iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VI **Month of publication:** June 2022

DOI: https://doi.org/10.22214/ijraset.2022.45041

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

Waste Control at Construction Project by Adopting Lean Management Tool for Quality Measurement Framework

Mohini Khopade[1], Miss. Yogita Fulse[2]
[1] *PG Student, Civil Engineering Department, Sandip University, Maharashtra, India*
[2] *Assistant Professor, Civil Engineering Department, Sandip University, Maharashtra, India*

Abstract: Lean manufacturing and lean construction have the same goals according to Paez et al. (2005): elimination of waste, cycle time reduction, and variability reduction. One of the ways of reaching the goals of lean construction is flow according to Paez et al. (2005). When trying to attain flow in construction one need to realize that there are differences between manufacturing and construction, which may make it difficult to attain the same flow between different processes, attained within manufacturing (Koskela, 1992). These differences are certain construction peculiarities such as one-of-a-kind projects, site production, temporary organization and regulatory intervention, aspects more common with construction projects than manufacturing. According to Koskela (1992) however, the same production principles apply and there is room for improvement when it comes to flow in the construction industry. By using lean thinking and lean tools and adapting them to the construction industry this master's thesis purpose is to develop a tool to identify and measure waste, guide in which order waste should be reduced and by this enabling estimations of potential consequences that might occur by implementing a lean approach at a construction site. This is of interest in order to bridge the research gap between conceptual lean construction and research based on empirical studies.
Index Terms: Lean management, waste control in construction, economical

I. INTRODUCTION

The concept lean, originating from the Japanese car manufacture Toyota's production system and often called Lean Production is constantly under development. Since the lean concept was first introduce to the producing industry and the success was significant it has now evolved to other fields than car manufactures. Due to the dynamic business environment the original lean has transformed and is today merely one part of the whole lean concept. This section attempts to present the essence of the lean concept for the reader and this is of importance since it is this philosophy that the authors aim to introduce in the construction industry.

Lean as a concept has evolved beyond Lean Production and it continues to develop. Therefore, the development of lean has led to confusion with regards to what constitutes lean and what does not. Hines, Holwe & Rich (2004) have proposed a model covering the whole lean concept where two levels are distinguished: the strategic (Lean Thinking) and the operational (Lean Production). The customer-centered strategic thinking is applicable to every organization that provides customer value, but the shop floor tools are not. The distinction of these two levels is crucial for understanding lean as a whole in order to apply the right tools and strategies to provide customer value. However, Hines, Holwe and Rich (2004) state that much of the academic discussions concerning lean thinking still focuses on the shop-floor which demonstrates a rather limited understanding of what contemporary lean approaches are about. This lack of a holistic view might result in organizations missing the strategic aspect and assuming that quality, cost, and delivery is equal to customer value. This is a common mistake by organizations implementing lean (Liker, 2004) since if only a cost perspective is addressed and the customer-perceived value is overlooked might in the end lead to sub-optimization in the value chain (Hines, Holwe, & Rich, 2004). In other words, lean is about both increasing customer value and reducing waste, and the essence is to understand that these two are not the same. It is possible to increase customer value without reducing waste.

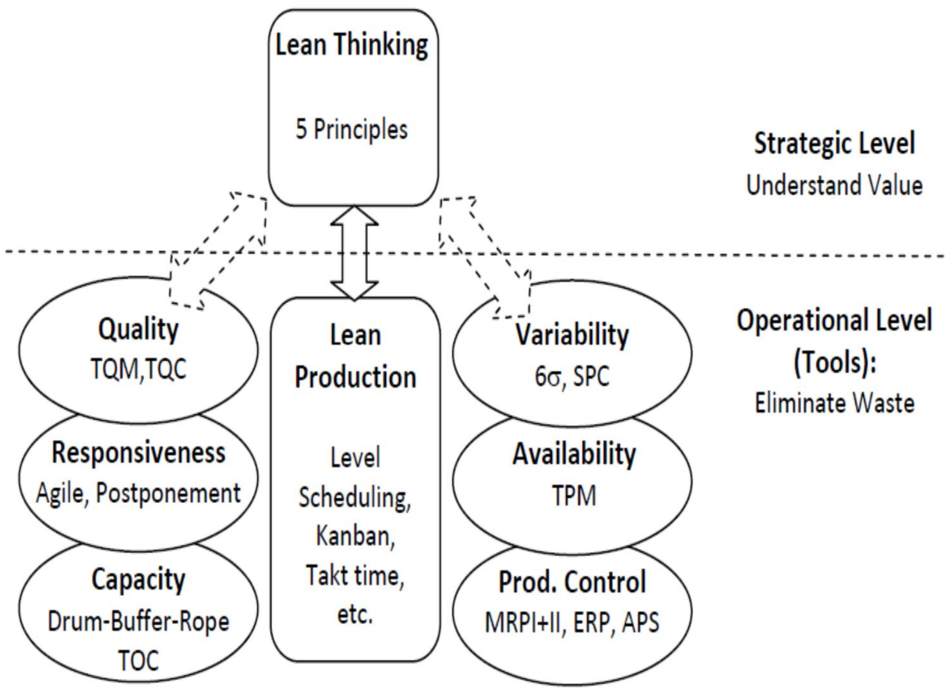
Lean construction is the application of lean manufacturing principles in the context of the construction industry. While the definition of lean manufacturing is quite clear, there is debate about what lean construction is. Many say they have been lean for a long time, e.g. using JIT delivery, long before the term Lean or Lean Construction was on every ones tongue. Many also associate lean more with partnering than the principles of lean manufacturing (Green & May, 2005). In his article, Koskela (1992) concluded that there was, both in construction and manufacturing, too little focus on processes and value.

His work has become the foundation of lean construction and in 1993 the 1st International Workshop on Lean Construction was held. Jørgensen and Emmitt (2008) also identify a few common elements between lean manufacturing and lean construction.

Focus on the elimination and reduction of waste.

- End customer focus in order to determine what value is and what waste is.
- Pull approach from a customer perspective
- Focus on processes and flows of processes
- System perspective

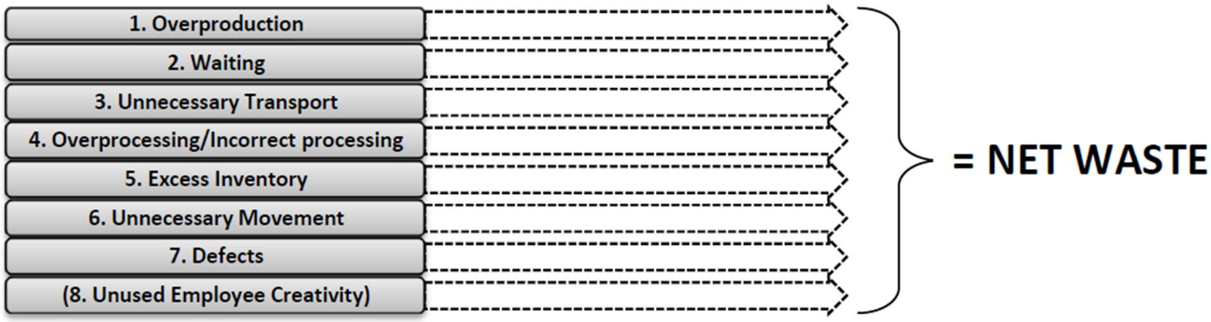
In order to further try to explain how construction can become lean, a seminar by Koskela (2008) is used. If construction is decomposed into tasks and each task is to be completed within a certain timeframe and budget two decision rules are given. If each task keeps its start and end date *and* if each task is kept within budget then the entire project is completed on schedule and within the set budget. Why is this then so difficult? That is because reality is almost never like it seems on paper. As with lean manufacturing, flow is the goal in order to have the same average output each week or day. In a real project however there are always problems, which will mean large fluctuations in the output each day or period.



II. WASTE

Toyota identified seven major types of waste in manufacturing and business processes and Liker (2004) later came to include an additional form of waste, namely *unused employee creativity*. The eight forms of waste, or *muda* as it is called in Japanese is being displayed below. It might appear that a little waste does not matter but if all these kinds of waste are added up, in the long run, the inefficiency is apparent and could be substantial. It is usually the buzzword waste or *muda* that people identify lean with, however, it should be emphasized that only focusing on eliminating waste could hurt the productivity of people and the production system.

In an article by Hines and Rich (1997) these three classifications were explained where VA operations involve the conversion of processing of raw materials or semi-finished products through the use of manual labor, e.g. sub-assembly of parts, forging raw materials and painting. The second one is clarified as pure waste and involves unnecessary actions that should be eliminated completely, e.g. the eight types of waste such as waiting time and excess inventory. Thirdly and last is the NW-category, which is activities that may be wasteful, but necessary to perform in the operation procedure. In other words, they are necessary but non-value adding activities, e.g. unpacking deliveries.



In addition, when examining a process with the aim to detect waste and eliminate these, activities need to be classified in some way. Monden (1993) identified three different types of operations in an internal manufacturing context. The activities could be:

1) Value Adding (VA)
2) Non-value Adding (NVA)
3) Necessary Waste (NW)

III. LITERATURE

The Lean philosophy was born within the production environment of physical goods and is based on an industrial concept developed in Japan during the 1900s. The automaker Toyota is often ascribed as being the founder of Lean Production through its Toyota Production System (TPS) (Shingo, 1989). In the early 1960s a number of principles had been developed that later become known as the foundation of Lean Production (Womack, Jones, & Roos, 1990). However, it was not until in the 1980s that Toyota first caught the world's attention by designing cars faster, with more reliability and yet at a competitive cost compared to other car manufactures (Liker, 2004). The term Lean Production was coined by the International Motor Vehicle Program researcher Krafcik (1988) and was made popular by Womack, Jones & Roos (1990) in the critically acclaimed book *The Machine That Changed the World*. According to Womack, Jones & Roos (1990) Lean Production is best described as a method which combines the advantages of craft production and mass production, e.g. avoiding the high costs of craft production and avoiding the rigidity of mass production. Eriksson (2010) summed up much of what lean construction is in his article, including the six groups in which he classified the aspects of lean construction. In Paez *et al.* (2005) article they do not summarize the literature available on what lean construction is but rather focus on specific techniques that can be applied in order to reach the goals of lean construction.

Even though there are similarities in the industries they are of course also vastly different. According to Koskela (2008) there are two views on if TPS can be applied in construction. One is that there are no hindrances in transferring TPS, its methods and practices from manufacturing to construction. The Egan Report (Department of Environment Transportation and the Regions, 1998) is an example of this view. The Egan report states that Lean thinking describes the core principles underlying this system that can also be applied to every other business activity. The other view is that construction is fundamentally different and that the methods and practices need to be reinterpreted to fit the construction industry. The construction peculiarities mentioned by Koskela (2008) are one-of-a-kind production, site production and temporary project organization. Two alternatives for tackling these obstacles is either to eliminate them by standardizing products, using off-site production and long-term alliances or to accept them and develop new methods to overcome them. According to Koskela (2008) the ends for lean construction are the elimination of making-do and lead time reduction. The means for getting there is using the Last Planner system of production control and using practices and methods from lean production and lean product development when applicable.

1) Lean Construction Techniques: In their study, Paez *et al.* (2005) presented seven techniques within lean construction used to create flow and reach lean construction goals:
2) Concurrent Engineering: The execution of parallel development tasks in multi-disciplinary teams in order to obtain an optimal product keeping functionality, quality and productivity in mind.
3) Last Planner: Introduced by Ballard (2000) as a planning technique to deal with project variability in construction.
4) Daily Huddle Meetings: Last Planner manages operations while Daily Huddle Meetings is a way to follow-up the highly variable events that affect assignments.

5) *Kanban System:* Used to organize the flow of certain materials (consumables, personal protective equipment, hand tools, power tools, and consumables for power tools. This was shown to work by Arbulu, Ballard and Harper (2003).
6) *Plan Condition and Work Environment in the Construction Industry (PCMAT):* It is proposed by Saurin *et al.* (2002) as way of introducing health and safety into the project execution. Here safety practices are integrated into short-term planning.
7) *Quality Management Tools:* Integration of quality tools into lean construction. Marosszeky *et al.* (2002) propose a shift from conformance-based quality to quality at the source. This means a checklist, which is to be enforced by the workforce.
8) *Visual Inspection:* Increased speed of operation and reduction of the risk of choosing the wrong material through easy material identification. Schedules, milestones, or progress charts to enforce commitment to assignment completion. Increased communication between decision makers and executers.

IV. METHODOLOGY

The research process will be explorative (Holmström, Ketokivi, & Hameri, 2009), trying to improve the understanding of waste in construction and trying to adapt lean thinking and methods to the construction industry.

Following steps were taken:

1) *Problem Formulation:* A brief literature review on the construction industry and the field of lean will be conducted in order to acquire basic knowledge. This is necessary to structure, shape, and define the thesis problem area, purpose, and research question.
2) *Literature Review:* Literature assumed to be relevant for the subject under study will be reviewed and connections between the field of lean and the construction industry will be made. The literature review will covered key concepts within the fields of lean, construction, value stream mapping, waste, and other relevant topics.
3) *Interviews:* Sets of interviews will be conducted with different stakeholders participating. These stakeholders are actors within the construction business and people who possess knowledge and expertise in the lean or construction field.
4) *Observations:* Since observations are seen as a source of relatively objective information author will performed several field trips to construction sites. Data will be then collected from the interviews and the literature review. In addition, to gain lean experience within the construction industry the author will looked into a 5S-project that was being implemented at a construction site.
5) *Development Of Tool:* Findings from the literature review, interviews and observations will then combined and a tool will be developed to identify and measure waste, guide in how to prioritize eventual waste reduction activities and by this enabling estimation of potential consequences that might occur if lean is implemented.
6) *Validation:* Validation tool will be then from available literatures.

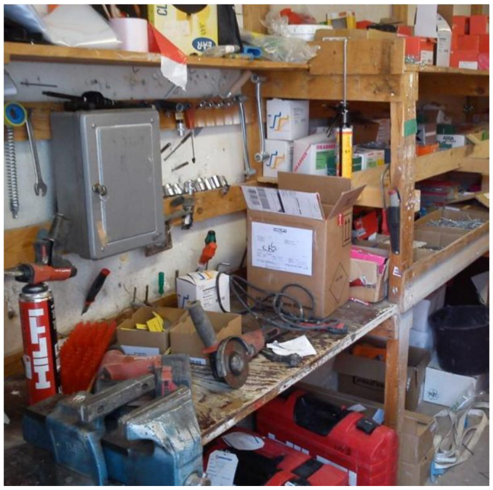
V. PROBLEM AREA

Lean was not applied to construction until 1992, with Lauri Koskela stating the possibility of using the new production philosophy in construction (Koskela, 1992). Since then the theoretical area of lean construction has grown from a simple idea of using lean manufacturing principles into many elements linked more specifically to construction. The Lean Construction Institute (2007) defines lean construction as “a production management-based approach to project delivery”. Another definition is that lean construction is the application of the lean production philosophy, with the current form of production and project management focusing on activities while ignoring flow and value

VI. OBSERVATION OF A 5S PROJECT AT A CONSTRUCTION SITE

When conducting the interviews with the Practitioners, visits were made at different construction sites. From these visits many observations were made, for example the authors got the unique possibility to experience a start-up lean construction program where the lean tool 5S was in the process of being implemented.
As can be seen in the below figures, differences are significant and the construction workers at the construction site were very positive towards this start-up.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com




VII. OBSERVATIONS MADE DURING VSM STUDIES

In addition, other site visits have been made where VSMs have been conducted resulting in a number of observations. Several different construction workers have been followed during a whole day or a half day.

Sr. No	Observations
01	It was rather common that when a construction worker needed a specific tool it was nowhere to be found, especially not where it was supposed to be such as in the tool shed or where the construction worker left it. In that sense the worker had no idea of where the tool might be or who might have taken it. This resulted in a lot of unnecessary walking around at the construction site searching for the tools and starting up conversations with random colleagues which lead to time being wasted on small talk.
02	It happened from time to time that when a construction worker needed material that was not at hand the worker had to walk relatively long distances to pick it up. It was common that the worker had to take this walk to the same place several times during the same day. Furthermore, it happened that material was not where it was supposed to be since it was processed by a colleagues at another location at the site, forcing the worker to start looking for the colleague. All of this resulted in a lot of unnecessary walking at the construction site and sometimes conversations with random colleagues were initiated which lead to time being wasted on small talk.
03	Some material could not be processed at the place where it was later needed due to the size of the material, safety circumstances, etc. Therefore this material was forced to be processed at another location. The consequences of this were unnecessary walking at the construction and starting up conversations with random colleagues which lead to time being wasted on small talk. Furthermore, if material was not shaped perfectly the workers had to go back for tools in order to correct their mistakes. At many times the moving of material at the construction site was time consuming and difficult.
04	The authors observed how construction workers sometimes had to stop performing their activities in order to help out colleagues in looking for material, tools or solving a problem. At other times workers had to wait on colleagues to finish their work first before the worker could carry on with the activity that was under process. It was in those cases common for the waiting construction worker to take a break and sit down, looking at the colleagues and waiting for them to finish. This resulted in time being spent on nothing at all.
05	If mistakes had been made in earlier construction processes this was not identified until much later on in the project. This could sabotage a whole working day and lead to a lot more extra processing of material, use of machines and time. Furthermore, sometimes mistakes were tried to be solved with muscle strength (e.g. lifting heavy materials) which increased the risk of injuries.
07	Some processes are less complicated than others and do not require the same level of problem solving as other processes do. More ad hoc problem solving is more time consuming. Additionally, some processes take more time than others resulting in that other construction workers have to wait on others. It was also observed that the faster

	construction processes could cause problems for the slower ones i.e. if a wall was set up before window frames had been installed.
08	In line with the earlier described Hawthorn effect it is the authors' belief that their presence at the construction site might have slightly affected the outcome of the individual VSMs. Some workers were keener on socializing during their work tasks than others resulting in more sessions with small talk at these occasions. However, the authors have the perception that they might have observed construction workers who tried to work faster and more efficient than usual. This gives higher value on VA and lower value on NVA for some VSMs but the opposite on other VSMs.
09	For a few construction processes material was deployed by external worker who ensures that the needed material was in place for the construction worker when they arrived in the morning. The result of this is that time was mostly spent on value adding activities since there was no need for walking around at the site to pick up material in different locations or looking for lost material. With everything in place the workers could achieve a good work pace.
10	For those construction workers who kept good track of their tools and material they hardly had to going around looking for these. It was the authors' perception that these workers also took better care of their tools.
11	It was obvious that good communication and focus on problem solving instead of long sessions of small talk resulted in fast moving construction processes with a good work pace and with few interruptions.

Work	VA	NVA	NW	Total
Brick Work	52.52 %	17.23 %	30.25 %	100 %
Frame Work	30.91 %	48.33 %	20.77 %	100 %
Centering	27.19 %	43.92 %	28.89 %	100 %
Material Handling	52.62 %	26.38 %	21.01 %	100 %
Transportation	33.90 %	54.51 %	11.59 %	100

The above table shows VSM data.

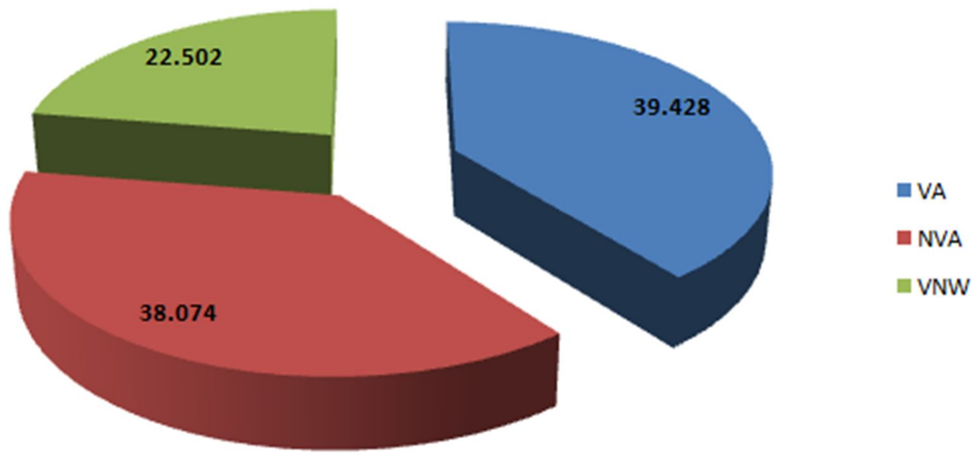
VIII. VSM ANALYSIS

Sr. No	Observation	Analysis
01	It was common that when a construction worker needed a specific tool it was nowhere to be found, especially not where it was supposed to be such as in the tool shed or where the construction worker left it. In that sense the worker had no idea of where the tool might be or who might have taken it. This resulted in a lot of unnecessary walking around at the construction site searching for the tools and starting up conversations with random colleagues which lead to time being wasted on small talk	For some workers there seem to be no willingness to keep track of tools or keep the tool shed tidy. Since this do not goes for all workers it can be assumed to be an individual issue such as lacking a structural mind. However, since it was mainly plumbers who had these problems it could be lack of training or structural thinking within the firm performing the plumbing activities. Nevertheless, looking for tools turned out to be rather time consuming thus costly.
02	It happened from time to time that when a construction worker needed material that was not at hand the worker had to walk relatively long distances to pick it up. It was common that the worker had to take this walk to the same place several times during the same day. Furthermore, it happened that material was not where it was supposed to be since it was processed by a colleagues at another location at the site, forcing the worker to start looking for the colleague. All of this resulted in a lot of unnecessary walking at the construction site and sometimes conversations with random colleagues were initiated which lead to time being wasted on small talk.	It was observed that planning of the next day's activities was rather uncommon. Often it was planned that something was supposed to be done but not what kind of materials that were needed or how much of it. This point towards the lack of structuring a work day or a problem. That material cannot be found due to other workers processing it on another location show that the communication between workers should be improved. The lack of communication can also explain the problems with planning ahead since these often correlate. Nevertheless, the material issue resulted in a lot of time being spent on walking around at the construction site.

03	Some material could not be processed at the place where it was later needed due to the size of the material, safety circumstances, etc. Therefore this material was forced to be processed at another location. The consequences of this were unnecessary walking at the construction and starting up conversations with random colleagues which lead to time being wasted on small talk. Furthermore, if material was not shaped perfectly the workers had to go back for tools in order to correct their mistakes. At many times the moving of material at the construction site was time consuming and difficult.	That some material is unwieldy to handle is difficult to change but to go back and forth will result in long lead times of the construction process. First of all, the material should be located as close to the place where it is needed since this reduces the distance to walk. It can also be argued that through more thorough measuring the workers will not have to go back with the material and process it again or go back for the tools. The aim should be to do it right on the first try. Rather time consuming and several workers said: "it is a lot of walking in my job". However, this should not be the case.
04	It is observed that how construction workers sometimes had to stop performing their activities in order to help out colleagues in looking for material, tools or solving a problem. At other times workers had to wait on colleagues to finish their work first before the worker could carry on with the activity that was under process. It was in those cases common for the waiting construction worker to take a break and sit down, looking at the colleagues and waiting for them to finish. This resulted in time being spent on nothing at all.	In this case it was obvious to be a planning mistake by the manager who had assigned too many workers for the job. However, it is partly the workers fault as well due to their unwillingness to inform the manager of the over capacity. Some people prefer to find ways to work as little as possible where others have a better work ethic. Another explanation to the scenario could be that specific tools which requires special license were needed for the work task and perhaps only a few people possess these. This could therefore justify the over capacity of human resources.
05	If mistakes had been made in earlier construction processes this was not identified until much later on in the project. This could sabotage a whole working day and lead to a lot more extra processing of material, use of machines and time. Furthermore, sometimes mistakes were tried to be solved with muscle strength (e.g. lifting heavy materials) which increased the risk of injuries.	The underlying factor to this problem might be poor communication between different kinds of construction workers (e.g. the plumber do not talk to the carpenter). Therefore it could be argued that all the actors within a construction project have to be better at team work and help each other. It is also problematic to not have any systematic procedure to make follow ups if quality is deficient. This results in that more mistakes will be made in the future without any possibility to avoid them or find the source of the problem.
05	If mistakes had been made in earlier construction processes this was not identified until much later on in the project. This could sabotage a whole working day and lead to a lot more extra processing of material, use of machines and time. Furthermore, sometimes mistakes were tried to be solved with muscle strength (e.g. lifting heavy materials) which increased the risk of injuries.	The underlying factor to this problem might be poor communication between different kinds of construction workers (e.g. the plumber do not talk to the carpenter). Therefore it could be argued that all the actors within a construction project have to be better at team work and help each other. It is also problematic to not have any systematic procedure to make follow ups if quality is deficient. This results in that more mistakes will be made in the future without any possibility to avoid them or find the source of the problem.
06	Some processes are less complicated than others and do not require the same level of problem solving as other processes do. More ad hoc problem solving is more time consuming. Additionally, some processes take more time than others resulting in that other construction workers have to wait on others. It was also observed that the faster construction processes	The more complicated construction processes requires better planning, however, the extra planning was not present. From time to time the work day was all about ad hoc problem solving which could be rather time consuming. With better planning the lead time could be reduced and reducing the time that worker is waiting on other workers. The issue with the finished wall and the not yet installed pipes shows the

	could cause problems for the slower ones i.e. if a wall was set up before pipes had been installed.	lack of communication between construction workers and managers.
07	In line with the earlier described Hawthorne effect it is the authors' belief that their presence at the construction site might have slightly affected the outcome of the individual VSMs. Some workers were keener on socializing during their work tasks than others resulting in more sessions with small talk at these occasions. However, the authors have the perception that they might have observed construction workers who tried to work faster and more efficient than usual. This gives higher value on VA and lower value on NVA for some VSMs but the opposite on other VSMs.	This might have affected the outcome of some of the VSMs by their presence and their participative observation approach. However, since some studies may have given a higher level of VA activities and other lower level of VA activities the authors have made the assumption that it will level out. Therefore, the aggregated result should be valid.
08	For a few construction processes material was deployed by external worker who ensures that the needed material was in place for the construction worker when they arrived in the morning. The result of this is that time was mostly spent on value adding activities since there was no need for walking around at the site to pick up material in different locations or looking for lost material. With everything in place the workers could achieve a good work pace.	What is common for the VSMs conducted on workers handling drywalls is that they had among the highest efficiency level. Sometimes double or triple the VA activities than other workers. Therefore it could be argued that having material at hand when it is needed give substantial benefits in terms of good work pace and shorter lead times. The management should consider paying the extra money to have the material transported and placed on the right spot for more construction processes. There might be some serious money and time to be saved.
09	For those construction workers who kept good track of their tools and material they hardly had to going around looking for these. It was the authors' perception that these workers also took better care of their tools.	By keeping track of all tools/material and taking care of these in a systematic way they facilitated a high work pace with very few interruptions. Since some construction firms where better at this than others it is plausible that the management of these firms are taking more responsibility and informing the workers about the importance of good structure and tidiness.
10	It was obvious that good communication and focus on problem solving instead of long sessions of small talk resulted in fast moving construction processes with a good work pace and with few interruptions.	The reason that some workers focused more on doing a great job than finding ways to take a break is a matter of the individuals' work ethic. This is something that managers can affect and change by teaching the importance of problem solving communication, work ethic and how more efficient work can improve the workers own financial situation.

If all the VSM studies are summarized an aggregated result will be given. Figure 6.2 shows roughly 39% of the workers' time at the construction site is spent on value adding activities that need to be optimized while 38% of the time is non-value adding activities which need to be eliminated. There is also necessary waste accounting for 22%, which needs to be minimized. These results may vary compared to other studies. Josephson and Saukkoriipi (2005) did their own study which gave results that were fairly similar in terms of non-value adding activities. However, in their study, 17.5% was recognized as value adding, roughly 45% as necessary waste and approximately 33% as non-value adding activities. The discrepancy in results concerning necessary waste and value adding activities stems. From different views on what actually is value-adding and what is necessary.



A. *Financial Implications*

In the below table, the total cost of all construction projects that were undertaken by company during the period 2015 – 2018 is presented. It is observed that 25% of a construction project's cost is linked to cost of labors. In addition, as the VSMs have pointed out, 60% of the time does not add value for the customer. This would mean that:

25% of project cost (labour cost) × 60% of workers time = 15% of the project cost is money being wasted

	2015	2016	2017	2018
Building contractors	149.071	175.424	185.931	191.074
Construction contractors	21.682	24.666	26.732	30.699
Specialized building and construction contractors	187.733	216.069	238.640	231.225
Total Net Sale	358.496	416.159	451.303	452.998
Total Cost (Total net sale minus 4% profit margin)	344.156	399.513	433.251	434.878
Wasted money (≈ 15% of Total cost)	51.623	59.927	64.988	65.232

This would mean that an immense amount of money is being spent on nothing at all in the construction industry every year.

B. *Overview Of Interview*

RQ I

		1	2	3	4	5	6	7	8	9
1.1	Is it generally difficult to see if an activity is value-adding or not in a project?	X	X	X	X	X	X	X	X	X
1.2	What would value-adding activities look like from a customer perspective?	X	X	X	X	X	X	X	X	X
1.3	What different forms of waste can you imagine that exist on a building site?	X	X	X	X	X	X	X	X	X

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

RQ II

		1	2	3	4	5	6	7	8	9
2.1	Have you any experience of improvement work?	X	X	X	X		X	X	X	
2.2	What tools and methods can be useful for identifying waste in an organization?	X	X	X	X	X	X	X	X	X
2.3	What kind of tools and methods can be appropriate specifically for the construction industry?		X	X	X	X	X	X	X	X
2.4	How can these tools and methods be standardized and applied within the construction industry?	X	X	X	X	X	X		X	X

RQ III

		1	2	3	4	5	6	7	8	9
3.1	How have you worked with the measurability of results of previous projects?	X	X	X	X		X	X	X	
3.2	How were the metrics chosen and what was the result?				X	X		X	X	X
3.3	How is the result visualized?	X			X	X	X			X
3.4	What metrics can be appropriate to measure waste?	X	X	X	X	X	X		X	X
3.5	What kind of KPIs can be useful for analyzing a construction site?	X	X	X	X	X	X	X	X	X

RQ IV

		1	2	3	4	5	6	7	8	9
4.1	Who determines in what order the waste reduction is prioritized?	X	X	X		X			X	X
4.2	How do you determine what problem to deal with first?	X	X	X	X	X	X	X	X	X
4.3	Is there a way to determine on what level to solve the problem or how deep into the causes to go?	X			X	X			X	X
4.4	Do you use a method to assure that local optimization is avoided?	X	X	X	X	X	X	X	X	X

RQ V

		1	2	3	4	5	6	7	8	9
5.1	What kind of consequences might waste reduction result in?	X	X	X	X	X	X	X	X	X
5.2	Would the benefits of a waste elimination approach overrun the efforts needed?	X	X	X	X	X	X	X	X	X

[X] Responded [ ] Question Not Asked

Value Stream Mapping Method (VSM)

IX. CONCLUSIONS

The industry struggles with inefficient processes leaving much to be desired. In order to meet this challenge the construction industry must become more efficient by using fewer resources. Small changes in the operational costs by reducing waste, which improves the efficiency, can make substantially changes in profit.

Previous researchers have identified the problems of how the industry works today and pointed to possible solutions by using the lean philosophy and tools along with solutions that are part of what is known as lean construction. There has however, been relatively little research on case studies, research based on quantitative data or research making categorization of the types of waste that exist in construction. In order to help bridge this cap, this thesis' academic contribution is to categorize waste in construction according to classifications more adapted to the construction industry rather than the generic waste categories originally developed from manufacturing. The new categorization of waste is called construction waste, where two new categories of waste, “Preparation” and “Breaks”, were added. In the VSM studies these two categories contributed a great deal to non-value adding work and necessary waste. This new categorization helps understand the main drivers of waste in the construction industry.

In addition, this thesis practical contribution aimed to be, by posing five research questions, to design a Lean Construction Tool by using a lean thinking approach and applying and adapting lean tools to the construction industry. This Lean Construction Tool explains how to identify and measure waste through the use of a value stream mapping tool, interviews and observations. To fully understand the reason behind the waste, the tool recommends that Toyota's Practical Problem-Solving Process and/or an Ishikawa diagram is used to study the waste. Furthermore, the Lean Construction Tool aims to guide in what order waste should be reduced by suggesting the use of a Pareto Analysis and/or looking into appropriate KPIs which are useful in measuring the waste as well. By performing these just mentioned activities, estimations of economical and environmental consequences can be made. This will give the construction companies the possibility to work out countermeasures for the wastes in the form of an action proposal plan that will later be implemented.

By using this Lean Construction Tool a company can gain a better understanding of the kinds of waste that exist in their construction processes. Furthermore, the tool can help companies to decide where change needs to begin by getting to the root cause of the problem thus facilitating prioritization of problem and avoiding sub-optimization. This could lead to improved efficiency of construction activities resulting in lower operational costs, increased profit margin and reduced environmental damages.

REFERENCES

[1] Akintoye, A. (1995). Just-in-time application and implementation for building material management. Construction Management and Economics , 13 (2), 105-113.
[2] Allway, M., & Corbett, S. (2002). Shifting to lean service: Stealing a page from manufacturers' playbooks. Journal of Organizational Excellence , 21 (2), 45-54.
[3] Andersson, P., & Ohlsson, H. (2007). Förbättringspotential för inköpsstrukturen i byggbranschen. Lund: Lund University.
[4] Arbulu, R. J., Ballard, G., & Harper, N. (2003). Kanban in Construction. In Proceedings of the Annual Conference IGLC-11 (pp. 350-361). Seford: International Group for Lean Construction.
[5] Arditi, D., & Mochtar, K. (2000). Trends in productivity improvement in the US construction industry. Construction Management and Economics , 18, 15-27.
[6] Atkinson, R. (1999). Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. International Journal of Project , 17 (6), 337-342.
[7] Ballard, G. (2000 йил June). The last planner system of production control. Birmingham, UK: University of Birmingham.
[8] Ballard, G., & Howell, G. (1998). Shielding Production: Essential Step in Production Control. Journal of Construction Management & Engineering , 11-17.
[9] Bankvall, L., Bygballe, L. E., Dubois, A., & Jahre, M. (2010). Inderdependence in supply chains and projects in construction. Supply Chain Management , 15 (5), 385-393.
[10] Bergman, B., & Klefsjö, B. (2004). Quality, from customer needs to customer satisfaction. Studentlitteratur.
[11] Bicheno, J. (1991). 34 for Quality. Buckingham: PICSIE Books.
[12] Björklund, M., & Paulsson, U. (2003). Seminarieboken - att skriva, presentera och opponera. Lund: Studentlitteratur.
[13] Black, J., & Miller, D. (2008). The Toyota Way to Healtcare Excellence. Chicago, Illinois, US: Health Administration Press.
[14] British Quality Foundation. (2010). EFQM Excellence Model. Retrieved 2011 йил 11-March from British Quality Foundation: http://www.bqf.org.uk/performance-improvement/about-efqm-excellence-model
[15] Bryman, A. (2004). Social Research Methods. Gosport, Hampshire: Oxford University Press.
[16] Camp, R. C. (1989). Benchmarking: The Search for Industry Best Practice that Lead to Superior Performance. Milwaukee: ASQC Quality Press.
[17] Capper, R. (1998). A Project-by-Project Approach to Quality. Aldershot, England: Gower Publishing Limited.
[18] Chakravorty, S. (2009). Process Improvement: Using Toyota's A3 Reports. The Quality Management Journal , 16 (4), 7-26.
[19] Chan, A., & Chan, A. (2004). Key performance indicators for measuring construction success. Benchmarking: An International Journal , 11 (2), 203-221.
[20] Clary, R., & Wandersee, J. (2010). Fishbone Diagrams: Organize Reading Content with a "Bare Bones" Strategy. Science Scope , 33 (9), pp. 31-37.
[21] Condel, J. L., Sharbaugh, D. T., & Raab, S. S. (2004). Error-free pathology: applying lean production methods to anatomic pathodology. Clinics in Laboratory Medicine , 24 (4), 865-899.
[22] Department of Environment Transportation and the Regions. (1998). Rethinking Construction. London.

[23] Department of the Environment, Transport and the Regions. (2000). KPI Report for the Minister for Construction. London: Crown Copyright.
[24] Doloi, H. (2008). Application of AHP in improving construction productivity from a management perspective. Construction Management and Economics , 839-852.
[25] Elfving, J. (2010, Mars 19). Lean construction - case Skanska.
[26] Eriksson, P. E. (2010). Improving construction supply chain collaboration and performance: a lean construction pilot project. Suppl Chain Management: An International Journal , 394-403.
[27] Fearne, A., & Fowler, N. (2006). Efficiency versus effectiveness in construction supply chains: the dangers of 'lean' thinking in isolation. Supply Chain Management: An international journal , 11 (4), 283-287.
[28] Ferdows, K., MacHuca, J. A., & Lewis, M. A. (2004). Rapid-Fire Fulfillment. Harvard Business Review , 1-7.
[29] Fortune. (2008 йил 5-May). Fortune 500. Retrieved 2011 йил 16-February from Fortune: http://money.cnn.com/magazines/fortune/fortune500/2008/performers/industries/profits/
[30] Freeman, M., & Beale, P. (1992). Measuring Project Success. Project Management Journal, 23 (1), 8-17.
[31] Gadde, L.-E., & Dubois, A. (2002). The construction industry as a loosely coupled system: implications for productivity and innovation. Construction Management and Economics , 20, 621-631.
[32] Gaupta, P. (2005). The Six Sigma Performance Handbook. McGraw-Hill.
[33] Gordon, P. (2001). Lean and Green: Profit for the workplace and the environment. Berrett-Koehler Publishers.
[34] Government Offices of Sweden. (2011). Publications. Retrieved 2011 йил 22-February from the
[35] Government Offices of Sweden: http://www.regeringen.se/sb/d/108/action/browse/c/135/all/true
[36] Graban, M. (2008). Lean Hospitals - Improving Quality, Patient Safety and Employee Satisfaction. New York: Productivity Press.
[37] Green, S. D., & May, S. C. (2005). Lean construction: arenas of enactment, models of diffusion and the meaning of 'leanness'. Building Research and Information , 33 (6), 498-511.
[38] Green, S. (1999). The Dark Side of Lean Construction: Exploitation and Ideology. Iris Tommelein's Proceedings of IGLC-7 (pp. 21-32). Berkeley: International Group for Lean Construction.
[39] Green, S. (2002). The human resource management implications of lean construction: critical perspectives and conceptual chasms. Journal of Construction Research , 3 (1), 147-165.
[40] Green, S. (1999). The missing arguments of lean construction. Construction Management and Economics , 17 (2), 133-137.
[41] Hannagan, T. (2008). Management: Concepts & Practices. Harlow, England: Pearson Education Limited.
[42] Hatmoko, J. U., & Scott, S. (2010). Simulating the impact of supply chain management practice on the performance of medium-sized building projects. Construction Management and Economics , 35-49.
[43] Hines, P., & Rich, N. (1997). The Seven Value Stream Mapping Tools. International Journal of Operations & Production Management , 17 (1), 46-64.
[44] Hines, P., Holwe, M., & Rich, N. (2004). Learning to evolve - a review of contemporary lean thinking. International Journal of Operations & Production Management , 24 (10), 994-1011.
[45] Holmström, J., Ketokivi, M., & Hameri, A.-P. (2009). Bridging practice and theory: a design science approach. Decision Sciences , 40 (1), 65–87.
[46] Howell, G., & Ballard, G. (1999). Bringing Light to The Dark Side of Lean Construction: A Response to Stuart Green. Iris Tommelein's Proceedings of IGLC-7 (pp. 33-38). Berkeley: International Group for Lean Construction.
[47] Jörgensen, B., & Emmit, S. (2008). Lost in transition: the transfer of lean manufacturing to construction. Engineering, Construction and Architectural Management , 15 (4), 383-398.
[48] Josephson, P.-E., & Saukkoriipi, L. (2009). 31 rekommendationer för ökad lönsamhet i byggandet - Att minska slöseriet! Gothenburg: The Swedish Construction Federation.
[49] Josephson, P.-E., & Saukkoriippi, L. (2005). Slöseri i byggproject: Behov av förändrat synsätt. Göteborg: FoU-Väst.
[50] Kagioglou, M., & Cooper, R. A. (2001). Performance management in construction: a conceptual framework. Construction Management and Economics , 85-95.
[51] King, A., & Lenox, M. (2001). Lean and Green? An empirical examination of the relationship between lean production and environmental performance. Production and Operations Management , 10 (3), 244-256.
[52] Koskela, L. (1992). Application of the new production philosophy to construction. Center for Integrated Facility Engineering. Stanford University.
[53] Koskela, L. (2008). Lean Construction. Retrieved 02 03, 2011, from University of Salford: http://www.scri.dev.salford.ac.uk/resources/uploads/File/LeanConstruction.pdf
[54] Koskela, L. (1999). Management of production in construction: A theoretical view. I. Tommelein (Ed.), Proceedings of the Annual Conference (pp. 241-252). Selford: International Group for Lean Construction.
[55] Koskela, L., & Huovila, P. (1997). On foundations of concurrent engineering. International Conference on Concurrent Engineering in Construction (pp. 22-32). London: The Institute of Structural Engineering.
[56] Kotzab, H., Seuring, S., Müller, M., & Reiner, G. (2005). Research Methodologies in Supply CHain Management. Heidelberg: Physica-Verlag.
[57] Krafcik, J. (1988). Triumph of the lean production system. MIT Sloan Management Review , 30 (1), 41-52.
[58] Kvale, S. (1996). Interviews - an introduction to qualitative research interviewing. Saga Publications.
[59] Lai, I. K., & Lam, F. K. (2010). Perception of various performance criteria by stalkholders in the construction sector in Hong Kong. Construction Management and Economics , 377-391.
[60] Lasa, I. S., Laburu, C. O., & de Casto Vila, R. (2008). An evaluation of the value stream mapping tool. Business process management journal , 14 (1), 39-52.
[61] Lean Construction Institute. (2007). Lean Construction Institute: What is Lean Construction. Retrieved Februari 17, 2011, from Lean Construction Institute: Lean Construction Institute: What is Lean Construction
[62] Li, H., Lu, W., & Huang, T. (2009). Rethinking project management and exploring virtual design and construction as a potential solution. Construction Management and Economis , 363-371.
[63] Li, M., & Yang, J. B. (2003). A decision model for self-assessment of business process based on the EFQM excellence model. International Journal of Quality & Reliability Management , 20 (2), 163-187.

[64] Lichtig, W. A. (2005). Ten Key Decisions to a Successful Construction Project - Choosing Something New: The Integrated Agreement for Lean Project Delivery. Sacramento, California: American Bar Association.

[65] Liker, J. (2004). The Toyota Way. New York: McGraw-Hill.
[66] Liker, J., & Meier, D. (2005). The Toyota Way Fieldbook. London: McGraw-Hill Professional.
[67] Love, P. E., & Li, H. (2000). Quantifying the causes and costs of rework in construction. Construction Management and Economics , 18, 479-490.
[68] Lutz, J., & Gabrielsson, E. (2002). Byggkommissionen - Byggsektorns struktur och utvecklingsbehov. Stockholm: Sveriges Byggindustrier.
[69] Marosszeky, M., Thomas, R., Karim, K., Davis, S., & McGeorge, D. (2002). Quality
[70] Management Tools for Lean Production:From Enforcement to Empowerment. Proceedings of the Annual Conference (pp. 87-99). Selford: Intenational Group for Lean Construction.
[71] Modig, N. (2004). The Impact of Project Characteristics on Temporary Logistics Solutions. Göteborg, Sweden: Chalmers University of Technology.
[72] Monden, Y. (1993). Toyota Production System: An Integrated Approach to Just-in-Time. Norcross, GA: Industrial Engineering and Managment Press.
[73] Nam, C., & Tatum, C. (1988). Major characteristic of constructed products and resulting limitations of cosntruction technology. Construction Management and Economics , 133-148.