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OGUNBIYI, O.E., OLADAPO, A.A. ORCID: 0000-0001-7094-7951 and Goulding, Jack Steven A REVIEW OF LEAN CONCEPT AND ITS APPLICATION TO SUSTAINABLE CONSTRUCTION IN THE UK. International Journal of Sustainable Construction Engineering & Technology .

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A REVIEW OF LEAN CONCEPT AND ITS APPLICATION TO SUSTAINABLE CONSTRUCTION IN THE UK

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Received 18 June 2013; Revised 26 September 2013; Accepted 6 November 2013

Abstract

The UK Government has recognised the importance of the construction industry in achieving the overall goals of sustainable development. Therefore the Government has put several policies and strategies in place to achieve a more sustainable construction. Sustainable construction is considered as the application of sustainable practices and sustainable development principles to the activities of the construction sector. Lean construction is a new production philosophy which has the potential of bringing innovative changes in the construction industry. The Lean principles focus on the minimisation of both material and process wastes which in turn contribute to sustainable construction in terms of energy consumption and improvement in health and safety etc. This study aims at exploring the concept of sustainable construction and examines how the lean approach can impact on the sustainability practices within the construction industry. The study uses literature review to achieve the stated aim. The findings revealed that the application of lean construction principle, tools and methods have direct contributions to the attainment of sustainable practices within the construction industry. However, the study postulates that the better understanding of lean concept, proper implementation and integration of lean and sustainability concepts are required for lean construction to contribute to sustainable construction.

Keywords: Lean construction, Sustainable Construction, Sustainability

1.0 Introduction

The UK construction industry is noted for its economic contribution with an output worth over £100billion a year. It provides employment for over three million workers and accounts for eight per cent of gross added value [1]. Nonetheless, the construction industry is also noted for its poor safety record evident from high rate of accidents on construction sites leading to workers injury or loss of lives [2]. This suggests the reason why more attention is paid to the sector. However, there are other benefits to be gained from a more sustainable construction industry. The adoption of a sustainable approach was suggested to lead to important business benefits and address the shortcomings of the construction industry identified in the Rethinking Construction report. This reflects that becoming more sustainable could lead to efficiency, profit-orientated practice and achieving value for money, as it is about helping society and protecting the environment. There is a growing awareness as to the competitive advantages that can be convened by businesses taking a sustainable approach [3].

Lean construction is a new production philosophy which has the potential of bringing innovative changes in the construction industry. The concepts and principles of lean is to generally make the construction process leaner by removal of waste which is regarded as non-value generating activities [4]. The removal of waste (process and material) and value generation in terms of adding value to the customer are the major contributions of lean construction to sustainable development [5]. This is achieved by the use of lean principles: pull system, flow, value stream mapping, continuous improvement and involvement of employees.

There are several key factors to be taken into action by the construction industry. These factors have been suggested by the UK Government in its strategy for more sustainable construction [6]. These factors include:

1. Design for minimum waste
2. Aim for lean construction
3. Minimum energy in construction and use
4. Pollution reduction
5. Preservation and enhancement of biodiversity
6. Conservation of water resources
7. Respect for people and local environment
8. Setting targets
9. Monitoring and reporting in order to benchmark the performance

Among several factors, the lean construction principles will be focused on, as the main area of this study is to critically review the concept of Sustainable Construction (SC), and examine how the application of lean principles can impact on the sustainability practices within the construction industry. Accordingly, this study pulls from two main bodies of literature: i.e. the literature on sustainable development and lean construction in the broader context of the construction industry (see Figure 1). As earlier mentioned, the construction industry is considered as a key sector for achieving sustainable development goals because it plays a vital role in the drive to promote sustainable growth and development.

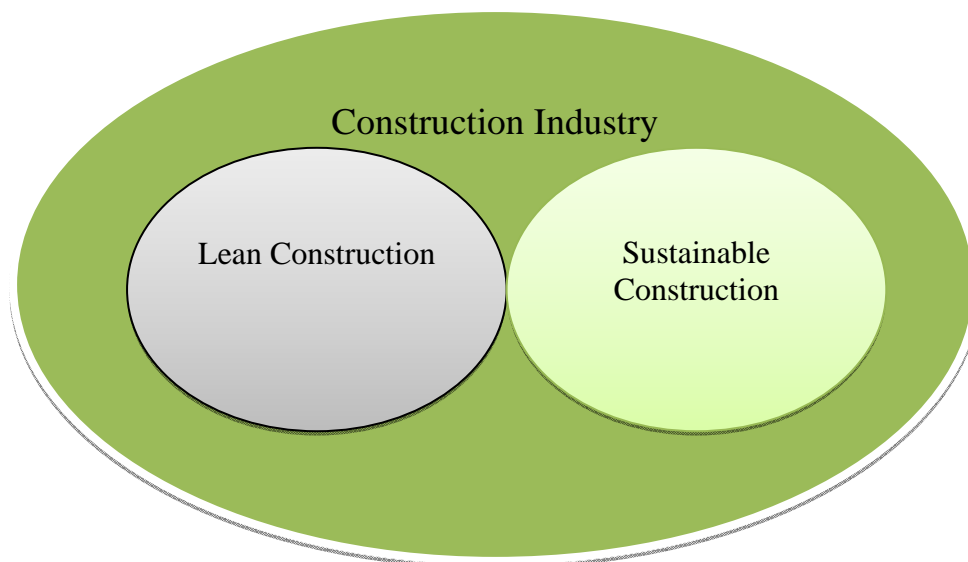


Figure 1: Literature review focus

The potential of lean to contribute to sustainable construction has been raised for discussion [5]. Therefore, it is of utmost importance to examine the possibilities of lean contributing to sustainable construction. Several studies have been carried out on lean and its application within construction at project level with great benefits achieved and there are many studies that have investigated lean construction and sustainability separately [7, 8]. However, studies that highlight the contributions of lean construction towards sustainability are few. The insufficiency of literature addressing this issue and the absence of research-based papers are assumed as a lack of awareness of the potential of lean construction as a means of achieving sustainability and an unrecognised relationship between sustainability and lean construction objectives. For instance, Forbes et al.[9] proposed a framework for providing technical support for lean methods application in some environments in developing countries. Sacks et al. [2] developed a research framework for analysis of the interaction between lean and BIM. However, there has been little or no study done to look at the impact of lean on sustainable construction in terms of developing a framework at the organisational level. Against this background, this study aims to examine the contributions of the implementation of the lean approach in sustainable construction.

2.0 Sustainable Construction

It is difficult to describe sustainable construction without defining or describing sustainable development. There are several definitions of sustainable development given in the literature [10, 11]. Sustainable development is a broad concept which has been adopted and interpreted in numerous contexts. For example many authors have seen the concept as vague and fuzzy [12, 13]. According to Sage [14], sustainable development refers to the fulfilment of human needs through simultaneous socio-economic and technological progress and conservation of the earth's natural systems. However, the most popular definition of sustainable development is the one given in the Brundant report "development that meets the needs of the present without compromising that ability of future generations to meet their own needs" [15]. Nevertheless, there are some areas of agreement in the various definitions. This reflects that the goal of sustainable development is to enable humanity all over the world to satisfy their basic needs and enjoy a better quality of life without compromising the quality of life of future generations. The concept of sustainable development has been described with three dimensions: economic, social and environmental aspect. Sustainable development and social responsibility have become increasingly important strategic issues for companies in virtually every industry [16].

The term sustainable construction means different things to different people as there are multiple definitions, and variance in terms of scope and context as well as practices [11, 12, 17]. Bourdeau et al. [17] stated that sustainable construction practices are widely different depending on how the concept of sustainable construction is developed in various countries. Therefore, simply put, sustainable construction is the response of the building sector to the challenge of sustainable development [5].

The implementation of sustainable construction is still under explored. The decision making process and the actors as well as the inter-relationship has to be understood when implementing sustainable construction [18]. The issues of sustainable construction are divided into 3 aspects: the environmental, economic and the social issues. CIEF [19] suggests sustainable construction as a solution for significant cost savings, to bring innovations and to enhance competitiveness for long time survival of any organisation. Sustainable construction practices not only provides increased market share and profitability but also brings many other intangible benefits such as visible brand name to the organisation in the industry, quality in construction, employee motivation and satisfaction, improved customer's satisfaction, and complements / awards from regulatory authorities and improved shareholder relations [19, 20].

3.0 Lean Thinking in Construction: Lean Construction

The application of lean thinking in construction was pioneered by Koskela who suggested that construction production should be seen as a combination of conversion and flow processes for waste removal. The concept of lean is attributed to the manufacturing industry and was introduced to construction [4]. The use of lean concept has been advocated in the UK, several seminars and initiatives have been undertaken in an effort to encourage its uptake. The Construction Industry Research and Information Association (CIRIA), Construction Productivity Network (CPN), Construction Lean Improvement Programme (CLIP) and the Lean Construction Institute UK (LCI-UK) are some of the examples of institutions established. Seminars and conferences have been organised to tease out the main issues in the development and awareness of lean construction principles with real life case studies of some construction organizations presented [19]. In spite of these efforts, there seems to be some barriers to the successful implementation of lean construction. Generally the rate of lean implementation within the UK construction industry is relatively low and the application of lean in sustainable construction is still under explored [21]. Some studies have identified the barriers to the implementation of lean construction. These barriers need to be overcome in order for construction industry to reap the benefits of implementing lean construction. The application of lean principle to construction has

been presented to result in benefits such as improved quality, improved safety, waste reduction, increased productivity, more client satisfaction, increased reliability, and improvements in design.

A study carried out by Sarhan and Fox [22] reveals that there seems to be positive trends in the development of a lean culture among UK construction organisations. Lack of understanding of how to successfully apply lean thinking principles to specific construction processes was also revealed. This study of lean culture within the UK construction organisations was carried out after the study of Common et al., and Johansen and Walter [22]. Lean thinking has become an important concept within the UK construction industry following the Egans report. There has been significant improvement in the agenda for change in the UK construction industry. Few studies have been carried out in order to establish the current levels of awareness and implementation of lean thinking within the UK construction industry. An example of such studies is the application of the Last Planner into a UK construction project. Last Planner is one of the lean tools and techniques and perhaps the most developed tool. The tool was applied to a UK construction project to ascertain its value and its possible barriers. However, the study raised a number of important structural and cultural problems for the success of Last Planner in the UK [23].

Shah and Ward [24] pointed out that it is essential to differentiate between those studies considering lean from a philosophical perspective related to guiding principles or overarching goals, and those analysing the concept from a practical perspective as a set of management practices, tools, or techniques that can be observed directly. The implementation of lean construction have been targeted towards some specific tools and principles without a full integration on different aspects such as supply chain, safety, planning and control, production design and management, culture and human aspects [25-27]. Framing an encompassing definition that covers all aspects of lean is seen as a difficult task [28]. Alves et al., [26] stated that there are many meaning of lean when applied to construction. Therefore, this study deems it fit to scrutinize various definition of lean as applied to construction. Table 1 presents various definition of lean.

Lean offers significant benefits in terms of waste reduction and increased organisational and supply chain communication and integration. The elimination of waste leads to cost benefits advantage, however these are pre-requisite for creating a lean process. The lean implementation effort stage one focus on waste elimination from a technical and operational perspective [29]. Process Mapping, Value Stream Mapping, and 5S (Workplace Organisation) are some of the tools for achieving such processes. There are 7 types of waste identified under lean: overproduction, overstocking, excessive motion, waiting time, delay and transportation, extra-processing, defect and rework. In the same manner, there are various methodologies for attaining lean production: just in time (JIT), total quality management, concurrent engineering, process redesign, value based management, total productive maintenance and employee involvement.

Table 1: Definitions of Lean

Sources	Definition
Manrodt[30]	Lean is a systematic approach to enhancing value to the customer by identifying and eliminating waste (of time, effort and materials) through continuous improvement, by flowing the product at the pull of the customer, in pursuit of perfection
Ballard et al. [31]	Lean is “a fundamental business philosophy – one that is most effective when shared throughout the value stream”
Lean Construction Institute [32]	Lean construction is a production management-based project delivery system emphasising the reliable and speedy delivery of

	value
Radnoret al. [33]	Lean is a philosophy that uses tools and techniques to create a change of organisational culture in order to implement the ‘good practice of process/operations improvement that allows the reduction of waste, improvement of flow, more focus on the needs of customers and which takes a process view’
Construction Industry Institute [34]	“The continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of a constructed project.”
Shah and Ward [24]	“an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimising supplier, customer, and internal variability.”

3.1 Lean Approach in Sustainable Construction

Lean construction is one of the strategies for improving the sustainability of construction, in other words one method of achieving sustainable construction. Lean approach in sustainable construction focuses on the removal of all forms of wastes from construction processes to allow more efficiency. Existing studies have suggested theories to support that lean is a method for optimising resources, improving safety, productivity, working condition and overall, the social, environmental and the economic bottom line [35]. There are several forms of waste under the lean terminology: processes, material and poor safety are considered as a potential wastes that hinder flow of value to the client. Construction should be seen as flow processes (consisting of both waste and conversion activities), not just conversion processes [4]. The promotion of health and safety practice can contribute to sustainable construction by enhancing workers’ social life and minimising direct and indirect cost of accidents. Material waste elimination has been identified as the most efficient and cost effective approach to promote sustainable practice on construction sites. Similarly, the principles of lean construction focus on creating a sustainable change by stressing on efficient, waste-free and safe flow, storage and handling of materials to minimise cost, energy and resource consumption, and provide value for clients and end users [7].

Some of the key issues of sustainability identified in the literature include: global warming and climate change which is seen as one of the main threats to the environment as a whole [36]. Peng and Pheng [37], investigated the contribution of the lean concept to achieve low carbon installation in the construction sites using precast concrete products and found that the lean concept can be adopted to reduce carbon emission in terms of re-designing the site layout, improving the supply chain and installation work flow. Many studies have highlighted the contributions of lean construction towards the environmental aspect of sustainability. For example Huovila and Koskela [5] presented minimisation of resource depletion, pollution and matching business and environmental improvement as the contribution of lean construction to sustainable development. However, the contribution of lean construction to sustainable development is not limited to the environmental aspect but also to the social and economic aspect. The different lean applications might have different results on the three pillars of sustainable development.

The lean impact has been described to cover the economic, social and environmental aspect of sustainable construction. This include more value to client with less waste of time and resources, process improvement and overall project delivery, productivity improvement, cost reduction, improved quality and safety as well as promotion of continuous improvement. A good example of this is the case study of the modular home building by Nahmens [29] which was

carried out to evaluate the use of lean construction to improve sustainability. Lean construction strategies serves as a platform for improvement in the delivery of the sustainable modular houses. Figure 2 presents the main effect of the application of the lean concept for the purpose of sustainability in the aforementioned example.

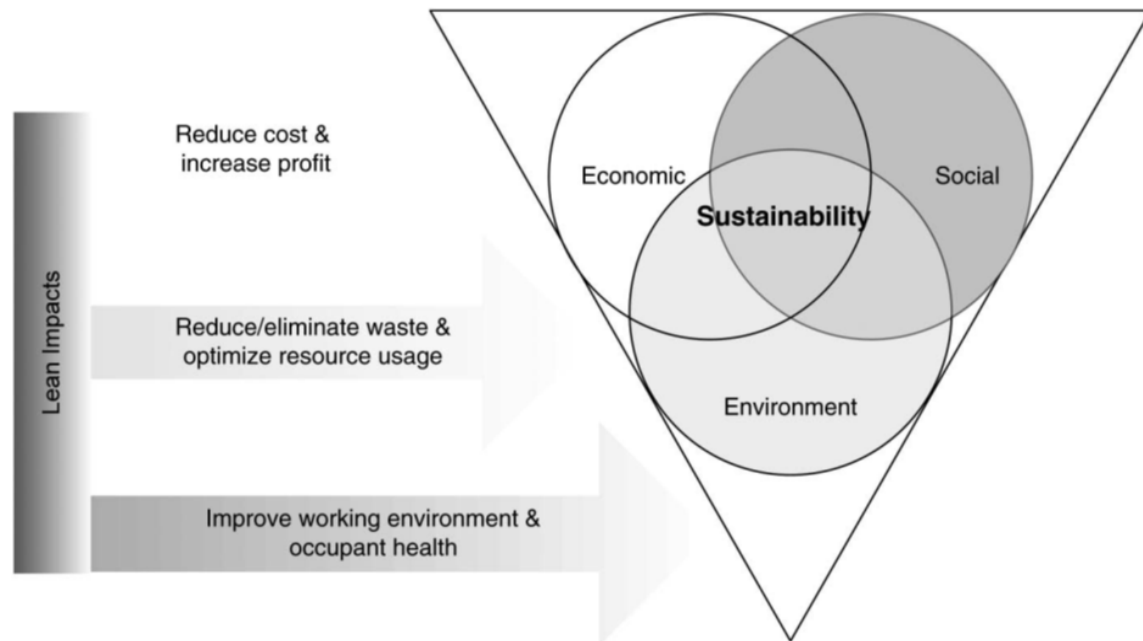


Figure 1: Conceptual model: effect of lean on sustainability
Source: (Nahmens and Ikuma, 2009)

As much as adopting lean concept has been attributed to positive influence on sustainable construction in terms of improved safety, many research works have shown both negative and positive effects of lean on safety. However, in terms of sustainability, lean and safety influence economic sustainability by reducing costs and increasing productivity, environmental sustainability by reducing or improving materials and social sustainability by affecting the well-being of workers.

3.2 Sustainable Practice and lean concept

According to Tan et al., [38], Sustainable construction practices include five major areas: compliance with sustainability legislation, design and procurement; technology and innovation; organisational structure and process; education and training; and measurement and reporting. The successful implementation of lean and sustainable concepts by an organisation depends on the level of commitment and knowledge. The implementation of sustainability throughout the organisation including the organisation's project will yield more result than when implemented only on the project [39]. Different company characteristics can influence the choices in sustainable construction practices. The selected sustainable construction practices should be consistent with the overarching strategy. The benefits of implementing sustainable practices include improved regulatory compliance requirements; reduction of liability and risk; enhanced reliability among customers and peers; reduction of harmful impacts to the environment; prevention of pollution and waste (which can result in cost reduction); improvements in site and project safety (by minimising injuries related to environmental spills, releases and emissions); improved relationships with stakeholders such as government agencies, community groups, and clients [40].

The benefits of implementing sustainable practices in construction can be grouped under environmental, economic and social aspects. Hall and Purchase [41] stated that numerous

sustainability and lean practices, such as productivity, safety, efficiency, and waste minimisation, are interconnected. The conceptual relationship between lean and sustainability has been presented in the literature. Lean practices can be adopted in a construction project at design phase to reduce costs and enhance sustainability [42, 43]. Few studies have been carried out to investigate the application of sustainability and lean concept. Despite the pressure on the construction industry to adopt the concept of sustainability to improve the current unsustainable pattern of project delivery, its uptake is relatively slow i.e. the adoption of sustainable practice in construction project. Koranda et al., [8] developed a framework for implementing lean techniques and sustainability in a construction project as shown in figure 3. This framework captured the major sustainability issues at project level.

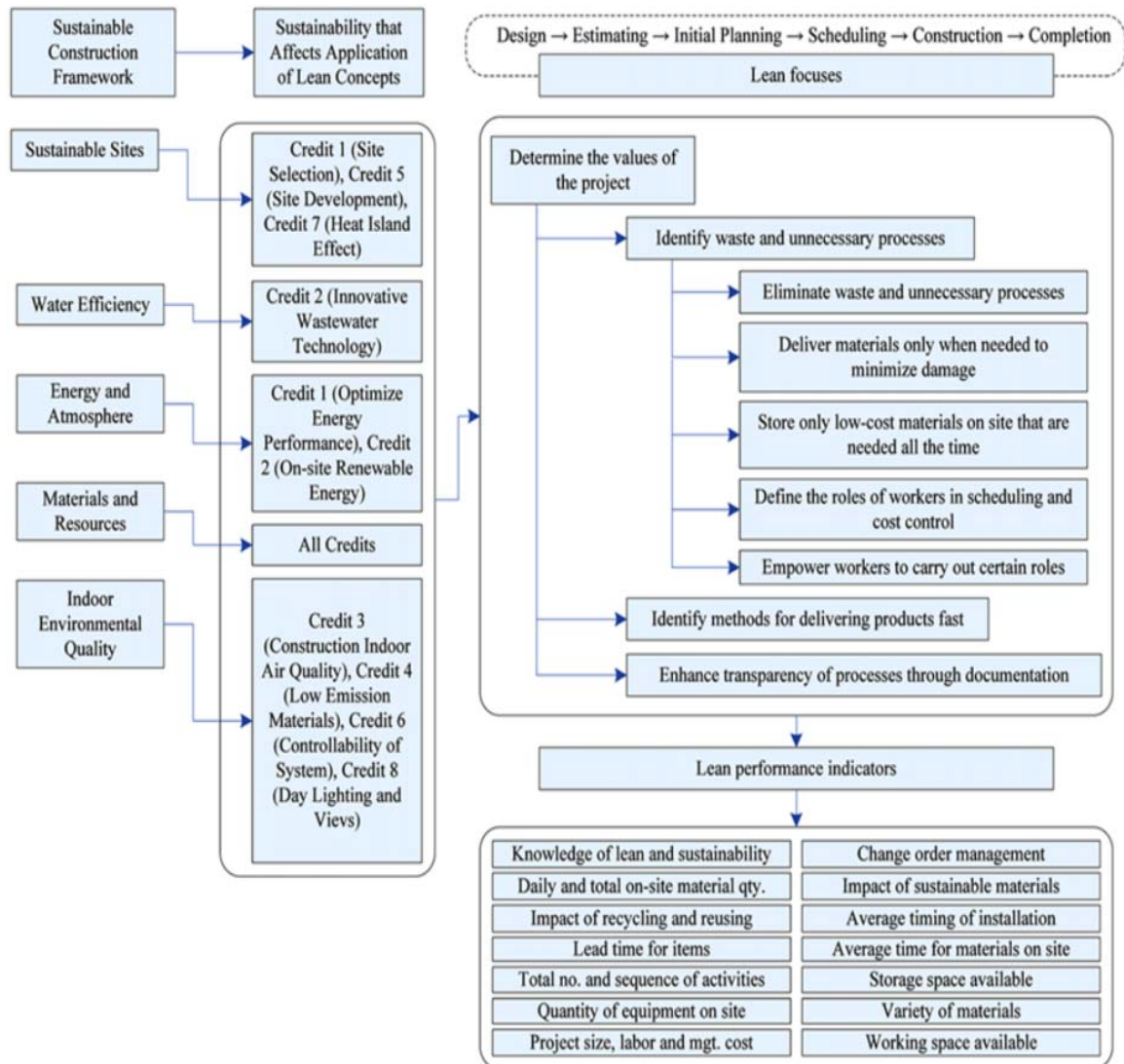


Figure 3: Framework for implementing lean techniques and sustainability in a construction project (Source: Koranda et al. 2012)

There is need for leadership participation in the quest for attaining a more sustainable construction as the leadership role in construction organisation is one of the paramount factors that can provide an overall vision, direction and vision towards the attainment of a sustainable construction. Therefore, it is highly essential that leaders have full knowledge of the concept of sustainability to be able to guide their organisations effectively [44]. Likewise, top level leadership commitment has been identified as one of the success factors for the implementation of

lean. This suggests that thorough understanding of lean and sustainability concepts as well as principles are necessary for proper application on a construction project.

3.3 Lean Tools and Methodologies for Sustainable Construction

Various lean tools and techniques for enabling sustainability have been discussed by several authors. Some studies have explored various issues of sustainability by means of lean initiatives and established the benefits that can be derived by applying the lean principles/tools [42, 45]. Lean design methods such as Integrated Design, Design for Maintainability (DFM), Set-based Design, Target Costing and 3D Modelling can be used during the construction of sustainable project. Many studies have suggested integrated design method to be one of the most critical methods for sustainable construction [46-48]. Just-in-time (JIT) is a major component of the lean construction concept, the principle of just in time is to ensure that the correct quantities of materials are delivered as at when needed in the right quantity to the exact location in good condition [49-51]. Bae and Kim [43] carried out the quantitative assessment of lean methods and sustainability impacts of construction project. This was based on the lean project delivery phases which include: lean project definition, lean design, lean supply, lean assembly and whole delivery process. It was revealed that most lean construction methods provide positive economic impacts for sustainable projects while there are few negative impact as well as the combination of both impact (positive and negative) on the social and the environmental aspects.

There are many lean tools and techniques/principles among which 5S, value stream mapping, just in time, visualisation tool, last planner, value analysis, pull approach and continuous improvement appears to be the commonly adopted lean tools and techniques/principles [45]. Value stream mapping (VSM) is the mapping of wastes throughout the organisation. 5S and value stream mapping are commonly noted for environmental improvement. 5S helps companies to look at their workplace in a new dimension. Companies use 5S to clean and streamline areas within their works, removing unwanted parts, tools and general debris and setting a new standard for cleanliness and tidiness. It also helps in organising construction site, thereby resulting to environmental improvement and health and safety improvement.

4.0 Conclusions

The study has drawn from literature on both lean and sustainability reflecting the principles of lean and how it impacts on sustainable construction. Better understanding of lean concepts by the construction industry can contribute to improvement in all aspect of sustainable construction. The concept of lean and sustainable construction both seeks to minimise waste, but this is achieved through different approaches. There is need for construction stakeholders to set their priorities before the start of a project for better integration of the two concepts. More emphasis should be laid on lean approach in sustainable construction framework. There should be more level of commitment and knowledge by an organisation in order to successfully implement and derive maximum benefits from the concept of lean and sustainability. However, the application of lean in sustainable construction is not only possible on the operational level; it could also be applied at the strategic level. Therefore, this study will go on to further present the application of lean and sustainability at the strategic level and also explore the benefits that can be achieved.

References

- [1] Construction Industry Research and Information Association CIRIA, "Guide to sustainable procurement in construction. London" Construction Industry Research and Information Association C695, 2011.
- [2] R. Sacks, B. Dave, L. J. Koskela, and R. L. Owen, "Analysis framework for the interaction between lean construction and building information modeling," Proceedings of the 17th annual conference of International Group for lean Construction, 2009.

- [3] Construction Industry Research and Information Association CIRIA “Sustainable construction: company indicators”, London: CIRIA, C563, 2001.
- [4] L. Koskela, “An exploration towards a production theory and its application to construction,” D. Tech. thesis, Helsinki University of Technology, 2000.
- [5] P. Huovila, and L. Koskela, “Contribution of the Principles of Lean Construction to Meet the Challenges of Sustainable Development,” In Formoso, C.T., ed. Proceedings of IGLC-6. Guaruja, Brazil, 1998.
- [6] Department of the Environment, Transport and the Regions DETR, “Sustainable development: what it is and what you can do”, DETR Green Ministers Report. 2000
- [7] I. Nahmens, and L. H. Ikuma, “An Empirical Examination of the Relationship between Lean Construction and Safety in the Industrialised Housing Industry,” *Lean Construction Journal*, vol. 5(1), pp.1-12, 2009.
- [8] C. Koranda, W. Chong, C. Kim, J. Chou, and C. Kim, “An Investigation of the Applicability of Sustainability and Lean Concepts to Small Construction Projects,” *KSCE Journal of Civil Engineering*, vol. 16(5), pp. 699-707, 2012.
- [9] L. H. Forbes, S. M. Ahmed, and M. Barcala, “Adapting lean construction theory for practical application in developing countries,” Proceedings of the first CIB W 107 International Conference: Creating a Sustainable Construction Industry in Developing Countries (Eds. Division of Building Technology, CSIR), Stellenbosch, South Africa, 11-13 November, 2000.
- [10] P. Glavic, and R. Lukman, “Review of sustainability terms and their definitions,” *Journal of Cleaner Production*, vol. 15 (18), pp. 1875-1885, 2007.
- [11] D. P. Wyatt, “Recycling and Serviceability: The Twin Approach to Securing Sustainable Construction,” In Proceedings of First International Conference of CIB TG 16 on Sustainable Construction, Tampa, Florida, 6-9 November, pp. 69- 78, 1994.
- [12] R. C. Hill, and P.A Bowen, “Sustainable Construction Principles and a Framework for attainment,” *Construction Management and Economics*, vol. 15(3), pp. 223-39, 1997.
- [13] P. S. Brandon, “Sustainability in Management and Organisation: The key issues?,” In Proceedings, Conference on Cities and Sustainability:Sustaining our Cultural Heritage, Kamdalama, Sri Lanka, February 11-16, 2000.
- [14] A. P. Sage, “Risk management for sustainable development,” *IEEE International Conference on Systems, Man and Cybernetics*, vol. 5, pp. 4815-4819, 1998.
- [15] G. H. Brundtland, “Our common future: Report of the World Commission on Environment and Development,” Oxford University Press, Oxford, 1987.
- [16] J. Fiskel, “Sustainability and resilience: towards a system approach,” *Sustainability: science, practice, and policy*, vol. 2, pp. 1-8, 2006.
- [17] L. Bourdeau, P. Huovila, R. Lanting, and A. Gilham, “Sustainable Development and the Future of Construction: A Comparison of Visions from various Countries,” CIB Report 225, Rotterdam. 1998.
- [18] Y. Rydin, U. Amjad, and M. Whitaker, “Environmentally sustainable construction: Knowledge and learning in London planning departments,” *Planning Theory and Practice*, vol. 8 (3), 363-380, 2007.
- [19] Construction Industry Environmental Forum CIEF, “Lean construction for sustainable business,” Joint CIEF and CPN seminar held at the Centre for Construction Innovation, CUBE, 113-115 Portland Street, Manchester M1 6DW, 2009.
- [20] WRI Report, “Hot climate, cool commerce: A service sector guide to green house gas management,” World Resources Institute, Washington D.C, <http://pdf.wri.org/hotclimatecoolcommerce.pdf> accessed 3/2/13, 2006.
- [21] A. Mossman, “Why isn’t the UK construction industry going lean with gusto?,” *Lean Construction Journal*, vol. 5 (1), pp. 24-36, 2009.
- [22] S. Sarhan, and A. Fox, “Trends and challenges to the development of a lean culture among UK construction organizations,” <http://www.iglc20.sdsu.edu/papers/wp-content/uploads/2012/07/116%20P%20015.pdf> accessed on 02/3/13, 2012.
- [23] E. Johansen, and G. Potter, “An experience of introducing last planner into a UK construction project,”<http://www.leanconstruction.dk/media/17682/An%20Experience%20of%20Introducing%20Last%20Planner%20into%20a%20UK%20Construction%20Project.pdf> accessed 5/4/13, 2003.
- [24] R. Shah, and P. T. Ward, “Defining and developing measures of lean production,” *Journal of Operations Management*, vol. 25 (4), pp. 785-805, 2007
- [25] F. Picchi and A. Granja, “Construction sites: using lean principles to seek broader implementations,” Proceedings of International Group of Lean Construction, 12th annual conference, Copenhagen, Denmark, August 3th – 5th, 2004

- [26] T. Alves, and C. Tsao, "Lean Construction – 2000 to 2007," *Lean Construction Journal*, vol. 3 (1), pp. 46-70, 2007
- [27] I. Pavez, and L. F. Alarcón, "Lean Construction Professional's Profile (LCP): implementation in Chilean contractor organizations," *Proceedings of International Group for Lean Construction 16th Annual Conference*, Manchester, UK, July 14th – 20th, 2008,
- [28] J. Petterson, "Defining lean production: some conceptual and practical issues," *The TQM Journal*, vol. 21 (2), pp.127-142, 2009.
- [29] S. Green, and S. May, "Lean construction: arenas of enactment, models of diffusion, and the meaning 'leanness'," *Building Research & Information*, vol. 33 (6), pp.498- 511, 2005.
- [30] K. B. Manrodt, K. Vitasek, and R. H. Thompson, "Lean practices in the supply chain, Jones Laselle 2008 Report," <http://www.joneslanglasalle.com/Documents/JLL-LeanPracticesInSupplyChain.pdf> accessed 4/4/13. 2008.
- [31] H. G. Ballard, Y. W. Kim, J. W. Jang, and M. Liu, "Roadmap for Lean Implementation at the Project Level," CII Research Report No. 234-11 Construction Industry Institute, The University of Texas, Austin, TX, 409pp, 2007.
- [32] Lean Construction Institute, <http://www.leanconstruction.org.uk/what-is> accessed 11/12/12, 2012.
- [33] Z. Radnor, P. Walley, A. Stephens, and G. Bucci, "Evaluation of the lean Approach to Business Management and its use to Public sector". <http://www.scotland.gov.uk/Resource/Doc/129627/0030899.pdf> accessed 9/10/12, 2006
- [34] Construction Industry Institute, "The Application of Lean manufacturing Principles to Construction". https://www.construction-institute.org/scriptcontent/more/rr191_11_more.cfm accessed 08/01/13, 2013.
- [35] I. Nahmens, and L. H. Ikuma, "Effect of lean construction on sustainability of modular homebuilding," *Journal of Architectural Engineering*, vol. 18 (2), 2012
- [36] IPCC, "Climate Change 2007: Synthesis Report", Intergovernmental Panel on Climate Change, available from <http://www.ipcc.ch/> accessed 10/05/2011, 2007.
- [37] W. Peng, and L. Pheng, "Lean and green: emerging issues in the construction industry – a case study. EPPM, Singapore, 20-21 September, 2011.
- [38] Y. Tan, L. Shen, and H. Yao, "Sustainable Construction Practice and Contractor's Competitiveness: A preliminary Study," *Habitat International*, vol. 35, pp. 225-230, 2011.
- [39] S. M. A. Beheiry, W. K. Chong, and C. T. Haas, "Examining business impact of owner commitment to sustainability," *Journal of Construction Engineering and Management*, vol. 132 (4), pp. 384-392, 2006.
- [40] G. Christini, M. Fetsko, C. Hendrickson, "Environmental Management systems and ISO 14001 certification for Construction Firms," *ASCE Journal of Construction Engineering and Management*, pp. 330-336, 2004.
- [41] M. Hall and D. Purchase, "Building or bodging? Attitudes to sustainability in UK public sector housing construction development," *Sustainable Development*, vol. 14 (3), pp. 205-218, 2006.
- [42] O. Ogunbiyi, A. Oladapo, and J. Goulding, "Lean procurement: the use of lean construction techniques in project value enhancement," *Joint CIB W070, W092 & TG72 International Conference on Facilities Management, Procurement Systems*, 23-25 January, 2012, University of Cape Town, Cape Town, South Africa, 2012.
- [43] J. Bae, and Y. Kim, "Sustainable Value on Construction Projects and Lean Construction," *Journal of Green Building*, vol. 3 (1), pp. 156-167, 2008.
- [44] A. Opoku, and C. Fortune, "The implementation of sustainable practices through leadership in construction organizations," In: Egbu, C. and Lou, E.C.W. (Eds.) *Procs 27th Annual ARCOM Conference*, 5-7 September 2011, Bristol, UK, Association of Researchers in Construction Management, 1145-1154, 2011.
- [45] S. Vinodh, K. R. Arvind, and M. Somanathan, "Tools and techniques for enabling sustainability through lean initiatives," *Journal of Technology and Environmental policy*, vol. 13, pp. 469-479, 2010.
- [46] A. Lapinski, M. Horman, and D. Riley, "Lean processes for sustainable project delivery," *Journal of Engineering and Management*, vol. 132 (10), pp. 1083-1091, 2006.
- [47] D. Riley, V. Sanvido, M. J Horman, M. McLaughlin, and D. Kerr, "Lean and Green: The Role of Design-Build Mechanical Competencies in the Design and Construction of Green Buildings," In Tommelein, T. (ed.), *Proceedings of the 2005 Construction Research Congress*, April 5-7, San Diego, CA, 2005
- [48] M. J Horman, D. Riley, M. H. Pulaski, and C. Leyenberger, "Lean and Green: Integrating Sustainability and Lean Construction," *CIB World Building Congress*, Toronto, Canada, 2004.

- [49] K. Birdi, C. Clegg, M. Patterson, A. Robinson, C. B. Stride, T. B. Wall, and S. J Wood, "The impact of human resource and operational management practices on company productivity: A longitudinal study," *Personal Psychology*, vol. 61 (3), pp. 467-501, 2008.
- [50] X. Mao, and X. Zhang, "Construction process reengineering by integrating lean principles and computer simulation techniques," *Journal of Construction Engineering and Management*, vol. 134 (5), pp. 371-381, 2008.
- [51] P. E. Eriksson, "Improving construction supply chain collaboration and performance: a lean construction pilot project," *Supply Chain Management: An International Journal*, vol. 15 (5), pp. 394-403, 2010