Published in Proceedings of IBEA Conference, Innovation and the Built Environment Academy, 7- 9th October, 2011, London South Bank University.

Construction Innovation: The Implementation of Lean Construction towards Sustainable Innovation

Ogunbiyi, O., Oladapo, Adebayo Akanbi and Goulding, Jack Steven

School of Built & Natural Environment, University of Central Lancashire' Corporation Street, Preston, PR1 2HE, United Kingdom

Abstract

The prevalent theory of construction has been seen as a hindrance to construction innovation. The concept of lean construction is concerned with the application of lean thinking to the construction industry. However, in lean construction there are many arguments supporting the view that 'the prevalent theory of production (or specifically, theory of construction) is counterproductive, and leads to added costs and reduced overall performance through the deficient production control principles based on the theory'. Presently, the construction industry and all other organisations face various problems as a result of the uncertainties of the global economic climate; including labour redundancies, delayed projects and zero margin contract bids. The construction industry is seen as one of the worst performing industry as regards innovation. This calls for concern about the poor state of construction innovation. The emergence of lean construction is to bring significant reform to the construction industry to achieve the objectives of sustainability within the built environment in the critical social, economic and environmental aspects. Increasingly, lean construction offers new techniques of constructing sustainable projects. It is about reducing costs by cutting waste, innovating by engaging people and organising the work-place to be more efficient. Hence, the aim of this paper is to highlight the cost and benefits of the potential contribution of lean construction to the attainment of sustainable innovation in construction. An exploratory method of investigation is adopted in achieving the aim of this paper by critically reviewing, exploring, and synthesising literature and industry case studies related to the subject matter. Evidence from the literature reveals that innovation through lean improvement in construction processes has provided proof of sustainability outcomes in terms of reduced waste, effort and time. Hence, lean

construction impacts significantly on innovation by enhancing competitiveness, innovativeness, and resource efficiency within the construction industry.

Keywords: Construction industry, Construction innovation, Lean construction, Sustainability

Introduction

Construction industry has been tagged with a poor record of innovation when compared with manufacturing industry. In the UK, the Department of Trade and Industry (DTI, 2007) stated that innovation is "the successful exploitation of new ideas" and that "it is the key business process to compete effectively in the increasingly competitive global environment". Innovation in construction is 'the act of introducing and using new ideas, technologies, products and/or processes aimed at solving problems, viewing things differently, improving efficiency and effectiveness, or enhancing standards of living' (CERF, 2000). This means that innovation can be of two types; namely, change in the product or service being provided, and change in the process by which the product or service is created. However, organisation's ability to promote both process and product has been argued to be no longer sufficient and a third type of innovation has been introduced as strategy innovation (Baker, 2002).

According to Sturges et al (1999), construction faces the challenge of minimising the environmental impact of its consumption of materials and energy; therefore there will be need to become more innovative to meet this challenge. However, complexities within the construction industry make introducing these innovative technologies difficult. For example, each technology may have to be compatible with numerous parties and the residential-construction industry contains a particularly high degree of uncertainty in innovative product adoption (Koebel, 2004; Conference Board of Canada, 2004). The result of the Third UK Community Innovation Survey (DTI, 2004) showed that the construction industry was the worst performing industry in five out of six categories of innovation compared to 11 other industry. This calls for concern about the poor state of innovation, as shown in Table 1.

Table 1- Percentage of construction companies exhibiting innovative activities (Source: DTI, 2004)

Innovative activity	Construction	All industries

Product innovation	6%	18%
Process innovation	6%	15%
Long term activity	3%	9%
Co-operation	7%	8%
Innovation expenditure	27%	36%

Lean construction approach of construction project delivery is aimed at eliminating waste by removal of all non-value adding activities; it's concerned about the environmental management as well as the social and economic aspect of sustainability. Even though innovation has been seen from diverse perspective, researchers and practitioner have agreed on the importance of innovation as a pre-requisite for competitive advantage (Egbu and Ilozo, 2007).

Methods

The methodology adopted in this paper is the review of relevant literature and industry case studies relating to lean construction implementation and sustainable innovation. In-depth exploration and review of research publications on lean construction implementation and innovation was carried out on origin of lean thinking in construction, history of innovation within construction, and impact of lean construction on sustainable innovation.

Innovation history in construction context

According to Koebel and McCoy (2006), researches on innovation have failed to establish standard definitions of associated terms and practices, thus creating confusion. So, innovation is a complex phenomenon which has long history in the literature. The organisation's ability to respond and adapt to external and internal changes have been addressed by early research. Koskela and Vrijhoe (2000) analysed the prevalent theory of construction production from innovation point of view and emphasised the need for more innovation in construction industry.

However, according to Koskela and Vrijhoe (2000), there are many argument in lean construction supporting that 'the prevalent theory of production (or specifically, theory of construction) is counterproductive, and leads to added costs and reduced overall performance through the deficient production control principles based on the

theory'. Different types of innovation according to Slaughter (1998) are presented in Table 2 below. Koskela and Vrijhoe (2000) further argued that the incremental and modular innovations are the most frequent in construction.

Table 2: Types of Innovation

Types of Innovation	Explanation
Incremental	Small change with limited impacts on surrounding elements.
Modular	More significant change in the basic concept, but also with limited impact on its surroundings.
Architectural	May consist of a small change in the respective component, but with many and strong links to other surrounding components
System	Consist of multiple linked innovations
Radical	A radical innovation is based on a breakthrough in science or technology and changes the character of the industry itself

Sustainability vs Sustainable innovation

According to de Sousa (2006), innovation can be defined as the outcome of a set of activities that use knowledge to create new value to those benefiting from its use. The keyword here is the creation of new value to those using the innovation. This distinguishes innovation from invention in that innovation is not so much the novelty of a given product or process but the creation of new value to those using the innovation.

According to the Pulse Survey Report of Towers Perrins (2008), there are three factors that can engender sustainable innovation:

1. An understanding that innovation has both external (market-facing) and internal (process and structure) components that must work in tandem and require different organisational competencies.

2. Leadership commitment to the internal side of innovation and to building and sustaining a ''machine.''

3. Recognition that different groups in the organisation enter and exit the innovation process at different points in time and in different ways. Alignment between

what is required in each phase and related organization capabilities and resources is essential to turn ideas into reality.

Barrett and sexton (2006) stated that there appears to be an ongoing shift from viewing innovation as an 'end' in itself, to innovation being a 'means' to achieve sustainable competitiveness. An organisation's innovation capability is defined as its ability to mobilise the knowledge possessed by its employees (Kogut & Zander, 1992), and combining this to achieve product or process innovation. Usually, innovation is seen as the conceptualisation of a new product or service, but this is not necessarily always the case. Conversely, Bowonder et al. (2010) argued that a form of innovation was also the introduction of the lean production system in the automotive industry, or even forming collaborative partnerships with suppliers or competitors was a form of innovation when it first occurred.

Hovgaard and Hansen (2004) stated that innovativeness can be manifested in the form of new products, new processes, or new business systems. Example of this is the adoption of an existing technology or product by a company or newness to the market as in the case of an invention (Crespell and Hansen, 2008). Even though doing business in an environmental sound way is often associated with additional costs, there are many driving factors for construction industry to engage in sustainability. The improved corporate image derived from offering a sustainable product is one of the driving factors (Yu and Bell, 2007). Cost savings generation and need to achieve a competitive advantage are other motives (Simpson et al. 2004; Masurel, 2007).

Lean thinking in construction

Lean construction is the application of lean thinking to the design and construction process creating improved project delivery to meet client needs and improve profitability for constructors. It places 'optimising the total value' instead of 'minimising the cost' as the main goal. Within lean, cost cutting has to be seen in perspective of eliminating non value adding activities (Womack and Jones, 2003). According to Höök and Stehn (2008) the adoption of innovative management practices, such as supply chain management and lean thinking, from a manufacturing context (based on continuous processes and relationships) to the discontinuous and project-based construction industry is, however, problematic.

Eriksson (2010) carried out a study on how to increase the understanding of how various aspects of lean thinking can be implemented in a construction project and how they affect supply chain actors and their performance. The core elements of lean construction are investigated reflecting how the various aspects of lean construction can be grouped into six core elements: waste reduction, process focus in production planning and control, end customer focus, continuous improvements, cooperative relationships, systems perspective.

Lean construction and Sustainable construction

There is a growing awareness of the need for sustainability within construction process; similarly, there have been an increased awareness of the implementation of lean construction. These issues have been raised for discussion in the extant literature. Several studies have established the benefits of lean construction in achieving the sustainability objectives in the critical aspect of environmental, social and economic. Huovila and Koskela (1998) state that sustainable construction is the response of the building sector to the challenge of sustainable development. The term 'green', and 'sustainable' construction are often used interchangeably. Sustainable construction does not only refer to the buildings and spaces themselves but also the processes or activities used to construct them (Presely and Meade, 2010). Thus, sustainable construction can be defined as a construction process which is carried out by incorporating the basic objectives of sustainable development (Asad and Khalfan, 2007; Parkin, 2000).

According to Sjöström (1998), construction, buildings and infrastructure are the main consumers of resources: materials and energy. In the European Union, buildings require more than 40 % of the total energy consumption and the construction sector is estimated to generate approximately 40 % of the man-made waste. However, the construction industry is bound to bring about positive changes, with the implementation of sustainable construction i.e. less pollution and waste, and even contributes to the well-being of future generations (Said et al, 2011). Sustainable development is a term generally associated with the achievement of increased techno-economic growth coupled with preservation of the natural capital that is comprised of environmental and natural resources. It requires the development of enlightened institutions and infrastructure and appropriate management of risks, uncertainties, information, and knowledge imperfections to assure intergenerational equity, and conservation of the ability of earth's natural systems to serve humankind (Sage, 1998). It was noted by the

Sustainable Construction Task Group (SCTG) in its *Reputation, Risk and Reward* report published in 2002, that pressures on businesses in the property and construction sectors to respond to the sustainability agenda were increasing from the environmental, social, governmental, and investment sectors (SCTG, 2002). Sustainable construction has evolved as the industry seeks alternative environmental ways to fulfill current levels of consumption (Presely and Meade, 2010). The business benefits of sustainable construction were considered by the CIRIA Report C563 (CIRIA, 2001). This revealed that adopting a sustainable approach would address the failings of the construction industry identified in the Egan's report *Rethinking Construction,* (DETR, 1998b), and lead to significant business benefits, including better understanding of client needs, identification of opportunities for innovation, increased shareholder value, reduced costs, reduced risk, enhanced public relations and community liaison, and increased employee motivation. This shows that becoming more sustainable is as much about efficient, profit-orientated practice, achieving value for money, helping society, and protecting the environment.

Impact of Lean construction on Innovation

The effect of lean practices on an organisation competitiveness have been carried out by Lewis (2000) using industry case studies. Two out of the three case studies conformed to the hypothesis that lean practices will result in an overall decrease in organisation's innovativeness while one of the companies maintained an innovative process while applying some lean concepts. Based on the study it was disclosed that the more successful lean principles are applied in an organisation, the more focused the organisation tends to be on incremental production changes, and the less innovative activities are involved. Consequently, another study was carried out by Christensen (2006) to investigate innovations that sustain or disrupt a company's existing competitive advantages. It was established that a sustaining innovation improves existing products along the dimensions of performance that the main stream customers value while on the other hand, a disruptive innovation underperforms in most desired areas by the main stream customers for at least short terms, but offers other valuable features.

In the review of three case studies on lean principles for rapid construction carried out by Yahya and Mohamad (2011), the benefits from lean principles into rapid

construction were highlighted as including the shortening of order fulfillment leading times, less project downtime, more innovation, and true reduction in the chronicle predecessor.

Case study 1: (Source: Constructing Excellence by Watson, 2004)

In construction excellence by Watson (2004), the Neenan Company, a design and build firm was identified as one of the fastest growing and most successful construction companies in Colorado. The firm has worked to understand and apply lean construction principles to its business, resulting in reduced project times of up to 30%. The changes were attributed to developments such as:

1. Facilitation of innovation in design and assembly for example via the use of off-site manufactured pre-fabricated bricks.
2. Improvement in site work flow by proper definition of production units, and visualisation of processes
3. Use of dedicated design team on any design from beginning to end.

Case study 2: (Source: Construction in Fortaleza, Brazil by Jose and Alves, 2007)

In the case study of Construction in Fortaleza, Brazil carried out by Jose and Alves (2007), Ceara State Brazil (a construction company in Fortaleza) adopted lean concepts and tools for innovation based on the work of the Lean Institute, Brazil. This was in the early years of the 21st century, and the initial implementation was supported by academics and experienced consultants. The implementation translated into fast and huge productivity gains for the company, and led to organisation of international seminars and events (International Seminar of Lean Construction 2004, 2006) about innovative practices in lean construction, which raised the interest of local and national construction companies.

With time, it became established and glaring that adoption of lean principles facilitated the progress of companies, sustains the innovative practices that have been introduced and implemented, and engenders the introduction of new ones. The inability of some companies to sustain the benefits arising from the use of lean construction

principles this way was attributed to lack of integration of lean construction implementation within their business strategy.

Case study 3: (Source: Shepherd Construction in CIRIA, 2009)

In the case study of the difference introduced via lean construction in practice, Shepherd Construction adopted and implemented lean construction in the development of the company's sustainability strategy, waste management procedures, lean construction and resource efficiency practices, and the ISO 9001 and ISO 14001 registered quality and environmental management systems.

The company's *view* of lean construction is elimination of all forms of waste and inefficiency from the construction delivery process while sustainable construction is seen as building the present without compromising the future. Collaborative planning is at the centre of the company's *lean approach* with aim of eliminating unnecessary work and maximising value adding work. Tools and tasks set in place to achieve the lean approach include programming workshops, process mapping, standardized work, workplace organisation, problem solving, data analysis, work sequence analysis, and visual management. The sustainable approach to Shepherd's activities is demonstrated through the triple bottom line of sustainability which is the social, environment, and economics. The links between lean and sustainability are clearly demonstrated in work processes of Shepherd Construction (See Figure 1 below) as there is direct integration of the essences of lean construction with construction sustainability. Thus, lean construction and sustainable construction run concurrently within the company and has led to happier stakeholders, supply chain, and environment.

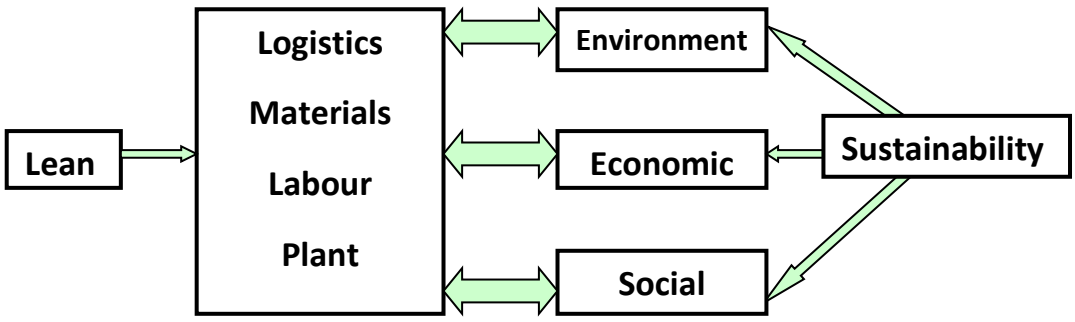

Figure 1: Shepherd's link between lean and sustainability (Source: CIRIA 2009)

Results and Discussion

It has been established through review of existing literature that lean construction contributes to the attainment of sustainable innovation in construction by means of innovation through lean improvement in construction processes. Likewise, review of industry case studies has shown that implementation of lean construction principles facilitates company's progress and engenders sustainable innovation practices in construction design and assembly. Even though the prevalent theory of production (or specifically, theory of construction) is seen as counterproductive, leading to added costs and reduced overall performance, the huge positive impact of lean implementation on sustainable innovation within construction have been quantified and provided proof of sustainability outcomes in terms of reduced waste, effort and time. With Lean construction, there is achievement of more for less by continuous reduction of waste in the construction process.

Conclusion

The lean principles/concepts have been identified and how lean construction impact on innovation towards a sustainable development. The concepts of sustainable construction have also been discussed reflecting the three aspect of sustainable development which are the environmental, economic and social sustainability. However, companies implementing lean construction tools and practices from an operational stand point are unable to sustain its use or derive maximum benefits from lean construction implementation since its practice is not grounded on a solid basis i.e. in their business strategy. To overcome this barrier, bridge the gap, experience the streams of benefits from lean thinking, and sustain the innovative practices within construction, there is need to integrate lean construction principles and tools within the company's business strategy.

References

Asad, S. and Khalfan, M.M.A. (2007). Integration of Sustainability Issues Within Construction Processes, Emirates Journal for Engineering Research, 12(2).

Baker, K. A. (2002). Innovation. http://www.au.af.mil/au/awc/awcgate/doe/benchmark/ch14.pdf, accessed 25/07/2011

Barrett, P. and Sexton, M. (2006) Innovation in Small, Project-Based Construction Firms, British Journal of Management, Vol. 17.

Bowonder, B., Dambal, A., Kumar, S., Shirodkar, A. (2010). Innovation strategies for creating competitive advantage. *Research-Technology Management*, 53 (3)

CERF (2000). 'Guidelines for Moving Innovations into Practice', Working Draft Guidelines for the CERF International Symposium and Innovative Technology Trade Show 2000. CERF, Washington, DC

Christensen, C. M. (2006) *The Innovator's Dilemma*, HarperCollins Publishers, New York

CIRIA (2001), 'Sustainable Construction: company indicators'. Report No. C563, Published in the UK.

CIRIA (2009). Lean Construction for Sustainable Business, Members' Report E9201, Joint CIEF and CPN seminar held at the Centre for Construction Innovation, CUBE, 113-115 Portland Street, Manchester M1 6DW

Conference Board of Canada (2004), *Sixth Annual Innovation Report – Progress Report*, The Canada Project, Ottawa

de Sousa, M. (2006). The Sustainable Innovation Engine, VINE: The Journal of Information and knowledge Management Systems, Vol. 36, No.4

DETR. (1998). Rethinking Construction: The Report of the Construction Task Force.

DTI (2004) "Detailed Results from the Third UK Community Innovation Survey" *(Available at: http://www.dti.gov.uk/iese)*, accessed 25/07/2011.

DTI (2007), *Innovation in Services*, Department of Trade and Industry, London.

Egbu, C. O and Ilozo, B. D. (2007). Construction Clients and Industry Innovation: an Understanding of their roles and impact. CIB World Building and Congress. Engineering and Management, 124 (3).

Eriksson, P. E. (2010) "Improving construction supply chain collaboration and performance: a lean construction pilot project", Supply Chain Management: An International Journal, Vol. 15 Iss: 5

Hongi Chen, R. (2009). Exploring the impact of lean management on innovation capability Proceedings of PICMET, August 2-6, Portland, Oregon USA

Höök, M., Stehn, L. (2008), "Applicability of lean principles and practices in industrialized housing production", *Construction Management and Economics*, Vol. 26 No.10.

Hovgaard, A., and E. Hansen. 2004. Innovativeness in the forest products industry. Forest Products J. 54(1).

Huovila, P. and Koskela, L (1998). The contribution of the principles of lean construction to meet the challenges of sustainable development, Proceedings of the International Group for Lean Construction-6, Guaruja.

Jose, P.B.N. and Alves, C.L. (2007). Strategic Issues in Lean Construction Implementation. Proceeding of IGLC-15, Michigan, USA.

Katayama, H., & Bennet, D. (1996). Lean production in a changing competitive world: A Japanese perspective. International Journal of Operations and Production Management, Vol. 16, Issue 2.

Koebel, C.T. (2004), "Residential construction diffusion research for the NSF-PATH program", in Syal, M., Hastak, M., Mullens, M. (Eds),*Proceedings of the NSF Housing Research Agenda Workshop, February 12-14, Orlando, USA*,

Koebel, C.T., McCoy, A.P. (2006), "Beyond first mover advantage: the characteristics, risks and advantages of second mover adoption in the home building industry", paper presented at the American Real Estate and Urban Economics Association Meeting, Washington, DC, .

Kogut, B. and Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. Organization Science, 3, 383–397.

Koskela, L. & Vrijhoef R. (2000). *The Prevalent Theory of Construction is a Hindrance for Innovation*, http://www.leanconstruction.org/pdf/25.pdf accessed 27/07/2011

Lewis, M. A. (2000). "Lean production and sustainable competitive advantage," *International Journal of Operations & Production Management*, Vol. 20, No. 8. London: Dept. of the Environment, Transport and the Regions.

M. A. Lewis, M. A. (2000). Lean production and sustainable competitive advantage, International Journal of Operations & Production Management, Vol. 20, No. 8.

Masurel, E. (2007). Why SMEs invest in environmental measures: sustainability evidence from small and medium-sized printing firms. *Business Strategy and the Environment*, 16.

Parkin, S. (2000). Context and drivers for operationalizing sustainable development. Proceedings of ICE Civil Engineering Journal, Vol. 138.

Presley A., Meade L. (2010) "Benchmarking for sustainability: an application to the sustainable construction industry", Benchmarking: An International Journal, Vol. 17 Iss: 3.

Sage, A. P. (1998) Risk management for sustainable development, IEEE International Conference on Systems, Man and Cybernetics, Vol. 5.

Said, I. Osman, O. Shafiei, M.W.M., and Kooi, T.,K. (2011). Modelling of Construction Firms Sustainability, Journal of Global Business Management, Vol. 7.

SCTG, (2002). Reputation, Risk and Reward: the business case for sustainability in the UK property sector. The Sustainable Construction Task Group, January 2002. Available at http://projects.bre.co.uk/rrr/RRR.pdf, accessed 20/07/2011.

Simpson, M., Taylor, N., Barker, K. (2004). Environmental responsibility in SMEs: does it deliver competitive advantage? *Business Strategy and the Environment*, Vol. 13

Sjöström, C. (1998). *CIB World Congress. Construction and the Environment*. Väg- och

Slaughter, E.S. (1998). "Models of construction innovation." Journal of Construction

Sturges, J. L., Egbu, C.O. and Bates M. B. (1999) Innovations in Construction. Construction Industry Development in the new Millennium. Proceedings of the 2nd International Conference on Construction Industry Development, and 1st Conference of CIB TG 29 on Construction in Developing Countries, The Pan Pacific, Singapore.

Towers, P. (2008). The "Art" of Successful Innovation: It's all in the Implementation. http://www.towersperrin.com/tp/getwebcachedoc?webc=USA/2008/200807/LeadershipInnovation_Pulse.pdf, accessed 28/07/2011

Watson, M. (2004). Constructing Excellence. Construction Lean Improvement Programme, Lean Institute, UK.

Womack, J. and Jones, D. (2003). "*Lean Thinking: Banish Waste and Create Wealth in your Corporation*". Revised and updated edition. Simon & Schuster Ltd, UK.

Yahya, M. A. and Mohamad, M. I. (2011). Review on Lean Principles for Rapid Construction, *Jurnal Teknology*, 54.

Yu, J., Bell, J.N.B. (2007). Building a sustainable business in China's small and medium-sized enterprises. Journal of Environmental Assessment Policy and Management, Vol. 9, Issue 1.