

House of Waste and its Implication for Project Management

Charles Igwe¹, Alireza Mohammadi², Fuzhan Nasiri³ and Amin Hammad⁴

¹Phd Student, Department of Building, Civil & Environmental Engineering, Concordia University, H3G 2W1 Montreal, Quebec; c_igwe@encs.concordia.ca

²Phd Student, Department of Building, Civil & Environmental Engineering, Concordia University, H3G 2W1 Montreal, Quebec; areza.moh@gmail.com

³Assitant Professor, Department of Building, Civil & Environmental Engineering, Concordia University, H3G 2W1 Montreal, Quebec; fuzhan.nasiri@concordia.ca

⁴Professor, Concordia Institute for Information Systems Engineering, Concordia University, H3G 2W1 Montreal, Quebec; hammad@ciise.concordia.ca

ABSTRACT

The ability of construction projects in satisfying the key performance indicators of time, quality and cost have long been the subject of concern to industry practitioners and the academia over the years. Many project management tools, techniques, and processes have been suggested as means of managing projects to ensure that they better meet the expectations of stakeholders, but these have not been entirely successful in improving value due primarily to the prevalence of waste. The underlying principle of lean thinking in construction is to enhance value through the elimination of waste. This study focuses on categorizing the lean wastes based on the transformation-flow-value theory and prioritizing them using the analytical hierarchy process (AHP). A new concept called the house of wastes was introduced to elucidate the interconnection of the lean waste. The goal of this research is to identify and rank the parameters required to facilitate waste reduction to improve the management of construction projects.

Keywords: Lean construction, waste, project management, AHP

INTRODUCTION

The ability of construction projects in satisfying the key performance indicators of time, quality and cost have for long been the subject of concern to industry practitioners and the academia over the years. The manufacturing industry, when compared to the construction industry, has recorded better performance in terms of productivity, flow, quality control, waste elimination and value generation by adopting a new production philosophy tagged “Lean Manufacturing” which was adapted from the Toyota production system (TPS) made famous by the Japanese auto industry. The focus of the lean enterprise is to ensure that the project delivers value to the project stakeholders by making certain that wastes are eliminated through a systematic approach based on transparent information flow and collaboration. Aziz and Hafez (2013), however, asserted that

the presence of waste has negatively affected the performance and overall productivity in the construction industry. To increase the productivity of the industry, it was suggested to transfer some lean manufacturing principles, tools, and techniques to construction.

The attempt to transfer the principles of lean manufacturing to construction was first proposed by Koskela (1992). It is based on the philosophy that rejects all kind of wastes (Waste in this instance is regarded as any non-value activity). According to Howell and Ballard (1997), lean thinking lays emphasis on value generation, Fewings (2013) asserted that lean thinking goes beyond seeking to eliminate waste but also extends its focus on value delivery to the client starting from the design through to the handover of a project. Lean thinking creates a means for specifying value and differentiates value adding from non-value adding activities and helps in the sequential arrangement of value-adding activities (Womack and Jones 2010). The main thrust behind lean thinking is the reduction, and eventual elimination of waste. Although there has been considerable number of research with respect to waste in the construction industry, there has been little attempt to prioritize these wastes in terms of its association with transformation activities, flow aspect of production and the role management activities play in the generation and elimination of waste.

The classification and prioritization of waste are important factors in its identification and elimination as this helps us to aggregate and rank the wastes in order of importance to be able to properly focus intervention measures. The objectives of this research are to classify and prioritize wastes based on the transformation-flow-value principle and highlight the interdependence of the lean waste using “the house of waste”, to better understand its implication for project management.

LITERATURE REVIEW

Lean construction was first discussed by Koskela (1992) who investigated what he referred to “the new production philosophy and its application to construction” and he went further to claim that the attempt to improve the construction processes will continue to fall short of the desired results due to the absence of a general theory of production. He posited that three fundamental elements (transformation, flow, and value) need to be added to a production theory for the gains of the lean production system in manufacturing to have any meaning for construction (Koskela 2000).

Lean construction has continued to evolve over the years and the lean construction literature is characterized by a lack of commonly used definitions to aptly capture its meaning. According to Emmitt (2014), lean construction has far-reaching interpretations that range from definitions which include design and construction activities to very limited interpretations related to precise functions and/or applications. Emmitt (2014) proposed a simple definition of lean and asserted that lean construction is a production system designed in a way to reduce waste of materials, time and effort to facilitate the creation of maximum value. Lean construction refers to the application and adaptation of the concepts and principles of the TPS to construction (Sacks et al. 2010) and places emphasis on reduction of non-value activities otherwise referred to as waste as a means of value improvement. Green and May (2005) asserted that lean construction can be regarded as consisting of a set of techniques, a social-technical paradigm or a cultural commodity that can be directly applied to construction while Koskela

et al. (2002) claimed that lean construction represents a way to design production systems to discourage, minimize and eventual eliminate waste of materials, time and effort to facilitate the generation of maximum value. Aziz and Hafez (2013) contended that lean construction has altered the traditional view of a project by embracing the concepts of flow and value generation. Regardless of the different definitions of “lean” there exist two common features in all the school of thoughts on lean and these are: reduction/elimination of waste and focus on value as defined by the client.

The concept and application of lean thinking

The reduction and eventual elimination of waste is the main idea behind lean thinking. It is based on the philosophy that rejects all kind of wastes. According to Howell and Ballard (1997), lean thinking lays emphasis on value generation, Fewings (2013) asserted that lean thinking goes beyond seeking to eliminate waste but also extends its focus on value delivery to the client starting from the design through to the handover of a project. Lean thinking creates a means for specifying value and differentiates value adding from non-value adding activities and helps in the sequential arrangement of value-adding activities (Womack and Jones 2010). The principles of lean thinking in production are based on different management philosophies like Just-In-Time (e.g. lot size reduction, cellular manufacture, continuous flow, etc.) Total Preventive Maintenance (preventive maintenance, maintenance optimization, corrective maintenance, maintenance scheduling, and strategies), Total Quality Management (benchmarking, quality management, continuous improvement, process measurement) and Human Resource Management (workforce diversity and flexibility). According to Koskela (2000), the principles of lean thinking are based on (i) reduction in the share of non-value activities; (ii) reduction in the lead time and variability and (iii) increased flexibility, transparency, and simplicity of operations. The five main principles of lean thinking as highlighted by Womack and Jones (2010) includes (i) value, (ii) value stream, (iii) flow, (iv) pull and (iv) continuous improvement. The application of the lean principles is geared towards creating value for the project stakeholders by ensuring that the share of non-value adding activities is reduced.

Transformation-Flow-Value model of production

Koskela (1992) proposed a means for adapting lean production concepts into construction and suggested three ways through which this can be attempted, namely: (1) Transformation; (2) Flow; and (3) Value generation (TFV) theory of production. This three-way view of production subsumes the transformation dominated construction management (Bertelsen and Koskela 2002; Koskela et al. 2002) and is one of the basic criteria for the implementation of lean construction. There are three basic features involved in production. The first has to do with the transformation of input into output. This input may be in the form of labor, equipment, and materials needed to convert raw materials into the finished product. The second feature is “flow” and concerns activities along the value chain such as transportation, storage, waiting and inspection. The third feature of production involves meeting the customer's expectation by ensuring that the final product conforms to the client requirements. These three features of production are encapsulated in the TFV model which regards construction as a transformation process.

A closer review of the TFV model shows the relationships between a project's key performance indicators (KPI's) of cost, quality and time. The transformation process of the model facilitates the reduction of project costs by ensuring the minimization of the cost of subprocesses. The flow view process reduces the time to completion of a project through the elimination and/or reduction of non-value adding activities while the value generation view aims at ensuring that the project quality requirements are achieved using the least functional cost ratio. The TFV model provides an important criterion for lean construction. Tezel (2011), however, warns that using the TFV approach requires that the interaction between flows and the construction processes be closely monitored to ensure the reduction of waste and process variability and Koskela (2000) argued that the peculiarities of the construction sector make it very challenging in creating continuous flows.

Construction Wastes

Waste in the construction industry has generated a lot of interest and research over the years. However, Aziz and Hafez (2013) claimed that the subject of these researches has been focused on material waste. Formoso et al. (2002) claimed that this is perhaps because material waste is tangible and therefore easy to see and measure. In lean thinking, however, waste is associated not just with tangible wastes but also intangible wastes and therein lies the problem as it is difficult to measure the intangible aspects of waste. Identification and elimination of waste are crucial to the success of lean. One of the most important definitions of waste was put forward by Womack and Jones (1996) when they asserted that waste is any activity that makes use of resources without creating value. However, Aziz and Hafez (2013) asserted that it is quite difficult to measure waste when it is being measured in terms of the efficiency of the process, equipment or personnel because the optimal efficiency is not always known.

Attempts have been made to classify construction wastes into controllable and non-controllable wastes. Controllable wastes, as the name suggests, are wastes that can be controlled. Alarcon (1997) separated these into three different activities:

- A. *Controllable wastes associated with flows*: resources (material, equipment, labor), information (lack of information, poor information quality, timing and delivery of information);
- B. *Controllable wastes associated with transformation*: planning (lack of workspace, poor work conditions, scheduling), quality (poor execution of work, damages to already finished work);
- C. *Controllable wastes associated with management activities*: Decision making (poor allocation of work to labor, poor distribution of personnel), poor supervision/control.

Uncontrollable wastes, on the other hand, are wastes caused by unforeseen circumstances such as force majeure.

Lean Wastes

Ohno (1988) identified seven wastes associated with the lean philosophy and this was expanded to eight by Liker (2004). These wastes are responsible for downtime experienced in construction projects (Table 1) which is directly reflected in the loss of productivity.

Table 1: Lean wastes (Adapted from Terry and Smith 2011)

	Type	Examples
D	Defects	<ul style="list-style-type: none"> • Incorrect information on drawings • Rework • Inspections to reduce/remove defects, • Production of defective work, not meeting specifications
O	Over-production	<ul style="list-style-type: none"> • Producing items earlier than needed or beyond specification • Producing more than is required • Generating waste through over-staffing
W	Waiting	<ul style="list-style-type: none"> • Equipment downtime • Documents awaiting approval, updating or processing • Workers unable to do value creating work • Waiting time between processes or for capacity to take the next step
N	Non-utilized talent	<ul style="list-style-type: none"> • People working one or two levels below their true capability • Lack of knowledge learned from one project transferred to another • Losing time and ideas, skills improvement and learning opportunities
T	Transportation	<ul style="list-style-type: none"> • Moving work in progress from one place to another • Moving temporary site facilities from one location to another • Delivering equipment, incomplete orders • Moving material to and from storage
I	Inventory	<ul style="list-style-type: none"> • Excess raw material, WIP or finished goods causing longer lead times, damaged goods, transportation/storage costs and delays • Too much material compromising the workspace • Large site storage of materials
M	Motion	<ul style="list-style-type: none"> • Unnecessary movement of people and equipment that does not add value • Walking between workplace and welfare facilities, manual paperwork processing • Unnecessary movement of personnel and equipment at site
E	Extra-processing	<ul style="list-style-type: none"> • Taking unnecessary steps • Providing higher quality products than necessary and produced to standards beyond specifications • Inefficient processing, especially due to poor design or work planning causing something unnecessary

RESEARCH METHODOLOGY

The Design science research methodology was adopted. Aken (2004) asserted that that design science is not concerned with action itself but with knowledge to be used in designing solutions. According to Lukka (20013 and Saunders et. Al, (2009), the design science involves the creation of new knowledge through design of novel things or processes and analyzing what has been created through reflection and/or abstraction. The methodology flowchart is shown in Fig. 2.

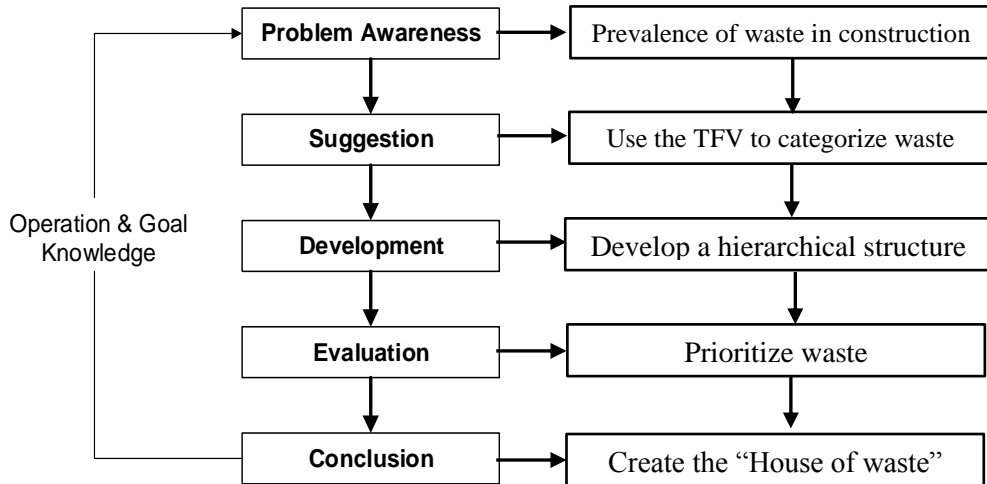


Figure 2: Methodology Flowchart

The research objectives were achieved starting from a theoretical approach that formed the basis of classifying the lean wastes into three categories using the classification by Alarcon (1997) as a starting point and modifying it to suit the TFV theory. The wastes were grouped into (i) wastes associated with transformation activities, (ii) wastes associated with flows and (iii) wastes associated with management activities shown in Fig. 3.

A decision hierarchy was constructed to derive priorities for the criteria based on a pilot questionnaire survey conducted on industry practitioners and the results were analyzed using the AHP. The AHP is a decision-making strategy used to compare alternatives on given criteria based on assigning priority weighing to the alternatives (Saaty 1980). The goal of the AHP in this research is to obtain priority weights for the sub-criteria (Level 2) of the developed framework and elucidate its implication for project management.

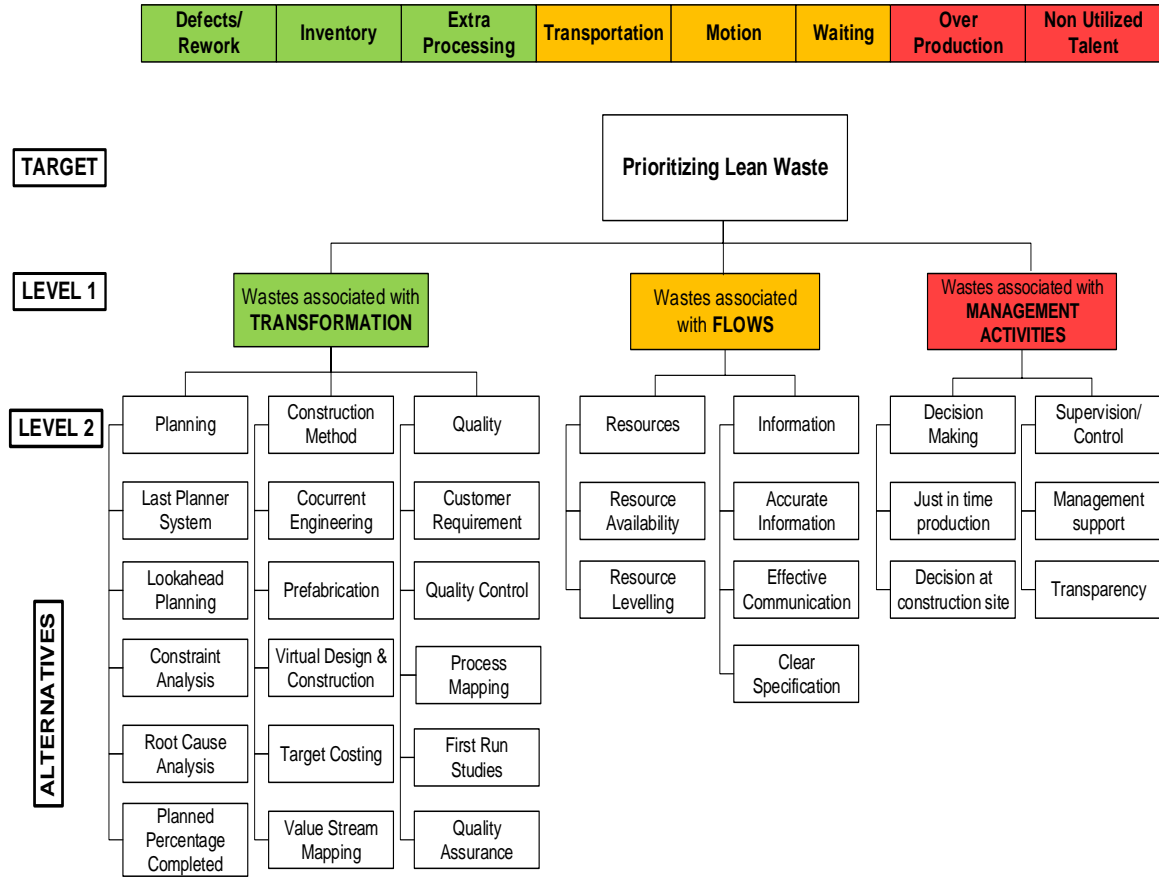


Figure 2: AHP for prioritizing lean wastes

The procedure required for the AHP as proposed by Saaty (1980, 1987) includes the following steps:

1. Pairwise comparison is determined for each level of the AHP by constructing a matrix for the pairwise elements.
2. The values in each column of the pairwise matrix are summed, thereafter, each element of the matrix is divided by its column total to generate a normalized pairwise matrix.
3. When all the normalized pairwise comparison is made, the priority vectors are calculated by finding the row averages, the consistency of comparison is determined by using the eigenvalue (λ_{\max}) to calculate the consistency index (CI), $[CI = (\lambda_{\max} - n) / (n - 1)]$ where n = No of criteria.
4. The consistency ratio (CR) is then calculated by dividing the CI with the appropriate value of the random index (RI), shown in Table 3. If CR does not exceed 0.10, it is acceptable but if it does, the judgment matrix is inconsistent and should be reviewed and improved (Saaty 1980; Al-Harbi 2001).

Table 2: AHP scales (Saaty 1987)

Weight	Definition
9	Extremely Important
8	
7	Strongly more important
6	
5	More important
4	
3	Slightly more important
2	
1	Equally important

Table 3: Random index (RI) values ((Alonso and Lamata 2004)

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Data Analysis

Data were collected from 6 respondents each being a leader in the field of lean construction and analyzed using the AHP steps, scales and random index value explained above. A sample calculation for one of the respondents is shown in Table 4 and the overall analysis of the results with the relative weights is presented in Table 5

Table 4: Example of Judgement matrix

				Transformation Matrix					
				Planning	Construction Method	Quality			
Level 2 (Transformation)	Planning	1.00	1.00	5.00	0.45	0.45	0.45	0.45	3.08
	Construction Method	1.00	1.00	5.00	0.45	0.45	0.45	0.45	3.08
	Quality	0.20	0.20	1.00	0.09	0.09	0.09	0.09	3.08
		2.20	2.20	11.00				λ_{max}	3.08
								ci	0.04
							cr	0.069	

Wastes due to management activities had the highest overall weights and this is consistent with the demands of the lean construction paradigm which places great importance on management commitment and participation in the lean journey of any organization. Priority was given more to wastes associated with flows than wastes associated with transformation. This is again consistent with research on lean construction as flows typically drive transformation.

Table 5: Summary of Results

Level 1	Level 2	Relative Weights
Transformation	Planning	0.21
	Construction method	0.04
	Quality	0.04
	Total	0.29
Flows	Resources	0.19
	Information	0.16
	Total	0.35
Management Activities	Decision making	0.24
	Supervision/control	0.12
	Total	0.36

DISCUSSION

The identification and elimination of waste is the driver to adding value as both waste and value are at different ends of the spectrum of what project stakeholder's desire. However, although there is a significant amount of non-physical wastes in the construction industry, the drive towards the identification and elimination of waste has been mainly focused on tangible wastes (such as material waste). It is important to put into perspective how the lean wastes contribute to the physical construction wastes through a concept we name "the house of wastes". Wastes that cannot be identified, cannot be seen. Thus, waste identification is a precursor to its elimination.

House of wastes

The idea for the house of wastes was adopted from the house of quality. The house of quality is a diagram resembling a house used for representing and defining the relationship between customer desires and an organization capability for meeting those desires either through its products or services. Representing the lean wastes as a "house" presents a holistic way of viewing and understanding the relationship and interconnection between them with the aim of elucidating how one waste can serve as a driver for the others and how the reduction and elimination of the "driver" waste can lead to the creation of more value for stakeholders.

Non-physical wastes play an important part in the discussion of wastes, but they have typically not been given the same attention as physical wastes. It is important to consider the interrelationship between these non-physical wastes and how they affect the management of projects.

Wastes associated with overproduction is considered the tipping point of all other wastes associated with the lean construction paradigm. This waste includes any resources more than what is required to perform an activity whether they are people, equipment, material or facilities. Overproduction increases cash outlay without an attendant increase in value. A typical example of this can be found in construction projects where excessive workforce leads to increased overhead cost, and excess equipment and facility increases the cost of depreciation. Overproduction has a strong impact on the cost aspect of project management and typically is the precursor to other forms of waste in the "house of wastes". Overproduction requires the "transportation" or transfer of the overproduced components to a storage facility where they will be stored till needed, leading to the waste of motion and inventory. During the process of trans-

ferring the overproduced material, storing or retrieving it, the waste of defect may occur. All these give birth to the waste of extra processing (the process of trying to restore the defect). At the center of these wastes is the waste of non-utilized talent/ employee creativity. These wastes have the effect of reducing productivity, reducing value for the stakeholders through an increase in cost and generally affect project management.

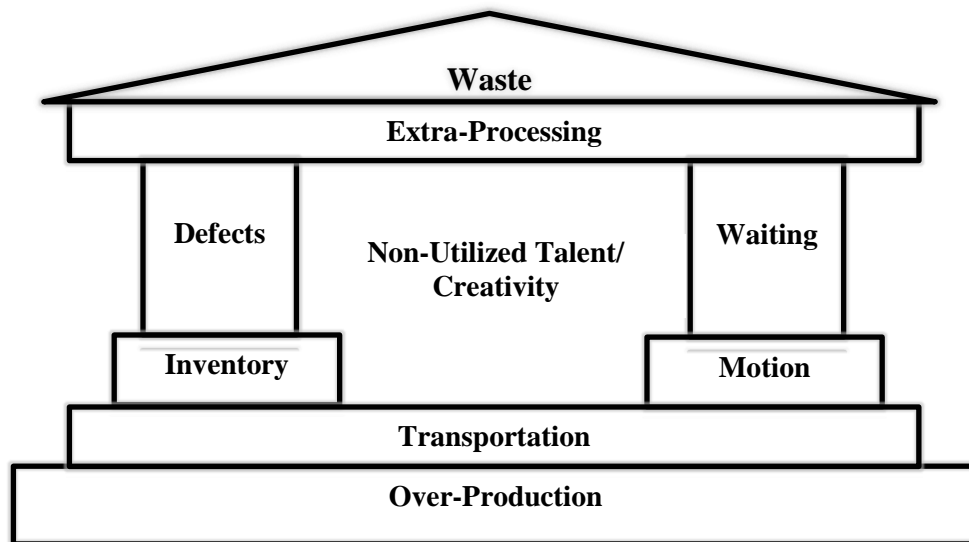


Figure 2: House of waste (adapted from house of lean)

CONCLUSION

Lean thinking in construction provides an excellent opportunity for reducing wastes. Regardless of the extensive body of literature, few works have been dedicated to classifying and prioritizing the lean wastes. This study focused on prioritizing the lean wastes based on a categorization system adapted from the TFFV theory of production. The essence of this prioritization is to better understand where to focus intervention measures to help reduce the effect of these wastes to improve value. The “house of wastes” was also introduced to explain the interdependency of the lean wastes and its implication for project management. However, the research has some limitations and one of the limitations is that the main consideration of the AHP was in prioritizing the wastes associated with transformation, flow, and management activities and their criteria. Prioritizing the alternatives was not considered as part of this research. The research also did not provide solutions on how to reduce the effect of the waste through the selection and use of an appropriate lean tool/technique.

Future works would include combining the analytical network process (ANP) to show the decision relationship between the wastes associated with transformation, flow, and management activities, the AHP to show the relative weights of the sub-criteria relating to the wastes of transformation, flow and management activities and the choosing-by-advantage (CBA) method to select the appropriate lean tool/technique to optimize waste reduction with specific focus on highway projects.

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