A PRELIMINARY PROPOSAL FOR A WASTE-BASED MANAGEMENT APPROACH TO IMPROVE PERFORMANCE IN CONSTRUCTION

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ABSTRACT

The 20th IGLC Conference held in San Diego revealed that waste is a key concept of lean production philosophy which has not been stressed enough in construction management. However, the concept of waste has been widely addressed in the last 20 IGLC Conferences, and studies so far have been mainly focused on identifying and classifying different types of waste and its consequences, although only a few of them refer to quantifying, controlling and removing waste.

Therefore, the concept of "waste-based management" and a preliminary approach for its implementation will be introduced to fill some of these gaps. Regarding this fact, we will emphasize the importance of identifying the driving forces of waste and its root causes in early stages of the project; and then, quantifying and controlling waste in order to take quick decisions across the organization. We will also introduce the concept of "waste direct cost" during the execution phase, expressed in monetary terms, as a key indicator to control the cost of waste.

KEYWORDS

Waste, Management, Process, Transparency, Continuous improvement, Lean construction, Gemba.

INTRODUCTION

Removing waste has been largely used as a driver for improvement in the manufacturing industry; on the contrary, it has not been strongly emphasised in the construction management books and mainstream journals (Viana et al. 2012).

In fact, the concept of waste has been used in Lean production and Lean construction, but without much reflection and conceptual analysis. This concept deserves being sharpened and the full consequences of the acknowledgement of waste on our views on decision-making, organization and management merit to be clarified. The prospect is that waste will evolve to the central, mainstream idea for developing design and production, rather than being just in the vocabulary of "Lean" (Koskela et al. 2012).

According to the literature review focused on waste in construction, the following points summarize some of the more outstanding gaps which refer Viana et al. (2012) and Koskela et al. (2012):

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- The number of papers talking about how to avoid waste in construction is relatively small and main studies on waste have been focussed on the consequences and not on the root causes.
- The number of studies that have produced metrics of construction waste is relatively small and reports of Lean implementations have not emphasized enough waste measurements.
- Studies which analyze root causes of different kinds of waste in construction are based on surveys.
- A broader conceptualization of waste is needed, based on the idea that is necessary to remove activities which do not add value from the client's side.

As the concept of waste-based management is widespread and part of a Ph.D. thesis currently underway by the first author, in this paper we will introduce a preliminary approach of a waste-based management and its implementation in order to conceptualize from a practical point of view some of the gaps listed above. Furthermore, as the Project Delivery is quite broad, including design, contract, supply chain and construction stages, we will focus on construction/execution phase and direct costs.

Records based on numeric data will not be presented since the main objective of this paper is presenting an introduction to the concept named in the title and its implementation. In this regard, data presented has been taken from literature review.

A WASTE-BASED APPROACH IN CONSTRUCTION MANAGEMENT

The approach of a waste-based management[3] means that the focus of the stakeholders should be aligned to bring to surface the waste and doing so visibly in the different phases of the project by identifying the driving forces of waste (waste drivers), measuring and monitoring waste, and working out its impact from an economical basis, with the aim of improving productivity in construction.

This approach should involve all the stages of the Project Delivery, since its conceptualization and design till construction stages, including both, indirect and direct costs. But in this paper, we will only consider direct costs and will focus on the construction phase.

Additionally, the way we manage a project, the production system design and the contractual form adopted (IPD, EPC or DBB for instance)[4] can influence the waste in the next stages of the project. In this sense, adopting IPD, LPDS and BIM in early stages of the Project Delivery can contribute positively to reduce waste in the construction stage; but waste will still appear in the execution phase of the project and we should consider this fact from a waste-based management approach. The following figure shows the differences between a traditional system (left bar) where

[3] The concept of *waste-based management* was suggested by Lauri Koskela during a short stay at University of Salford, U.K. in 2012, in order to develop the concept for the PhD dissertation currently underway by the first author.

[4] IPD (Integrated Project Delivery), EPC (Engineering Procurement Contract), DBB (Design Bid Build).

waste has not been considered from an economical basis, and a waste-based management approach (right bar) where waste has been considered as an initial cost.

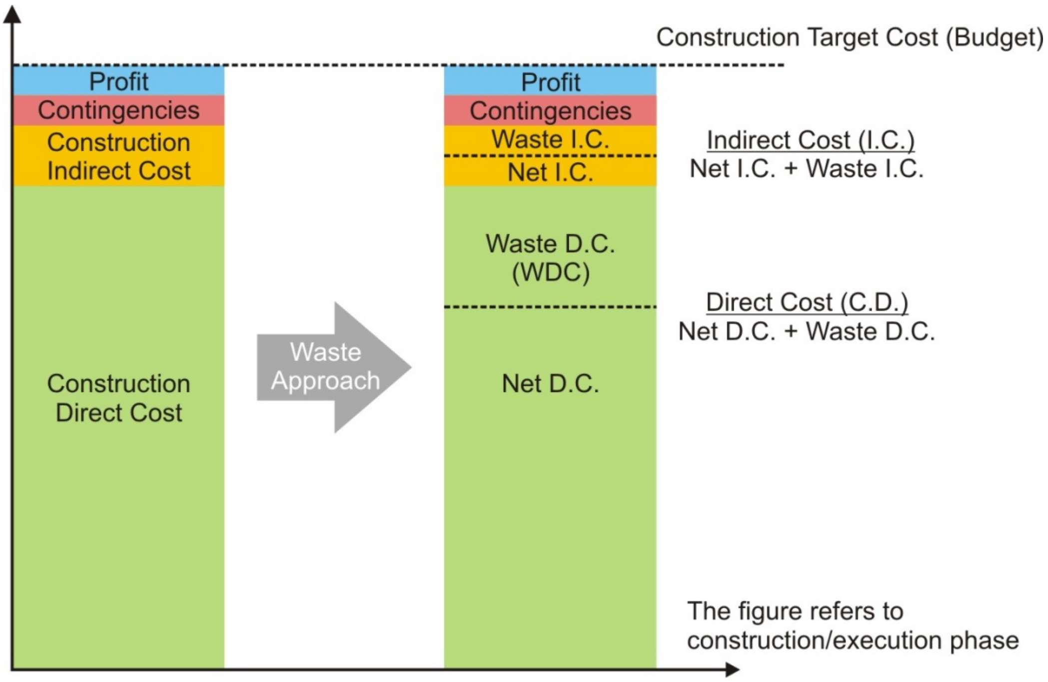

Figure 1: Waste-based management approach vs. Traditional approach[5].

IMPLEMENTING WASTE-BASED MANAGEMENT IN CONSTRUCTION: A PRELIMINARY APPROACH.

According to our definition mentioned above, a preliminary approach for implementing a waste-based management in construction should be grouped in three main points (notice that this approach refers to the construction phase):

- Identifying waste.
- Quantifying waste.
- Controlling waste.

IDENTIFYING WASTE

Identifying waste in construction within a Lean context is not easy if one has not been trained. Many operators, site managers or executives think that waste refers to scrap, and the concept of waste and its link to productivity is still hardly known by most of them. Teaching the concepts of *muda* and value, learning to identify the different types of waste, doing *gemba walks* in the construction site and drawing VSM of the production processes are a first step we propose for a waste-based management.

Regarding training, Alarcon (1995) highlighted the importance of teaching construction site managers by means of brainstorming sessions and he proposed a

[5] A similar graphic was exposed in the report "IPD for Public and Private Owners" by NASFA et al. (2010) comparing IPD Delivery Methods and Traditional Delivery Methods.

methodology for identifying waste. In a waste-based management approach we would like to remark Toyota's Commitment Learning and the more recent approaches by Liker and Meier (2007), Spear (2009) and Rother (2009) in manufacturing and services. They emphasized the importance of having internal coaches or *senseis* across the organization from CEOs to operators, in order to train people to identify waste, to solve problems and to find out root causes of problems.

According to the definition of waste-based management presented in the previous headline, we emphasized the importance of identifying driving forces of waste. For instance, limited IT resources, absence of training, lack of definition in the project, ineffective communication or undefined roles among others, could be drivers which trigger waste. In this sense, the table below presents a description of wastes identified in construction (Formoso et al., 1999; Garas, 2001; Polat and Ballard, 2004; Rashid and Heravi, 2012; etc.) which have been classified according to the 7 Ohno's wastes.

Table 1: Waste in construction (classified according to 7 Ohno's wastes)

7 Main Wastes	Description
Overproduction	Production of a quantity greater than required or earlier than necessary; additional drawing (non essential, impractical and excessively detailed); the use of highly sophisticated equipment where a much simpler one would be enough; higher quality than expected.
Waiting Time	Waiting for data, information, specifications, drawings, materials, equipment, preceding activities, approvals, laboratory results, funding, personnel; work area inaccessible due to other work; idle time; stoppages; iteration between various specialists; rework due to design changes and revisions; contradictions in design documents; delay in transportation and/or installation of equipment; scarcity of crews; lack of coordination among crews; accidents due to lack of safety.
Unnecessary Transport	Refers to unnecessary transportation concerned with internal movement of resources (material, data, etc.) on site. It is usually related to poor layout and the lack of planning of material flows. Its main consequences are: waste of man hours, waste of energy, waste of space on site, and the possibility of material waste during transportation.
Over processing	Additional processes in construction and installation that cause excessive use of raw material, equipment, etc. Additional monitoring and controlling (excessive inspections or duplicated inspections).
Unnecessary Inventory	Refers to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery and vandalism), extra personnel and financial costs.
Motions	Refers to unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.
Quality Defects	Errors in design and drawings; mismatch between design and facilities drawings; incorrect methods; unskilled labor. The two main consequences of poor quality are rework and customer dissatisfaction.

On the other hand, Value Stream Mapping (VSM) has contributed positively in order to analyze and control processes, reducing cycle times and lead time, identifying waste and the ratio between value-adding activities and non-value-adding activities, improving communication, gathering data on key indicators, and determining in which area the problem is, in both, industrial (Rother and Shook 2003) and construction processes (Lee et al. 1999, Akel et al. 2004, Pasqualini and Zawislak 2005, Bulhões and Picchi 2008, Yu et al. 2009, Rosenbaum et al. 2012; and others). Consequently VSM contributes identifying where waste is produced in the whole process.

Tools for reduction and minimizing waste

As a result of the literature review, the table below classifies a set of Lean tools used in construction in order to reduce or remove waste. On one hand, LPS and BIM are well known tools and there are a lot of references in the Lean literature, but on the other hand, there is a less known and used set of Lean tools in construction as 5S, Andon Lights, Kanban System, Heijunka Box and Poka-yokes.

Table 2: Tools for reduction and minimizing waste in construction site

Tools	Description
Last Planner System	For removing variability and waiting through a Pull System. Improving work flow reliability. Ref: Ballard (2000).
BIM	Managing data in 3D. BIM helps to reduce variability and prevent mistakes from design phase to construction stage. Example: clash-detection analysis.
Flow-Line	To schedule tasks according to locations. Useful to prevent overlapping gangs in work place. Ref: (Seppänen et al. 2010).
Organizing Layout	For avoiding unnecessary transport, excessive movements and looking for tools, people, materials, etc. For instance, Park et al. (2011) devised a floor-level construction material layout planning model that could reduce unnecessary transportation time in a building project.
5S	The 5S is useful for increasing transparency and practices targeting standardisation of the workplace elements in terms of classification, location, quantity, type, etc. It is considered as the first step to the other lean manufacturing practices and to creating a visual workplace. See examples in (Tezel et al. 2010).
Andon Lights	The andon is a Japanese term for the lantern and it shows the status of operations in an area and signalizes the occurrence of abnormalities (waste, problems or errors). See examples in (Kemmer et al. 2006).
Kanban System	Useful in a Pull System, in which production is controlled by the workers themselves through some signals (for instance, small cards or kanban). See examples in (Tezel et al. 2010).
Heijunka Box	To organize and schedule activities, processes, purchasing, etc. See an example of concrete mixture in (Tezel et al. 2010).
Poka-Yoke	If combined with source inspections and quick feedback cycles, auto-inspection and successive check, it is a useful tool to prevent making errors. See examples in (Tommelein 2008).
IT	BIM is considered an IT tool but, for the last few years, the number of applications of IT (for instance, Smartphone and cloud software) to AEC industry has increased and become a main category in the IGLC Conferences and Construction Industry.
Others	TPM for avoiding the waste of waiting due to lack of maintenance in machinery and tools, and SMED or Quick Changeover have been largely used in manufacturing and lately in service, but the references in lean construction literature are slim to none.

QUANTIFYING WASTE

According to the literature review analyzed, for the last few years there have been several attempts to estimate the amount of waste in construction, but results vary quite between them, and studies have been focused on different kinds of waste or have used different methods and measurement criteria. Therefore it is quite difficult to draw conclusions about the actual truthful amount of waste in construction and to compare data between different studies.

In this sense, there has not been a systematic attempt to calculate all waste cost in the construction site, although, a study which sought to capture the amount of all types of waste in four Swedish construction projects, showed that the amount of waste was around 30-35% of a project's production cost (Forsberg and Saukkoriipi, 2007). A more recent attempt to measure all types of waste in a construction site, not only in terms of dimensions but in terms of cost, was made by Ramaswamy and Kalidindi (2009), who presented a set of formulas to work out the following parameters: material scrap, excess inventory, labor inefficiency and equipment inefficiency. Additionally, in a waste-based management, we need to emphasize the importance of quantifying and controlling waste. In this regard, as we can see in figure 1, one of the main aims of a waste-based management should be working out the Waste Direct Cost (WDC) expressed in monetary terms.

In the formula below, W_i refers to every parameter able to be measured and monitored (material, inventory, labor, equipment, quality, time, others) of the construction processes and tasks; where "n" represents the number of wastes measured (in this first approach to the study n=6). Notice that the following is an opened formula where one can add other measurable parameters:

$$WDC = \sum_{i=1}^{n} W_i$$

$$(where\ W_i\ is\ W_{material}, W_{inventory}, W_{labour}, W_{equipment}, W_{quality}\ and\ W_{time}\ if\ n = 6)$$

Table 3: Description of measurable parameters to work out the Waste Direct Cost.

Concept	Description
$W_{material}$	Refers to the waste of material (scrap) of each of the materials, in every process, during the construction phase. It includes material from over-production, breakages, losses of material, robberies, obsolescence, changes in the project once the material has already been purchased, changes of the customer, etc. Ref: (Formoso et al. 2002) and (Ramaswamy and Kalidindi 2009)
$W_{inventory}$	Refers to excess of inventory. It includes financial cost and management of inventory (renting storage, vigilance personnel, handling, internal transport, etc.). Ref: (Ramaswamy and Kalidindi 2009)
W_{labor}	Refers to excess of labor and idle time due to lack of material, lack of information or lack of work place available for a gang. Ref: (Ramaswamy and Kalidindi 2009)
$W_{equipment}$	Refers to excess of transport, equipment breakdowns, underutilization of equipment, lost tools, etc. Ref: (Ramaswamy and Kalidindi 2009)
$W_{quality\ defects/rework}$	It mainly refers to rework due to final or intermediate product which does not fit the quality specifications. Ref: (Josephson and Saukkoriipi 2003) and (Love 2003).

Concept	Description
W_{time}	Kalsaas (2010) identified waste as amounting to 17% of working time, and Kalsaas (2012) research was focused on identifying time losses in the production according to its different causes, such as the seven flows, "making-do" and rework. However Ramaswamy and Kalidindi (2009) considered time as part of labor waste.

CONTROLLING WASTE

Formoso et al. (1999) pointed out the lack of perception from managers of variability in production and productivity rates, the lack of integration of waste control with the planning and control process, and the need for not only verifying but also monitoring the efficiency of construction processes.

Having identified a set of measurable parameters in order to measure waste (see table 3), the next step is to monitor it (first in terms of dimensions, and then in monetary terms) and finally make waste visible. In this regard, a weekly waste cost control allows us to control the cost of non value adding activities. In addiction, for controlling and monitoring waste cost in a construction site and finding out cost deviation we propose to introduce the following 4 indicators:

- Waste classification (%): a percentage of the measurable waste parameters (bar diagram showing one column per parameter of the formula above).
- WDC (%): Waste Direct Cost expressed as a percentage in order to compare values between different projects and different tasks inside the same project:
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- $WDC(\%) = \frac{W_{material} + W_{inventory} + W_{labour} + W_{equipment} + W_{quality} + W_{time}}{Direct\ Cost\ (DC)} \times 100$
-
- Control chart in order to monitor waste: a graph ox: Time and oy: WDC. Hence, construction site managers are able to control the amount of waste in a timeline in both ways, monetary terms and as a percentage.
- Waste control table (see an example in table 4):

Table 4: Waste Control Table.

Waste	Description	Hour in	Hour out	Root Cause	Solution	Waste Cost	Solution Cost

Finally, displaying data information about measured parameters and transparency are needed to bring waste and problems to the surface and manage indicators. In this sense, Visual Management (VM) has been evolving and effectively used in some manufacturing and service organizations for a long time. In the construction industry, for instance, some examples were presented by Tezel et al. (2009), who emphasized the need of a better understanding of how to implement VM in the construction environment and highlighted VM as an important future research opportunity.

CONCLUSIONS

Waste seems to be embedded in Construction. Previous studies trying to measure the amount and cost of waste in construction are not homogeneous and it is quite difficult to compare data between them (results presented in different studies vary from 0 to 35%). In any case, in the global competitiveness, companies cannot afford such rates and its impact in their income statement. In this sense, we think that if construction companies could measure the cost of waste, it would be an extra motivation for them to focus their attention on identifying, quantifying and removing waste.

As noted in the introduction, despite the widely literature focused on the topic, there are still many gaps to cover. Therefore, a first contribution of this paper is to define the concept of waste-based management. A similar approach in manufacturing related to this topic is called "lean accounting". It means that we will have to consider both, the ratio of expenses on productive activities and unproductive activities in each process; and decisions should be taken as a criterion for the benefit of the value chain as a whole, not the product or customer individually, because otherwise waste would remain hidden in the whole project.

A second contribution is to present a preliminary approach for implementing a waste-based management in the construction phase, as part of the definition. We have classified the implementation in three main steps: identifying, quantifying and controlling waste. We have also presented a list of tools used in construction projects to reduce waste and have noted that, in addition to identifying and classifying waste, we need to emphasize the importance of indentifying waste drivers and its root causes in early stages of the process.

Even having presented a conceptual approach of the concept of waste-based management and its implementation, further verification is needed, for instance, the performance of case studies in construction companies. In this regards, in order to achieve reliable data, truthful collaboration and transparency among people involved in the construction processes are needed. Moreover, further studies are necessary to work out the rate of waste in all construction stages, including contract and design phase and Waste Overhead Cost or Indirect Cost. Finally, further research in development of other lean manufacturing tools for construction is still needed.

Looking after perfection has been quoted many times as the fifth principle of lean production, but as cited in the report by Viana et al. (2012), many authors consider that it is not possible to eliminate waste completely and it seems to be rather an ideal. For this reason, waste based management is a kaizen approach. If waste is visible and numeric, there is a good opportunity to turn it into profit.

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