the townhouses with the lowest resultant carbon footprint. Students could log onto the competition website to view the carbon footprint and utility use for their house in real-time, as well as check on who is winning. By this way, carbon emissions were reduced by 11.3% for January-April 2009 compared with the same period in 2008, when there was no carbon contest. Students achieved this by taking some simple actions such as switching off the TV at the mains, not leave anything on standby, half-filling the kettle, cooking together, and filling up the washing up bowl instead of running the tap.

Achievements of the project

Significant financial, environmental and social benefits have been achieved for both the University and student residents. A key benefit is expected to be reputational, with Lancaster University being seen as a leader in terms of environmental design and construction, but also in terms of stakeholder and end user participation in development and input into the eco-residences design and concept. External recognition and interest in the project has been very significant. Estates Department Directors from many universities have toured the eco-residences developments. The following details some of the main achievements of the project in use compared to the previous phase:

- The cost of a student room was decreased by 7%, while rent charged to the students dropped down by 15%.
- Gas consumption is anticipated to reduce by 5-10% per student room.
- Carbon emission is predicted as 963kg CO_2/annum/student compared to the design target of 1,147kg CO_2/annum/student based on the Building Regulations.
- The transport linkages from the eco-residence developments have been carefully designed to minimise transport impacts. They are provided with excellent pedestrian linkages to the main pedestrian walkways.

CONCLUSIONS

Climate change and environmental sustainability has become a central issue for construction practitioners, policy makers, and academics worldwide. Key to this is energy efficiency and carbon reduction in buildings and as such the construction industry contributes to a large proportion of carbon emissions. The case study shows that environmental sustainability through the construction value chain can be achieved by a strong commitment to deliver innovative solutions. Due to the project based nature of construction, innovation requires a joint effort throughout the project life cycle.

In this paper, a case was analysed to exploring the role of design, process, and service innovations in achieving sustainability by investigating the role of key parties. The eco-residences project of Lancaster University was examined, where a client and regulation led innovation approach was observed with building regulations and HEFCE guidance on sustainability taken into account in developing design and planning the construction process. The University's devotion and investment in environmental issues played an important role in the design, construction, and operation of the residences. The conditions that created the commitment to a through-life solution were threefold. Firstly, the university client had wider aspirations to engender behaviour change amongst the users of its estate. Secondly, the developer's business model included a novel financial relationship that depended not only on efficient construction of the residences as a product but on their through-life use. Thirdly, the developer was using this development as a pilot in order to deliver similar schemes to universities throughout the UK with declining capital budgets. Thus, the additional investment in design for construction informed by end-users would be repaid over and over again in future projects that would be informed by data of performance in use. Although the paper is based on the achievements of a single project executed in the UK, it is expected to shed light on similar future work on investigating innovative activities in collaborative environments in different countries.

REFERENCES

Barlow, J., 2000. Innovation and learning in complex offshore construction projects. *Research Policy*, 29(7-8), pp. 973-989.

Boddy, S. and Abbott, C., 2010. *Review of CIB Collected Outlook Reports*. Rotterdam: CIB.

Brandon, P. S. and Lu, S.L., 2008. *Clients Driving Innovation*. Chichester, West Sussex: Wiley-Blackwell.

Department for Communities and Local Government (DCLG), 2006. *Code of Sustainable Homes - A Step-Change in Sustainable Home Building Practice*. London: Department for Communities and Local Government.

Design for Manufacture Competition, 2005. *Stage 1 Q&As answer 51*. Retrieved November 10, 2009 from www.designformanufacture.info/page.aspx?pointerid=307FE1A776AD4E8D8AC46662DF7FDA56#q51.

Friedman, A., 2007. *Sustainable Residential Development: Planning and Design for Green Neighborhoods*. New Yok: McGraw-Hill.

Gann, D.M., 1997. Should governments fund construction research? *Building Research and Information*, 25(5), pp. 257-267.

Gann, D.M., 2001. Putting academic ideas into practice: technological progress and the absorptive capacity of construction organisations. *Construction Management and Economics*, 19 (3), pp. 321-330.

Gann, D.M. and Salter, A., 2000. Innovation in project-based, service-enhanced firms: the construction of complex products and systems. *Research Policy*, 29(7-8), pp. 955-972.

Hampson, K.D. and Brandon, P.S., 2004. *Construction 2020: A Vision for Australia's Property and Construction Industry*. Brisbane: Cooperative Research Centre for Construction Innovation.

Ivory, C., 2005. The cult of customer responsiveness: is design innovation the price of a client focused construction industry? *Construction Management and Economics*, 23, pp. 861-870.

Lansley, P., 1996. Innovation: the role of research, education and practice. *Construction Papers*, No. 59, Ascot: CIOB.

Ling, F.Y., 2003. Managing the implementation of construction innovations. *Construction Management and Economics*, 21, pp. 635-649.

NESTA (National Endowment for Science, Technology and the Arts), 2007. *Hidden Innovation*. London: NESTA.

Ozorhon, B., Abbott, C., Aouad, G. and Powell, J., 2010. *Innovation in Construction: A Project Life-Cycle Approach*. Salford: University of Salford.

Reynolds, T. and Enjily, V., 2005. *Timber Frame Buildings - A Guide to the Construction Process*. Berkshire: Building Research Establishment Press.

Seaden, G. and Manseau, A., 2001. Public policy and construction innovation. *Building Research and Information*, 29(3), pp. 182-196.

Slaughter, S.E., 1993. Builders as sources of construction innovation. *Journal of Construction Engineering and Management*, 119(3), pp. 532-549.

Winch, G., 1998. Zephyrs of creative destruction: understanding the management of innovation in construction, *Building Research and Information*, 26(5), pp. 268-279.