Arroyo, P. and Gonzalez, V. 2016. "Rethinking Waste Definition to Account for Environmental and Social Impacts." In: *Proc. 24rdAnn. Conf. of the Int'l. Group for Lean Construction*, 20-22 July, Boston, MA, USA, sect.10 pp. 13-22, Available at: <www.iglc.net>.

RETHINKING WASTE DEFINITION TO ACCOUNT FOR ENVIRONMENTAL AND SOCIAL IMPACTS

Paz Arroyo[1] and Vicente Gonzalez[2]

ABSTRACT

Onho´s types of waste have been used in lean construction as guidelines. However, we argue that the lean construction community should question and rethink the definition of waste, and update the types of wastes in order to account not only for the production/economic impacts from design and construction, but also their environmental and social impacts. This paper provides insights about this issue and a literature review pertaining types of environmental and social waste derived from the construction industry.

We think that the transformation and value flow also needs to account not only for the products derived from the design and manufacturing process, but also needs to account for the inputs, such as energy and water as well as the by-products, such as air emissions, contamination of water, and soil. Finally, we think that more research is needed in this area, in order to extend the positive impacts of applying combined lean and sustainable principles in construction.

KEYWORDS

Waste, sustainability, lean.

INTRODUCTION

This paper deals with understanding waste as a broader concept that should consider sustainability. Onho´s types of waste have been used in lean construction as guidelines. However, we argue that the lean construction community should question and rethink the definition of waste, and update the types of waste in order to account not only for the production/economic impacts from design and construction, but also their environmental

[1] Assistant Professor. Pontificia Universidad Católica de Chile, Chile. Phone +56 22354-4244, parroyo@ing.puc.cl.

[2] Senior Lecturer, Department of Civil and Environmental Engineering, The University of Auckland, New Zealand. E-Mail: v.gonzalez@auckland.ac.nz.

and social impacts. This paper provides insights about this issue and a literature review pertaining types of environmental and social waste derived from the construction industry.

CURRENT WASTE DEFINITIONS

Waste in construction has received much attention by industry and academia (Rahman et al., 2012; Viana et al., 2012). Project managers have been often inclined to conceptualize "waste" as physical construction waste (Wong et al., 2012). From a lean construction standpoint, waste represents resources or activities that are time and cost consuming, but creates no value (Koskela, 1992). Thus, it is about the elimination of all non-value-added steps in a process. The elimination of waste through the application of lean principles has well-known and positive impacts on cost savings and productivity in projects (Fliedner, 2008).

The lean concept incorporates the flow and value angles to production. A smooth process flow can increase value to the customer by minimizing waste. Inefficiencies in the flow of work (Koskela, 1992) may result in production waste (Ohno, 1998).

Ohno (1998) defines the following types of waste for production: Overproduction, Rework, Material Movement, Processing, Inventory, Waiting and Motion. In addition, Liker and Meyer (2006) add a new type of waste: Unused employee creativity: Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to employees. From a construction standpoint, production waste such as waiting times may happen due to the delay of a previous activity, inefficient space allocation, low productivity of a crew, deficient or insufficient equipment, delay in information flow, unavailability of material and external situations such as heavy downpour. Relatively, shortage of material may cause waiting, overproduction of other activities and defective output if less favored material were used to replace the current unavailable material. It has been claimed that each of the mismanaged flows may affect different types of production waste and it varies across different projects (Belayutham and Gonzalez, 2013). According to Viana et al. (2012)'s review on construction waste, all those wastes can be characterised into the traditional production waste.

However, the type of waste, including its impacts, that has not been considered in the common production waste definition is the environmental waste (Belayutham and Gonzalez, 2013). Environmental waste could be defined as the excessive use of resources that results in affluence released into the air, water or land that may endanger people and also the environment (US EPA 2007). From a lean standpoint, environmental waste does not add value instead increases cost through the excessive consumption of resources. This concept is similar to lean whereby lean waste also does not add value to the customer; in turn it elevates cost and time to the end user. In theory, production waste may cause environmental waste. However, the difficulty in relating both lean and environment is due to the fact that environmental waste is not the focus of improvement in traditional lean management (Belayutham and Gonzalez, 2013).

On the other hand, most management approaches in construction are technically-oriented methodologies focused on project and contract management, neglecting central social aspects related to peoples' behaviour both in individual and collective domains (Pavez and Alarcón, 2007). Lean thinking has been applied systematically to construction over 20 years (Alarcón et al. 2008), but implementation has largely focused on technical aspects rather than on the human and social aspects of projects (Pavez and Alarcón, 2007). Notwithstanding research of various social matters within the lean construction community, little research has been undertaken to understand the interactions between lean thinking and the social behaviour in a construction organization (González et al. 2015). Therefore, it can be argued that the classical definition of production waste from a lean standpoint also neglects the social dimension.

RESEARCH QUESTIONS AND METHODOLOGY

This research answers the following questions:

- What types of waste have been considered in previous studies dealing with sustainability and lean?
- What other types of wastes maybe incorporated to lean construction philosophy to account for social and environmental wastes?
- Are we reducing environmental and social wastes when removing Onhos´ wastes?

In order to answer the first question we have done a literature review using lean construction research in order to understand previous work trying to link sustainability and lean construction. To answer the second question we searched for literature outside of lean construction network in order to look for advice to incorporate other types of wastes related to sustainability in design and construction practice. Finally, to answer the third question we look at two previous case studies where researchers or practitioners have been focused on removing Onhos's wastes and we analysed whether or not other environmental and social wastes identified in this study have also been removed.

PREVIOUS WORK

Table 1 shows a literature review undertaken over recently published lean construction papers from the IGLC and journals matching with the terms "construction process", "waste generation" and "lean". This literature review does not aim to be exhaustive, but a sample of the trends in the investigation of waste from a lean construction perspective. Also, this provides insight on to what extent the lean thinking and the concept of waste is extensive to the environmental and social domains. It is observed that the majority of lean construction research deals with production waste in the first place, some on the linkages between production and environmental waste, and none on the impacts on the social dimension.

Table 1: Waste in lean construction research.

Authors	Title	Type of waste
Nikakhtar, A., A. Hosseini, K. Wong, and A. Zavichi (2015).	Application of lean construction principles to reduce construction process waste using computer simulation: a case study	Production waste
Mao, X., & Zhang, X. (2008).	Construction process reengineering by integrating lean principles and computer simulation techniques.	Production waste
Hosseini, A., Nikakhtar, A. and Ghoddousi, P. (2012).	Flow production of construction processes through implementing lean construction principles and simulation	Production waste
Nordin, N., Md Deros, B., A bdul Wahab, D. and Ab Ra hman, M.N. (2012).	A framework for organizational change management in lean manufacturing implementation	Production and environmental waste
Bertelsen, S., and L. Koskela.(2004).	Construction Beyond Lean: A New Understanding of Construction Management	Production waste
Alazmi. S., Belayutham. S., Rahman,A., and Vicente. G. (2013).	Integration of Production and Environmental Waste: A Theoretical Exploration	Production and environmental waste
Belayutham, S., González, V. A. and Yiu, T. W. (2015).	Clean-Lean Administrative Processes: A Case Study on Sediment Pollution During Construction.	Production and environmental waste
Sacks, R., Koskela, L., Dave, B., and Owen, R. (2010).	Interaction of Lean and Building Information Modelling in Construction	Production waste
Golzarpoor, H. and González, V. (2013).	A Green-Lean Simulation Model for Assessing Environmental and Production Performance in Construction	Production and environmental waste
Banawi, A. (2013).	IMPROVING CONSTRUCTION PROCESSES BY INTEGRATING LEAN, GREEN, AND SIX-SIGMA	Production and environmental waste
Hosseini, S.A.A, Nikakhtar, A, Wong, K.Y, & Zavichi, A. 2012.	Implementing Lean Construction Theory to Construction Processes' Waste Management	Production and environmental waste
Rosenbaum, S., Toledo, M., and González, V. (2014).	Improving environmental and production performance in construction projects using Value-Stream Mapping: Case Study	Production and environmental waste
Ghosh, S. , Bhattacharjee, S. , Pishdad-Bozorgi, P. & Ganapathy, R. (2014).	'A Case Study to Examine Environmental Benefits of Lean Construction	Production and environmental waste (CO_2 emissions)
Saurin, T.A. , Formoso, C.T. & Guimaraes, L.B.D.M. (2001),	Integrating Safety Into Production Planning and Control Process: An Exploratory Study	Production and Social waste
Saurin, T.A. , Formoso, C.T. , Guimaraes, L.B. & Soares, A.C. (2002),	"Safety and Production - An Integrated Planning and Control Model"	Production and Social waste

ENVIRONMENTAL AND SOCIAL WASTES

Literature from other fields have accounted for environmental and social impacts on construction industry, especially literature related to life cycle assessment (LCA) and social impact assessment (SIA).

LCA accounts for environmental aspects of construction (ISO 14040). "LCA is a method that attempts to systematically quantify the environmental effects of the various stages of a product's or a process' entire life cycle: materials extraction, manufacturing / production, use / operation, and ultimate disposal or end-of-life" (Pacca and Horvath 2001). Some of the impacts can also be stated as wastes, since they are the byproduct of fabricating building materials, transporting them or assembly them on site, and these impacts do not provide value for the customers. For example, building users, do not value the CO_2 emissions that resulted from manufacturing concrete. In summary, some wastes that are needed in order to account for environmental impacts of construction industry are:

Table 2: Environmental wastes from the literature.

Waste	Description
Air emissions	Accounts for all gases that are emitted to the air and can affect the environment or human health (EPA 2015). For example, global warming (CO_2, CH_4, N_2O, NO_2, CFC-11, CFC-12), stratospheric ozone depletion (CFC-11, CFC-12, CFC-113), photochemical ozone formation (VOC and NO_x), acidification (NO_x and SO_2).
Solid Waste	Accounts for materials are unwanted or unusable. For example, municipal waste (household waste, commercial waste, and demolition waste) and hazardous waste includes industrial waste (EPA 1998).
Waste water	Accounts for any water that has been adversely affected in quality by anthropogenic influence. Wastewater can originate from a combination of domestic, industrial, commercial or agricultural activities, surface runoff or stormwater, and from sewer inflow or infiltration (Tilley et al. 2014).
Noise disturbance	Accounts for any sound or vibration which: may disturb or annoy reasonable persons of normal sensitivities or; causes, or tends to cause, an adverse effect on the public health and welfare or; endangers or injures people or; endangers or injures personal or real property. This can also be defined as noise nuisance (Hogan and Latshaw 1973).
Over Illuminating	Accounts for the presence of lighting intensity higher than that which is appropriate for a specific activity (Simpson, 1990).
Excess of soil use	Accounts for the use of soil for the built environment, which prevents the use of that soul for animal's habitat (RCCAO 2012).

SIA accounts for the consideration of social aspects in corporate and public work. "SIA is the process of identifying the future consequences of a current or proposed action which are related to individuals, organizations and social macro-systems" (Becker 2001). Geibler et al. (2006) provides a comprehensive list showing the experience from the biotechnology industry. Some of the environmental waste may have social impacts too, such as air emissions and water scarcity but here we have listed the wastes directly related to social needs. We have identified wastes that can be easily found in the construction industry, such as:

Table 3: Social wastes from the literature.

Waste	Description
Lack of health	Accounts for wastes due to professional diseases, associated with performing a job. For example: risk for manipulating toxic substances (Geibler et al. 2006).
Lack of safety	Accounts for wastes produced by accidents and incidents that may happen in a job (Geibler et al. 2006).
Suboptimal working conditions	Accounts for wastes produced by not providing adequate tools, materials, spaces, ergonometric, and knowledge to perform a job (Geibler et al. 2006).
Lost of employment	Accounts waste of for not creating jobs, creating jobs that do not have continuity, or creating jobs in an area that may needed it less than other area (Geibler et al. 2006).
Lack of education and trainee	This refers to the waste that arises when people have a lack of training or education to perform their task, but also refers to the lack of professional growth (Geibler et al. 2006).
Knowledge not capitalized	Accounts for the lost of knowledge or know how of a company, maybe do to poor information systems, high personnel rotation, poor quality of personal knowledge exchange, poor review of personal knowledge exchange, low employee involvement in decision making (Geibler et al. 2006).
Unused innovation	Accounts for wasting employee creativity (Liker and Meyer, 2006). This may lead to losing improvement ideas and disappointment of employees.
Underestimating social acceptance	Accounts for wastes due to lack of client and stakeholder involvement, and lack of contribution to societal benefits (Geibler et al. 2006).
-Lack of societal dialogue	Accounts for wastes generated due to lack of dialogue with stakeholders involved in a project, such as lack of reporting activities, lack of communication with local community, lack of stakeholder involvement in decision making, and lack of engagement in political dialogue (Geibler et al. 2006).

Sustainability, in the beginning, considered people at the core of the concept according to the Brundtland Commission. Over time, however, it has been overlooked to pay more attention to the environmental and economic aspects of sustainability. In fact, social sustainability is often conceived as the mere indirect effect of the economic and environmental dimensions of sustainability. However, social sustainability is more than the improvement of some social variables such as improving the workplace climate or decreasing the environmental noise in a neighbour resulting from some industrial activity. It involves the overall social wellbeing (Brain, 2016)

These wastes presented in the literature are only a short list of what may be environmental and social wastes in construction. Some of them have been already introduced in previous studies in the IGLC, especially environmental wastes such as air emissions and solid wastes, and social wastes related to safety in construction. However, most of them are not traditionally included in the lean construction literature. In addition, lean research is often focused on the construction phase and do not considers all project´s lifecycle stages to quantify social and environmental wastes, while a significant amount of wastes are produced in the materials extraction, manufacturing, and operation stages of a construction project.

ANALYSIS OF TWO CASE STUDIES

In this section we provide a brief discussion of previous case studies that have attempted to measure the environmental or social benefits of applying lean construction principles and/or tools to eliminate waste. We have analysed two case studies, previously developed by the authors, where Onhos's wastes have been removed and we analysed wether or not other social and environmental wastes were removed. The studies analysed are presented as follows:

- Golzarpoor and Gonzalez (2013) developed a green-lean simulation model for assessing environmental and production waste in construction. In this research, the reduction of several lean production wastes were studied such as transportation and inventory (batch size) by simulating an earthmoving operation. While the reduction of waste in most cases decreased environmental waste such emissions, there were some cases in which the only variable affected was production by reducing costs and time, with no significant improvements on the generation of emission, and accordingly consumption of energy. It seems to be that there is a necessary trade-off between production and environmental performance in construction (Gonzalez and Echaveguren, 2012), which is not explicitly considered in lean-based management approaches used in this sector negatively affecting environment.
- Fuenzalida et al. (2016) applied lean tools to reduce Onhos's wastes in a construction project, specifically analysing the ceramic installation trade. In this study it is found that the reduction of Onhos's wastes also lead to a reduction of material waste that can be translated into less CO_2 emissions due to less material wasted. However, this study does not consider all environmental wastes as other ceramic material could be used to minimize CO_2 emissions during fabrication, or other air emissions. In addition, this study does not report on reduction of social wastes such as improving suboptimal working conditions.

In light of the previous examples, we argue that we are not necessarily reducing environmental or social wastes when reducing Onho´s types of waste. For example, when constructing a building we can do it very efficiently using continuous workflow and using innovative human action. However, we may not take care of the operation of the building and how air emissions will undertake in the next 50 or 100 years after construction is done. Also, when reduction of batch size strategies (e.g. JIT) is introduced some negative environmental externalities may emerge as a result of increased transportation, and accordingly, more energy and emissions could be generated. No mention to the social impacts is made, which is the corollary of systematically neglecting this aspect in the waste reduction research within the lean construction community.

CONCLUSIONS

In this research we have been able to summarized what types of waste have been considered in previous studies dealing with sustainability and lean (Table 1), and we have found mainly that several studies have measured environmental wastes such as: air emissions, and solid wastes. Other studies have considered social wastes mainly focusing on safety. Through the literature review we have provided a list of other wastes (Table 2 and 3) that maybe incorporated to lean construction philosophy to account a broader definition of wastes considering environmental, social, and economic needs. Finally, when analysing the two case studies we argue that environmental and social wastes may or may not be removed when removing Onhos´ wastes. Therefore, as a community we required more research and understanding of a broader list of waste to eliminate and to account for this wastes in all project´s lifecycle stages.

ACKNOWLEDGMENTS

The authors would like to gratefully acknowledge the University of XX and YY for its support in this research.

REFERENCES

Alarcón, L. F., Diethelm, S., Rojo, O. and Calderón, R. (2008). Assessing the Impacts of Implementing Lean Construction. *Rev. Ing. Const.*, 23(1), 26-33.

Alazmi. S., Belayutham. S., Rahman,A., and Vicente. G. (2013). INTEGRATION OF PRODUCTION AND ENVIRONMENTAL WASTE: A THEORETICAL EXPLORATION. AUBEA 38th. The University of Auckland, New Zealand

Banawi, A. A. (2013). Improving construction processes by integrating lean, green, and six-sigma (Doctoral dissertation, University of Pittsburgh).

Belayutham, S., González, V. A. and Yiu, T. W. (2015). Clean-Lean Administrative Processes: A Case Study on Sediment Pollution During Construction. Journal of Cleaner Production http://dx.doi.org/10.1016/j.jclepro.2016.02.091 (Accepted).

Belayutham, S. and González, V. (2013), Integrating Lean into Storm water Runoff Management: A Theoretical Exploration, In: Formoso, C.T. and Tzortzopoulos, P., 21st Annual Conference of the International Group for Lean Construction. Fortaleza, Brazil, 31-2 Aug 2013. pp 875-884.

Bertelsen, S., & Koskela, L. (2004, July). Construction beyond lean: a new understanding of construction management. In Proceedings of the 12 th annual conference in the International Group for Lean Construction.

Brain, J. (2016). The social side of sustainability. Downloaded 21-4-16. https://www.planning.org.nz/Folder?Action=View%20File&Folder_id=185&File=Brain.pdf

Fliedner, G. (2008). Sustainability: a new lean principle. Paper presented at the 39th Annual Meeting of the Decision Sciences Institute, Baltimore, Maryland.

Ghosh, S. , Bhattacharjee, S. , Pishdad-Bozorgi, P. & Ganapathy, R. (2014), "A Case Study to Examine Environmental Benefits of Lean Construction" In:, Kalsaas, B.T., Koskela, L. & Saurin, T.A., 22nd Annual Conference of the International Group for Lean Construction. Oslo, Norway. pp 133-144

Golzarpoor, H. and González, V. (2013). A Green-Lean Simulation Model for Assessing Environmental and Production Performance in Construction. Proceedings 21st International Conference for Lean Construction, Fortaleza, Brazil, 29th July – 4th August.

González, V. A., Sacks, R., Pavez, I., Poshdar, M., Priven, V. and Ben Alon, L. (2015). Interplay of Lean Thinking and Social Dynamics in Construction. Proceedings 23rd International Conference for Lean Construction, Perth, Western Australia, 28th – 21st July.

González, V. and Echaveguren, T. (2012). Exploring the Environmental Modeling of Road Construction Operations using Discrete-Event Simulation. Automation in Construction. Vol. 24, pp. 100-110 (July).

Hogan, C.M. and Latshaw, G.L., (1973), May. The relationship between highway planning and urban noise. In Proceedings of the ASCE Urban Transportation Division Environment Impact Specialty Conference, May 21-23, 1973, Chicago, Illinois.

Hosseini, S. A., Nikakhtar, A., & Ghoddousi, P. (2012). Flow production of construction processes through implementing lean construction principles and simulation. International Journal of Engineering and Technology, 4(4), 475.

Hosseini, S.A.A, Nikakhtar, A, Wong, K.Y, & Zavichi, A. 2012. Implementing Lean Construction Theory to Construction Processes' Waste Management.

Koskela, L. (1992). Application of the new production philosophy to construction (Vol. 72): Stanford University (Technical Report No. 72, Center for Integrated Facility Engineering, Department of Civil Engineering). Stanford, CA.

Mao, X., & Zhang, X. 2008. 'Construction process reengineering by integrating lean principles and computer simulation techniques', Journal of Construction Engineering and Management, 134(5), 371-381.

Nikakhtar, A., Hosseini, A. A., Wong, K. Y., & Zavichi, A. (2015). Application of lean construction principles to reduce construction process waste using computer simulation: a case study. International Journal of Services and Operations Management, 20(4), 461-480.

Ohno, T. (1988). Toyota production system-Beyond large scale production. Productivity Press, New York, USA.

Rahman, H. A., Wang, C., & Lim, I. Y. W. (2012). Waste Processing Framework For Non-Value-Adding Activities Using Lean Construction. Journal of Frontiers in Construction Engineering.

RCCAO (2012). "Best Management Practices for Handling Excess Construction Soils in Ontario" http://rccao.com/news/files/RCCAO_NOV2012.pdf

Rosembaun, S., Toledo, M. and González, V. (2013). Improving Environmental and Production Performance in Construction Projects using the Value Stream Mapping: A Case Study. Journal of Construction Engineering and Management, ASCE, Vol.140, N°2, pp. 1-11, ISSN 0733-9364/04013045(11).

Saurin, T.A. , Formoso, C.T. & Guimaraes, L.B.D.M. (2001), "Integrating Safety Into Production Planning and Control Process: An Exploratory Study' In:, Ballard, G. &

Chua, D., 9th Annual Conference of the International Group for Lean Construction.Singapore, Singapore, 6-8 Aug 2001.

Saurin, T.A. , Formoso, C.T. , Guimaraes, L.B. & Soares, A.C. (2002), "Safety and Production - An Integrated Planning and Control Model" In:, Formoso, C.T. & Ballard, G., 10th Annual Conference of the International Group for Lean Construction. Gramado, Brazil, 6-8 Aug 2002.

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). Interaction of lean and building information modeling in construction. Journal of construction engineering and management, 136(9), 968-980.

Simpson, M.D. (1990). A Flexible Approach To Lighting Design. Proceedings of the CIBSE National Lighting Conference Cambridge, England April 8-11 1990. pp. 182-189. London, U.K. Chartered Institute of Building Services Engineers.

US EPA (1998) "Characterization of Building-Related construction and Demolition Debris in the United States" http://goo.gl/jeG4IK

US EPA. (2007). "The lean and environment toolkit." http://www.epa.gov/lean/environment/toolkits/environment/resources/LeanEnviroToolkit.pdf

US EPA (2015). "National Air Toxics Assessment" https://www.epa.gov/national-air-toxics-assessment/nata-glossary-terms

"Viana, D. D., Formoso, C. T., & Kalsaas, B. T. (2012). Waste in Construction: A Systematic Literature Review on Empirical Studies. Paper presented at the 20th Annual Conference of the International Group for Lean Construction, San Diego, USA.

Wong, K. Y., Hosseini, S. A. A., Nikakhtar, A., & Zavichi, A. (2012). Implementing Lean Construction Theory into Construction Processes' Waste Management. In ICSDC 2011 (pp. 414-420).

Ghosh, S. , Bhattacharjee, S. , Pishdad-Bozorgi, P. & Ganapathy, R. 2014, 'A Case Study to Examine Environmental Benefits of Lean Construction' In:, Kalsaas, B.T., Koskela, L. & Saurin, T.A., 22nd Annual Conference of the International Group for Lean Construction. Oslo, Norway, 25-27 Jun 2014. pp 133-144