WASTE IN CONSTRUCTION: A SYSTEMATIC LITERATURE REVIEW ON EMPIRICAL STUDIES

Daniela Dietz Viana[1], Carlos Torres Formoso[2] and Bo Terje Kalsaas[3]

ABSTRACT

Waste is one of the key concepts in the Lean Production philosophy. The elimination of waste has been largely used as driver for improvement in the manufacturing industry. By contrast, it has not been strongly emphasised in the construction management books and mainstream journals. This paper presents a review on papers that have systematically investigated the occurrence of waste in the construction industry, including concepts adopted, metrics, and type of feedback provided. This study is part of a wider research initiative that aims to conceptualize waste in production management theory. In order to ensure that the most relevant studies have been considered, a systematic literature review on that topic has been carried out. This kind of review makes explicit the criteria used to select publications, which enables an assessment of the search undertaken, as well as makes it possible to replicate or extend it. The main sources were the IGLC conference papers, the Lean Construction Journal and a set of mainstream construction management journal. This study intends to make a contribution towards the understanding of the nature of waste, particularly in the construction industry, and how the construction management community have approached this theme so far.

KEY WORDS

Lean Production; Waste; Systematic Literature Review

INTRODUCTION

The elimination of waste has been largely used as driver for improvement in companies that have adopted the Lean Production philosophy. This topic has also been the focus of investigation in the construction industry around the world in recent years both from inside and outside the IGLC community. Several studies from different countries have confirmed that waste represent a relatively large percentage of production costs (Formoso et al. 2002; Hwang et al. 2009; Koushki and Kartam 2004; Love and Li 2000; Love 2002). Distinct types of wastes have been measured in those studies, indicating that waste in construction has been understood in several different ways. As a consequence, a wide range of measures have been used, such as excess consumption of materials (Bossink and Brouwers 1996; Enshassi 1996;

[1] Architect, Doctorate Student, Building Innovation Research Unit (NORIE), Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil. danidietz@gmail.com

[2] Ph.D., Associate Professor, Building Innovation Research Unit (NORIE), Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil. Phone +55 51 33083518, formoso@ufrgs.br

[3] Dr Ing, Associate Professor, Faculty of Economics and Social Sciences, Department of Working Life and Innovation, University of Agder, 4846 Grimstad, Norway, Cellular +47 97082582, e-mail: bo.t.kalsaas@uia.no

Formoso et al. 2002; Nahmens and Ikuma 2011; Skoyles 1976), non-value adding activities (Choi et al. 2002; S. Han et al. 2011; Koskenvesa et al. 2008; Nahmens and Mullens 2011; Senaratne and Sexton 2009; H. Yu et al. 2009), rework (Hwang et al. 2009; Love and Edwards 2004; Love 2002; Zhao et al. 2010), and quality deviation (Burati et al. 1992; W B Ledbetter 1994). Those measures have been used to assess the performance of projects or production systems, since they usually allow areas of potential improvements to be pointed out, and the main causes of inefficiency to be identified. Compared to traditional financial measures, waste measures tend to be more effective to support process management, since they enable some operational costs to be properly modelled, and generate information that are usually meaningful for the work-force, creating conditions to implement decentralized control.

Several studies have focused on material losses, been often concerned with the environmental impact caused by construction and demolition material waste (Bossink and Brouwers 1996; Gavilan and Bernold 1994; Poon et al. 2004). In those studies the conceptualization of waste is rarely discussed: most of them simply adopt the definitions used by regional institutions, such as governmental departments. Often waste is understood as debris that need to be removed from construction sites. For instance, Al-Hajj and Hamani, (2011) adopted the definition of material waste as "the by-products generated and removed from construction, renovation and demolition workplaces or sites of building and civil engineering structures".

A similar problem is found on previous studies on the measurement of rework (Hwang et al. 2009). Although the importance of this type of waste is widely recognised, it is not clear in the literature whether rework is simply a consequence of quality deviation or if it is also a consequence of change orders or uncompleted tasks. Moreover, most papers on this topic do not discuss the cost components of this type of waste.

By contrast, there are several publications that discuss the conceptualization of waste in the lean production philosophy, which is strongly related to the existence of non value-adding activities i.e., activities that take time, resources or space but do not add value from the perspective of the final customer (Koskela, 1992). Ohno (1988), one of the seminal authors on the Toyota Production System, proposed seven categories of waste: (i) unnecessary movement of people (including waste of human energy); (ii) waiting by employees for process equipment to finish its work or an upstream activity; (iii) defects in products; (iv) overproduction of goods not needed; (v) inventories of goods awaiting further processing or consumption; (vi) unnecessary processing; and (vii) unnecessary transport of goods. Those categories were based on problems observed in the car industry. There are also other categories of waste that have been proposed in the literature, such as design of products that do not meet users' needs (Womack and Jones 2004), unnecessary capital investment (Monden 1983), theft and vandalism (Bossink and Brouwers 1996), making-do, defined as a reduction of performance due to the fact that a task is started or continued even if not all standard inputs are available (Koskela 2004), not listening and not speaking (Macomber and Howell 2004). However, there is not much evidence that those concepts have been used as a reference for measuring waste either by academics or in improvement initiatives by the construction industry.

This paper presents an overview on previous studies that have systematically investigated the occurrence of waste in the construction industry, including concepts

adopted, metrics, and type of feedback provided. A systematic literature review on that topic has been carried out, considering initially papers published in the last 20 years, with the aim of capturing the evolution of research on the measurement of waste in the construction management community. Such investigation is the first step of a broader research initiative which aims to conceptualize waste in production management theory.

RESEARCH METHOD

Systematic literature review is a technique for hypothesis testing, for summarising the results of existing studies, or for assessing consistency among previous studies (Petticrew 2001). It provides an overview of primary research through an explicit and reproducible method. Petticrew (2001) emphasized that it does not intent to be just a large literature review effort, but aims to answer a specific question, to reduce bias in the selection and inclusion of studies, to appraise the quality of the included studies, and to summarise them objectively. The research question that guided this investigation was: what are the main gaps in knowledge that could be identified from the studies, regarding concepts, kind of wastes and type of feedback provided to the construction waste research field?

A systematic literature review is usually carried out using large databases that contain a large set of publications as well as effective search mechanisms, which allow complex logical expressions to be used. The first run of the search was made in Google Scholar, with the aim of choosing suitable databases. After a preliminary analysis of the results, a set of specific journals with a high impact in the construction management research community was identified[4]. However, none of the available databases included all journals, and the decision was made to work with the individual database of each journal. Moreover, these individual databases had very limited resources for using expressions in the search. For that reason, the search of papers in each journal was very time consuming, since only one expression at a time could be used. After the first selection of papers, a database was created in a citation manager, in order to check duplicates and apply some quality criteria in the selection of papers. Some additional references cited in the selected papers were also included in the database.

As there are several papers concerned with waste measurement and reduction, but do not refer to this word explicitly, some other expressions commonly used for describing different types of waste were used in the search: rework, consumption of material, material wastage, non-value adding activities, work-in-progress, waiting, inventory, movement, overproduction, transport, defect and making-do. As all journals included in the search were from the construction management field, the word construction was not included.

The initial search resulted in 681 papers. The main criteria used for selecting suitable papers for this study were:

[4] The selected journals: Architectural Engineering and Design Management; Building Research & Information; Construction Management and Economics; Engineering, Construction and Architectural Management; Journal of Architectural Engineering; Journal of Construction Engineering and Management; Journal of Management in Engineering; and also the IGLC conference papers.

- Based mainly on the title and abstract, all papers that provided a discussion on the causes, measures, concepts, or preventive actions on construction waste were selected;
- Papers that did not make any analysis on the causes or how to avoid wastes were not included in the review. Therefore, the ones focused on the environmental impact of construction and demolition debris or the ones concerned with how to reuse and recycle debris were excluded from the database.
- Papers focused on the waste of a specific material in construction sites were also excluded.

After several refinements in the search, 56 papers were selected. This set of papers were then analysed in detail, considering the following content: (i) the concept of waste adopted, whether it was explicit or not; (ii) the kind of waste that has been analysed; and (iii) the main contribution of the paper to the topic of construction waste. table 1 presents the categories of contributions that were considered in the papers.

Table 1: Definitions of the main contributions of the papers

Main Contribution	Definition
Causes	Identifies the causes and propose some solutions for avoiding waste
Metrics	Measures waste in a sample of projects, producing metrics
Preventive Action	Describes the implementation of actions to reduce or eliminate waste
Method	Proposes a method to identify or measure waste
Concepts	Suggest a different way to understand waste

WASTE CONCEPT

Not all papers analysed presented a clear definition of waste, either explicit or implicit. Only 41% properly presented a conceptualisation of waste in a broad sense, and 16% defined a specific kind of waste that was addressed, such as rework, making-do, or defects. **Error! Reference source not found.** shows the most cited references used by the papers that had defined waste explicitly. There are some papers that provide their own definition of waste.

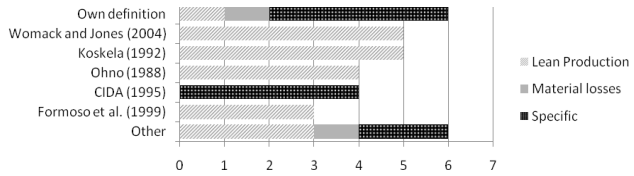


Figure 1: Most-cited references used for defining waste

Three different groups of concepts were identified in the set of papers: (i) waste as non value-adding activities (29 papers): several studies adopted this conceptualization, mostly from members of the Lean Construction community; (ii) waste as material loss (10 papers): some studies were focused on material waste and adopted an operational definition for this type of waste, usually based on the amount of debris generated; (iii) specific types of waste (17 papers): those studies have used

specific definitions of waste, according to the type of waste investigated, such as rework.

According to **Error! Reference source not found.**, most of the citations can be connected to the Lean Production Paradigm (Womack and Jones 2004; Koskela 1992; Ohno 1988; Formoso et al. 1999). The definition from CIDA (1995)[5] concerns particularly to rework, which was defined as "doing something at least one extra time due to non-conformance to requirements" (Love and Li 2000; Love and Smith 2003; Love et al. 1999 2000). Regarding material loss, an important reference is the investigation carried by Skoyles (1976) in the U.K. during the Sixties and Seventies. Most of the papers that have used the authors' own definition are concerned to a specific kind of waste, as shown in Table 2.

Table 2: Own definitions of waste identified in the literature

Definitions	Source	Group
Direct waste is defined as the loss of those materials which are damaged and cannot be repaired and subsequently used, or which are lost during the building process. Indirect waste is distinguished from direct waste because it normally represents only a monetary loss because usually the materials are not lost physically.	(Skoyles 1976)	Material Losses
Quality is defined as "conformance to established requirements."Deviation includes changes to the requirements that result in rework, as well as products or results that do not conform to all specification requirements, but do not require rework.	(Burati et al. 1992)	Specific – Quality deviation
Deviation correction costs plus unnecessary prevention and appraisal costs are often termed "quality losses" and their reduction (and ultimate elimination) will result in increased quality performance.	(W B Ledbetter 1994)	Specific – Quality deviation
Any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client.	(Formoso et al. 1999)	Lean Production
Making-do as a waste refers to a situation where a task is started without all its standard inputs, or the execution of a task is continued although the availability of at least one standard input has ceased. The term input refers not only to materials, but to all other inputs such as machinery, tools, personnel, external conditions, instructions etc.	(Koskela 2004)	Specific – Making-do
Rework means having to redo work due to non-conformance with requirements.	(Hwang et al. 2009)	Specific – rework

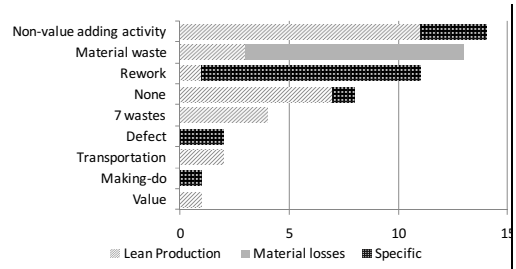
TYPES OF WASTE ANALYSED

Error! Reference source not found. presents a classification of the papers according to the kind of waste that was analysed. There were a small set of papers selected that have not focused on a specific kind. For instance, Howell (2011) provided some insights of a new operating system that could reduce the amount of waste generated by current systems. **Error! Reference source not found.**a reveals that different conceptualizations have been used to address to the same type of waste. For instance, there are papers focused on material loss that come from the Lean Construction Community (e.g., Formoso et al. 2002), which are based on the definition of waste as non value-adding activities, while other simply adopt a very operational definition of waste as debris.

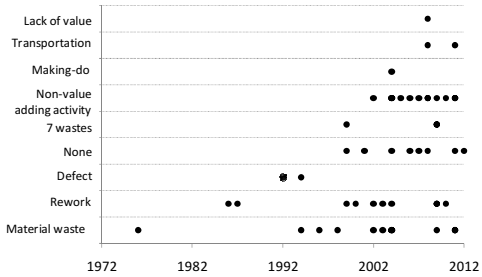
An attempt to analyse the kinds of waste investigated over time is presented in **Error! Reference source not found.**b. There is a clear trend of increasing the number of papers in recent years. Interestingly, the earliest studies on construction waste were concerned with material losses, which is still a popular topic in recent years. It is worth noting that waste as non-value adding activities has been a major

[5] CIDA (1995) *Measuring Up or Muddling Through: Best Practice in the Australian Non-Residential Construction Industry*, Construction Industry Development Agency and Masters Builders Australia, Sydney, Australia, pp. 59–63.

focus of investigation, but only started to be examined in 2002, in the study by Choi et al. (2002). Leong and Tilley (2008) was the only paper that was focused on value loss, a category of waste that was strongly emphasized by Womack and Jones (2004). In that study, Leong and Tilley make an evaluation of the downstream customer needs in the construction process in order to find waste sources.



Error! Reference source not found.a: Kinds of waste analysed in the selected papers



Error! Reference source not found.b: Kinds of waste analysed over the years

Figure 2: Kind of waste analysed

MAIN CONTRIBUTION

Error! Reference source not found. summarizes the main contribution provided by the set of 56 papers. The categories with the largest number of papers are the ones that contain papers that have investigated the causes of waste and the production of metrics. It indicates that most papers that have investigated the main causes of waste are focused on a specific kind of waste, such as material loss, or rework. However, a large percentage (47.3%) of those studies is mainly based on surveys. That includes a set of papers that discussed the causes of rework, explaining the interactions among them (Love et al. 1999), modelling these causes in System Dynamics (Love et al. 2000) and finally quantifying values (Love and Li 2000).

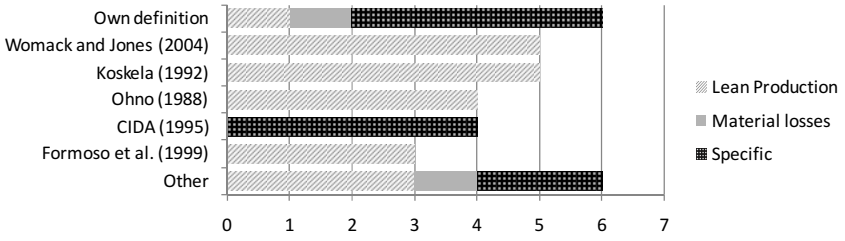


Figure 3: Main contributions of the set of papers

A wide range of indicators has been used for measuring waste, even when considering only one category of waste. For instance, material waste has been measured by the physical quantities, such as the volume of debris taken from the site (Gavilan and Bernold 1994; Poon et al. 2004), and the weight of materials directly or indirectly last (Formoso et al. 2002). By contrast, other specific types of waste, such as defective products (Burati et al. 1992; W B Ledbetter 1994) and rework (Hwang et

al. 2009) have been measured by their costs. Time has also been often used as an important waste measure, especially when the aim is to identify the share of non-value adding activities (Forsberg and Saukkoriipi 2007; Horman and Kenley 2005; Kalsaas 2010; H. Yu et al. 2009), as well as the number of steps that are non-value adding (S. Han et al. 2011; Lapinski et al. 2006; Mao and Zhang 2008; Nahmens and Mullens 2011). In this regard, some papers have criticized the simple analysis of non-value adding activities, proposing a differentiation between those activities that could be eliminated from the ones that could not (Choi et al. 2002; Lapinski et al. 2006; Mao and Zhang 2008).

The approaches used for proposing actions for reducing or eliminating waste are also very diverse. Some papers describe attempts to change practices in industry by implementing lean techniques. Nahmens and Ikuma (2011), and Nahmens and Mullens (2011), for instance, implemented some of those techniques in one specific project, and assessed the performance of the crews before and after the introduction of those changes. Some other papers use simulation models that could support decision making, by testing changes in the production system that could reduce the share of non value-adding activities. For instance, Sacks et al. (2007) and Tommelein et al. (1999) have devised games that could be used for teaching lean concepts. Porwal and Hewage (2011) developed a BIM model to simulate architectural and structural design requirements in order to minimize rebar waste. Park et al. (2011) devised a floor-level construction material layout planning model that could reduce unnecessary transportation time in a building project. Zhao et al. (2010) used a structure matrix method to analyze the causes of changes in construction projects.

Regarding the development of methods for identifying and measuring waste, the number of papers is relatively small and most of them are focused on two types of methods: the measurement of material losses, including direct and indirect waste (e.g., Skoyles 1976; Formoso et al. 2002), and value stream mapping (VSM) for assessing the share of non value-adding activities and designing a future state (e.g., Choi et al. 2002; Yu et al. 2009). Choi et al. (2002) applied VSM in a traditional way, with the aim to reduce cycle times, by eliminating non-value adding activities. By contrast, Yu et al. (2009) pointed out some limitations of this technique and proposed an adaptation of value stream mapping to the context of construction projects. Another method that has been used is system dynamics: Han et al. (2011) used it for understanding the relationship of non-value adding activities at a macro-level to design errors and changes.

CONCLUSIONS

This paper reports the initial results of a research project that has attempted to identify the main gaps in knowledge concerning construction waste. The systematic literature review identified that the number of papers focused on how to avoid waste in construction is relatively small, compared to what has been produced in the field of construction management. Some studies from the Lean Construction community pointed out the need to use a broader conceptualization of waste, based on the idea that is necessary to remove activities that do not add value from the perspective of the client. In fact, some papers have claimed the need for separating unavoidable and avoidable non-value adding activities, based on the assumption that it is uncomfortable to consider all of them as waste, since it is not possible to eliminate

them completely (Choi et al. 2002; Lapinski et al. 2006; Mao and Zhang 2008). Regarding the conceptualization of waste, most studies do not discuss the conceptualization of waste at an abstract level. Some of them simply adopt an operational definition of waste, founding order to guide data collection.

The number of studies that have produced metrics of construction waste is also relatively small. In fact, Forsberg and Saukkoriip (2007) claimed that reports of lean implementations have not emphasized enough waste measurements. In fact, studies that have produced an analysis of the root causes of different kinds of waste in construction are based on surveys. By contrast, studies on the development of explanation models are often the result of an in-depth analysis of a specific kind of waste.

The main contribution of this article is to point out gaps in the literature on waste in construction. It reveals that the effort of the construction management community for understanding waste is relatively small, compared to other topics, and many studies about waste have focused on the consequences and not on the root causes that should be avoided. Further studies are necessary to increase the existing knowledge in order to help the construction industry to better conceptualize waste and to analyse deeply its main causes.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contribution from several colleagues that have participated in the 2nd Workshop "Understanding Waste in Construction", carried out at the University of Salford, UK, on the 16th and 17th of February 2012, who provided an important feedback for the development of this paper.

REFERENCES

Al-Hajj, A. and Hamani, K. (2011). "Material Waste in the UAE Construction Industry: Main Causes and Minimization Practices," *Architectural Engineering and Design Management*, Vol. 7 No. 4, pp. 221-235.

Bossink, B.A.G. and Brouwers, H.J.H. (1996). "Construction waste: quantification and source evaluation," *J. Constr. Eng. Manage.*, ASCE, Vol. 122 No. 1, pp. 55-60.

Burati, J.L.J., Farrington, J.J. and Ledbetter, William B. (1992), "Causes of Quality Deviations in Design and Construction," *J. Constr. Eng. Manage.*, ASCE, Vol. 118 No. 1, pp. 34-49.

Choi, S., Ku, T.H., Yeo, D.H. and Han, S.H. (2002). "Waste Elimination of Mucking Process of a Petroleum Storage Tunnel through the Value Stream Analysis," *Proceedings of the 10th Annual Conference of the IGLC*, Manchester, pp. 155-167.

Enshassi, A. (1996), "Materials control and waste on building sites," *Building Research & Information*, Vol. 24 No. 1, pp. 31-34.

Faniran, O.O. and Caban, G. (1993). "Minimizing waste on construction project sites," *Engineering, Construction and Architectural Management*, MCB UP Ltd, Vol. 5 No. 2, pp. 182-188.

Formoso, C.T., (M.ASCE), L.S., Cesare, C.D. and Isatto, E.L. (2002). "Material Waste in Building Industry: Main Causes and Prevention," *J. Constr. Eng. Manage.*, ASCE, Vol. 128 No. 4, pp. 316-325.

Formoso, C.T., Isatto, E.L. and Hirota, E.H. (1999). "Method for Waste Control in the Building Industry," *Proceedings of the 7th Annual Conference of the IGLC*, Berkeley, pp. 325-334.

Forsberg, A. and Saukkoriipi, L. (2007). "Measurement of Waste and Productivity in Relation to Lean," *Proceedings of the 15th Annual Conference of the IGLC*, Michigan, Vol. 46, pp. 67-76.

Gara, G.L., Anis, A.R. and Gammal, A.E. (2001). "Materials Waste in the Egyptian Construction Industry," *Proceedings of the 9th Annual Conference of the IGLC*, Singapore, pp. 1-8.

Gavilan, R.M. and Bernold, L.E. (1994). "Source evaluation of solid waste in building construction," *J. Constr. Eng. Manage.*, Vol. 120 No. 3, pp. 536-552.

Han, S., Lee, S. and Peña-Mora, F. (2011). "Identification and Quantification of Non-Value Adding Effort Due to Errors and Changes in Design and Construction Projects," *J. Constr. Eng. Manage.*, ASCE, Vol. 1 No. 1, p. 291.

Horman, M.J. and Kenley, R. (2005). "Quantifying Levels of Wasted Time in Construction with Meta-Analysis," *J. Constr. Eng. Manage.*, ASCE, Vol. 131 No. 1, pp. 52-61.

Howell, G. (2011), "New Operating System for Project Management: Consequences and Opportunities," *J. Constr. Eng. Manage.*, ASCE, Vol. 137 No. 10, pp. 882-886.

Hwang, B.-G., Thomas, S.R., Haas, C.T. and Caldas, C.H. (2009). "Measuring the Impact of Rework on Construction Cost Performance," *J. Constr. Eng. Manage.*, ASCE, Vol. 135 No. 3, pp. 187-198. doi:10.1061/(ASCE)0733-9364(2009)135:3(187)

Kalsaas, B.T. (2010). "Work-Time Waste in Construction," *Proceedings of the 18th Annual Conference of the IGLC*, pp. 507-517.

Koskela, L. (1992), *Application of the New Production Philosophy to Construction*, Finland, p. 81.

Koskela, L. (2004). "Making do-the eighth category of waste," *Proceedings of the 12th Annual Conference of the IGLC*, Elsinore, pp. 1-10.

Koskenvesa, A., Koskela, L., Tolonen, T. and Sahlstedt, S. (2008). "Waste and Labor productivity in Production Planning," *Proceedings of the 16th Annual Conference of the IGLC*, Haifa, pp. 477-486.

Koushki, P.A. and Kartam, N. (2004). "Impact of construction materials on project time and cost in Kuwait," *Engineering, Construction and Architectural Management*, Emerald Group Publishing Limited, Vol. 11 No. 2, pp. 126-132.

Lapinski, A.R., Horman, M.J. and Riley, D.R. (2006). "Lean Processes for Sustainable Project Delivery," *J. Constr. Eng. Manage.*, ASCE, Vol. 132 No. 10, pp. 1083-1091.

Ledbetter, W B. (1994), "Quality Performance on Successful Project," *J. Constr. Eng. Manage.*, ASCE, Vol. 120 No. 1, pp. 34-46. doi:10.1061/(ASCE)0733-9364(1994)120:1(34)

Leong, M.S. and Tilley, P. (2008). "A Lean Strategy to Performance Measurement – Reducing Waste by Measuring ' Next ' Customer Needs," *Proceedings of the 16th Annual Conference of the IGLC*, Manchester, pp. 757-768.

Love, P. (2002). "Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects," *J. Constr. Eng. Manage.*, ASCE, Vol. 128 No. 1, pp. 18-29.

Love, P. and Edwards, D.J. (2004). "Determinants of rework in building construction projects," *Engineering, Construction and Architectural Management*, Emerald Group Publishing Limited, Vol. 11 No. 4, pp. 259-274.

Love, P. and Li, H. (2000). "Quantifying the causes and costs of rework in construction," *Constr. Mgmt and Econ.*, Vol. 18 No. 4, pp. 479-490.

Love, P., Mandal, P and Li, H. (1999), "Determining the causal structure of rework influences in construction," *Constr. Mgmt and Econ.*, Vol. 17 No. 4, pp. 505-517.

Love, P., Mandal, Purnendu, Smith, J. and Li, H. (2000), "Modelling the dynamics of design error induced rework in construction," *Constr. Mgmt and Econ.*, Vol. 18 No. 5, pp. 567-574. doi:10.1080/014461900407374

Love, P. and Smith, J. (2003). "Benchmarking, Benchaction, and Benchlearning: Rework Mitigation in Projects," *J. Manage. Eng.*, ASCE, Vol. 19 No. 4, pp. 147-159.

Macomber, H. and Howell, G. (2004). "The Two Great Wastes," *Proceedings of the 12th Annual Conference of the IGLC*, Elsinore.

Mao, X. and Zhang, X. (2008). "Construction Process Reengineering by Integrating Lean Principles and Computer Simulation Techniques," *J. Constr. Eng. Manage.*, ASCE, Vol. 134 No. 5, pp. 371-381.

Monden, Y. (1983). *Toyota production system: Practical approach to production management.*, Industrial Engineering Management, p. 247.

Nahmens, I. and Ikuma, L.H. (2011). "Effects of Lean on Sustainability of Modular Homebuilding," *J. Archit. Eng*, ASCE, Vol. 1 No. 1, p. 25.

Nahmens, I. and Mullens, M.A. (2011). "Lean Homebuilding: Lessons Learned from a Precast Concrete Panelizer," *J. Archit. Eng*, Vol. 17 No. 4, p. 155.

Ohno, T. (1988), *Toyota production system*, Cambridge, Mass., Productivity Pr.

Park, M., Yang, Y., Lee, H.-S., Han, S. and Ji, S.-hyun. (2011). "A Floor-Level Construction Material Layout Planning Model Considering Actual Travel Path," *J. Constr. Eng. Manage.*, ASCE, Vol. 1 No. 1, p. 363.

Petticrew, M. (2001). "Systematic reviews from astronomy to zoology: myths and misconceptions," *Bmj*, Vol. 322 No. 7278, pp. 98-101. doi:10.1136/bmj.322.7278.98

Polat, G. and Ballard, G. (2004), "Waste in Turkish Construction: Need for Lean Construction Techniques," *Proceedings of the 12th Annual Conference of the IGLC*, Elsinore, pp. 3-5.

Poon, C.S., Yu, A.T.W., Wong, S.W. and Cheung, E. (2004). "Management of construction waste in public housing projects in Hong Kong," *Construction Management & Economics*, Taylor & Francis, Vol. 22 No. 7, pp. 675-689.

Porwal, A. and Hewage, K.N. (2011). "Building Information Modelling Based Analysis to Minimize Waste Rate of Structural Reinforcement," *J. Constr. Eng. Manage.*, ASCE, Vol. 1 No. 1, p. 376.

Sacks, R., Esquenazi, A. and Goldin, M. (2007). "LEAPCON: Simulation of Lean Construction of High-Rise Apartment Buildings," *J. Constr. Eng. Manage.*, ASCE, Vol. 133 No. 5, pp. 374-384.

Senaratne, S. and Sexton, M.G. (2009), "Role of knowledge in managing construction project change," *Engineering, Construction and Architectural Management*, Emerald Group Publishing Limited, Vol. 16 No. 2, pp. 186-200.

Skoyles, E.R. (1976), "Materials wastage – a misuse of resources," *Batiment International, Building Research and Practice*, Vol. 4 No. 4, p. 232.

Tommelein, I.D.I.D., Riley, D.R.D.R. and Howell, G. (1999), "Parade Game: Impact of Work Flow Variability on Trade Performance," *J. Constr. Eng. Manage.*, ASCE, Vol. 125 No. 5, pp. 304-310.

Wan, S.K.M. and Kumaraswamy, M.M. (2009), "Industrial management approaches for improving material control in building services works," *Engineering, Construction and Architectural Management*, Emerald Group Publishing Limited, Vol. 16 No. 3, pp. 208-223.

Womack, J.P. and Jones, D.T. (2004). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Free Press, p. 396.

Yu, H., Tweed, T., Al-Hussein, M. and Nasseri, R. (2009). "Development of Lean Model for House Construction Using Value Stream Mapping," *J. Constr. Eng. Manage.*, ASCE, Vol. 135 No. 8, pp. 782-790.

Zhao, Z.Y., Lv, Q.L., Zuo, J. and Zillante, G. (2010). "Prediction System for Change Management in Construction Project," *J. Constr. Eng. Manage.*, ASCE, Vol. 136 No. 6, pp. 659-669.