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LEAN CONSTRUCTION IN ROAD PROJECTS

Keywords: Management, Lean Construction, Road projects, Waste, Last Planner System.

Abstract

By far civil engineering represents one of the fields with lower productivity. This fact can be explained by a number of reasons, such as the lack of standardization in their projects, insufficient attention to building details or inadequate automation. The Lean approach stands as a management method aiming to reduce all project wastes leading to higher productivities and lower costs. Since the introduction of this concept after WWII, this has been successfully implemented into a number of disciplines, such as industrial or the aerospace engineering. Nevertheless, because of its peculiarities, the application to the civil engineering field is not as straightforward. Among the civil engineering, the road projects stand as one of the most economically and environmentally costly. For this reason, special attention to increase the productivity and to reduce the cost of this kind of projects is required. To fill this gap, this paper reviews the current state of the art of the application of the lean approach for the management of road projects. This review will present the main contributions of this approach in the road management field to encourage scholars and practitioners the use of this methodology.

1. INTRODUCTION

Construction industry is considered one of the most important and critical industries in which work never stops; houses, roads, bridges and factories are and will remain essential. However, contrary to other industries, the construction field has been suffering from low productivity over the last decades, (Pettersen, 2017). This goes back to the many problems and challenges faced by the industry, such as cost overruns, schedule durations behind the estimated time, poor quality of the finished works, which lead to rework and repairing in addition to workers’ accidents and environmental obstacles that
might arise. Such complications eventually result in conflict between projects stakeholders (Rodewohl, 2014).

2. LEAN CONCEPT

One of the main reasons behind these problems is that some tools and methods applied in the traditional project management approach have been implemented without any updates for the last seven decades. Adaptation of tools from the manufacturing industry has been taking place to fit implementation to the construction industry. Lean Construction (LC) is one of these tools, which was initially invented by Toyota Production System. The Lean concept was named as Lean Production (LP): by applying Lean concept to Toyota Production System, products are delivered with higher quality and productivity opposite to the case before (Pettersen, 2017).

2.1 History for Lean concept

The history of developing Toyota Production System (TPS) began in the 1950s. This system was not developed because of the lower productivity or poor quality, but because it was regarded as a need. After WWII, Japan started to rebuild their infrastructure sector as whole. However, there were two challenges, which needed to be addressed first. First, Japan had a few amount of domestic resources, and second there was a restricted access to foreign trade options. Due to these two challenges, the country needed to use the domestic resources wisely. Toyota Motor Company recognized that it was necessary to develop a different approach, which required decreasing the number of unsold products due to defects problems or because they did not match the customers' requirements. From this point, the approach was shifted from “manufacture push” to “customer pull” (Kahlen and Patel, 2011).

2.2 Lean concept principles and tools

Figure 1 shows the five lean principles; (Rodewohl, 2014)

a) Value; understand the customer requirements and needs.

b) Value Stream Mapping (VSM); has three main steps: make the current state map, determine the non-adding value activities and make modifications by applying the future state map.

c) Flow; focuses on removing the non-adding value activities.

d) Pull; more specifically focuses on delivering the material on time not before or after; concept of Just In Time (JIT).

e) Perfection; focuses on the continuous improvement and continuous application of the previous steps.
Lean Production (LP) has many tools to be applied in their right sequences; some of these tools can be adapted to the construction industry. Lean Construction (LC) tools are mainly: (Gaio and Cachadinha, 2011; Pettersen, 2017; Tezel, et al., 2016a; 2016b; Jang and Kim, 2007; Tezel and Aziz, 2016)

a) Last Planner System (LPS); which relates to production planning and control tools and focuses on improving workflow reliability.
b) Just In Time (JIT); delivering the material on time not before or after.
c) 5S; is a housekeeping methodology.
d) Total Productive Maintenance (TPM); controls the maintenance of equipment.
e) Target Value Design (TVD); relevant to the clients’ value, minimizing wastes and satisfying or maybe exceeding the client’s expectations.
f) Visual Management (VM); is a visual information management tool.

2.3 Lean concept duration activities and wastes

As shown by Kivistö, Ohlsson and Jacobsson, (2013), there are three types of time duration for any activity. First type is Value Adding activity (VA) which relates to the actual time needed to finish an activity, while the other two are named as wastes because they do not add value to the activity. First type of wastes that are essentially occurring; in other studies, this can be referred to as Essential Non-Value Adding activities (ENVA). Second is the wastes that are not essentially occurring and can be removed.

Kivistö, Ohlsson and Jacobsson, (2013) presented eight types of wastes that can occur in any construction project. Heyl, (2015) explained that the reason of the
waste existence in road construction projects is related to the “unreliable schedules, insufficient supply and troubleshooting”\(^1\), besides the trucks having actual work time 50% of their cycle time. As displayed in Figure 3, the eight types of wastes are: (Kivistö, Ohlsson and Jacobsson, 2013):

a) Over-production; is producing too much of the product.

b) Waiting; which occurs in case the labour or the machines are waiting for something to occur before they could accomplish their work, for example waiting for the shop drawing for an activity.

c) Unnecessary motions; is making a useless motion (of labour) within an activity (process).

d) Transportation; making a useless motion (of machine) in the middle of an activity (process). This may lead to the damage of the material or the final product.

e) Inappropriate processing; using the inappropriate machine within the activity, which can lead to accomplishing the work in an incorrect manner or even to damages.

f) Inventory; includes three parts raw material, work in progress and finished goods. Increase in this type of wastes leads to increase in handling and increase in the costs of the material; being damaged in storage area.

g) Defects; relates to rework in the activity.

h) Unused human potential; engaging the inappropriate workers within the activity; they will not add benefit or value in contrast to the appropriate workers.

Lean construction in road projects

2.4 Lean concept benefits

The main goal of Lean Production (LP) is to deliver the final product with the best quality, in the shortest time with an empty warehouse. This concept can be better reflected through these points, (Farrar, AbouRizk and Mao, 2004):

a) Remove the activities that add no value to the final product; Non-Value Adding activities (NVA).

b) Apply the concept of pull, which seeks to deliver the material on time not before or after its need.

c) Reduce the variability changes by determining the uncertainties while creating the final product.

The reasons and benefits of the below three Visual Management (VM) tools are: (Tezel, et al., 2016a)

- Visual performance system: to monitor the teams’ performance in the construction project, also to increase the efficiency of the meetings by solving the problems.

- Visual specification/indicator; to increase the coordination and transparency during the project’s closure and decrease the non-added-value activities, because many contractors face penalties of the number of closure they incurred by their contracts.
Visual control; is the project control board that has data from Last Planner System (LPS) on the board.

Rodewohl, (2014) summarized the main benefits that Toyota Production System (TPS) gained after inventing Lean Production (LP):

a) No reworks were required and defects almost completely disappeared.
b) The customers’ trust increased.
c) The production engineering costs were decreased, so Toyota offered more types of cars.
d) The relationship between Toyota and its customers became better, because there was better understand of their requirements and needs. The concept of pull system was born.

Fullalove (2013) explained that the Highway Agency (HA) Lean Division in the UK was established in 2009. After this establishment, there has been successful implementation of Lean concept in some major road projects, such as the M6 extension from Carlisle to Guards Mill. One of the most important benefits is related to cost saving; around £4.7Million in the last project compared to the one before it. The UK Highway Agency (HA) approved to apply Lean concept in internal process and procedures. Moreover, before using Lean concept, the Highway Agency (HA) spent £1Billion on capital projects and more than £1.5Billion on maintenance. These were payed to repair the road projects.

2.5 Lean Construction requirements

There are general requirements that should be respected to have successful implementation of Lean Construction (Rodewohl, 2014):

a) Every project member carries the whole responsibility for the project.
b) Project team will solve uncertainties and defects.
c) The first priority is the project's success.
d) Good relations and close collaboration between project members.
e) The whole team searches for their improvements and as every project member responsible for the whole project so the successful for the project is the successful for project members.

Further, Gaio and Cachadinha, (2011) demonstrated specific requirements to have successful implementation of Lean Construction specifically in road projects:

a) Understand and determine the sequence of tasks.
b) Gather all the activities that are non-adding value.
c) Determine the duration of the tasks.
d) Determine the present state of the project.
e) Determine which activities need improvement for the future state. Focus on activities, which require the highest improvement.

f) Decrease or remove any activity that is non-adding value (not essential activities).

g) Apply the concept of Just In Time (JIT), to deliver the material on time not before or after (Pull system).

h) Determine the future state of the project.

i) Determine how to improve the durations of the adding value activities.

j) Add buffer to face the uncertainty and variability of the activities.

2.6 Lean Construction barriers

In contrast to Lean Production (LP), Lean Construction is still being applied in few countries around the world. The main barrier to applying Lean concept to the construction industry or the reason why it could be applied in a wrong way has been the site management and workers' lack of awareness of this tool (Gaio and Cachadinha, 2011; Heyl, 2015). Farrar, AbouRizk and Mao, (2004), presented another reason for not applying Lean concept to the construction industry; many construction parties feel hesitate of applying a new management tool (Lean Construction) to their projects, since these projects’ cost can reach multi-million dollars.

The purpose of Tezel, et al., (2016b) is to determine the drivers and barriers for implementing the concept of Visual Management (VM), and also to identify the opportunities of applying the concept of Visual Management (VM) in the future England’s highways construction supply chain. These points were identified by sites observations of five highways construction projects in England. The determined data were obtained by conducting interviews, focus group discussions and observation during the site observations for the case studies. The barriers that emerged challenging the implementation of Visual Management (VM) from the five case studies and focus group discussions mainly include:

a) Lack of awareness of Visual Management (VM).

b) Limited view to the visual performance board.

c) Lack of personal driving of Visual Management (VM) and Lean Construction (LC) in highway projects.

d) Limited communication with operational staff to drive Visual Management (VM) further.
3. APPLICATION FOR LEAN CONCEPT IN ROAD PROJECTS

Many scholars used lean techniques to achieve improvements in road projects (Tezel, Koskela and Aziz, 2017; Pettersen, 2017; Tezel, et al., 2016a; 2016b; Daniel, Pasquire and Dickens, 2016; Tezel and Aziz, 2016; Heyl, 2015; Rodewohl, 2014; Kivistö, Ohlsson and Jacobsson, 2013: Fullalove, 2013, Gaiò and Cachadinha, 2011, Kahlen and Patel, 2011; Jang and Kim, 2007; Farrar, AbouRizk and Mao, 2004). These studies used different Lean tools; Tezel, Koskela and Aziz, (2017) focused on determining the condition of Lean Construction in Small-Medium Sized Enterprises (SMEs) in England’s Highway (Current condition of Lean Construction) and finding the way to spread the Lean concept to England’s Highway supply chain by using survey to experts (Future condition of Lean Construction). According to the current condition of Lean Construction in Small-Medium Sized Enterprises as demonstrated in the literature, there is lack of resources, which affect the deployment of Lean concept; clients’ traditional commercial teams could be a barrier for Lean concept and training for Lean covers the basics knowledge. Regarding the anticipated future condition of Lean Construction Small-Medium Sized Enterprises, Current tendering mechanism will support the creativity of Lean concept and share the risk, besides applying more training sessions for Lean concept, engaging with Small-Medium Sized Enterprises and determining the number of resources needed.

Pettersen, (2017) conducted a qualitative research to investigate the current situation, the possibility and the barriers of applying Lean concept to infrastructure projects, especially road projects. The study relied on interviews to experts from three case studies; the interviews and literature review are the main sources of information. The study results show that two of the three case studies were using Lean concept, however the researcher did not have full answer if there was any challenge to apply Lean concept in the Norwegian road construction projects. The author did not see any challenges related to transport infrastructure and implementation of Lean Construction compared to other construction sectors, such as building construction, from client’s perspective.

Tezel, et al., (2016a) sought to identify the benefits that can result from Visual Management (VM) tools such as 5S (which will be explained more in details below), visual performance system, visual specification/indicator and visual control. The scholars used two infrastructure projects to achieve the study’s aim. There were benefits on the savings of time after applying the concept of 5S, (Table 1). Before using Visual control board on project two, Planned Percentage Complete (PPC) values were about 55% to 60%, but after including it, PPC values reached 85%. PPC is the percentage of the total number finished tasks over the total number of planned tasks.
The implementation of Tezel, et al., (2016b) based on the five case studies and focus group discussions include:

a) Increasing the attention given to Lean Construction (LC) and its techniques in the UK.
b) Highways England’s commitment to affect contractors’ decisions.
c) Visual Management (VM) can help decrease operational waste and increase work coordination.

Future opportunities for Visual Management (VM) implementation in England’s highway construction projects based on the five case studies, researchers’ observations and focus group discussions include:

a) 1st case study:
   1. Boards on the site with critical quality steps and schedule expectations.
   2. Determination of the reasons behind cost errors/mistakes.

b) 2nd case study:
   1. Having boards with Last Planner System (LPS) and performance boards.
   2. Visualization of method statements.
   3. Visualization of root cause analysis and continuous improvement process.
c) 3rd case study:
   1. Standardised visual performance board.
   2. Visualization of continuous improvement process.

d) 4th case study:
   1. Visual boards for costs and schedules.
   2. Simplifying the formats of the routine reports from clients and senior management that are shared with the workforce.

e) 5th case study:
   1. Apply 5S technique.
   2. Managers collect more Visual Management (VM) ideas from on-site workers.

Focus group discussions findings:

a) Extending Visual Management (VM) to have more performance boards.

b) Should have a visual system.

c) The data should be tackled before information visualisation.

d) In Visual Management (VM), it is important to show the ultimate project goals and company vision.

Researchers’ observations:

1. Application of 5S in different sectors of the projects.
2. Visual standard operating sheets on mobile boards or vans.
3. Visual control board linking Last Planner System with site teams.
4. Extended use of cloud Building Information Modelling, (BIM) for better information visualization among mobile work teams.

Daniel, Pasquire and Dickens, (2016) seek to determine the factors that influence Last Planner System (LPS) implementation on Joint Venture (JV) highway projects in the UK. The main reason of resorting to Joint Venture projects is that the project partner (for example: contractor) wants to share the risk, utilise skill, knowledge and resources with others. The author reached his target of the study by studying two case studies for twelve months, both with Joint Venture contracts. The methodology used includes interviews, document analysis and site observation. The data was collected from these projects by conducting interviews with a total of 21 interviewees. The researcher found that the following factors are essential to successfully implement Last Planner System (LPS):

a) Reduced batch size; it was observed that dividing the batch supports the concept of Last Planner System. The first case study was batched to three sections while the second one was batched to two sections. Batch means the working area.
b) Inclusion of Last Planner System practice in the contract; for both case studies, it was found that Last Planner System (LPS) is included in the contracts between client, contractor and subcontractors.

c) Use of collaborative form of contract and long-term relationship focus; both projects had JV contracts. The study stated that in this type of contract, it is better to share expectations among the teams of the project, which helps improve the general behaviour during the project.

d) Training and creation of awareness; the majority of the respondents stated that the subcontractors and main contractors need more training.

e) Appointment of facilitators and lean champions; from the conducted interviews many respondents stated that the appointment of facilitators and lean champions is essential for the improvement of Last Planner System (LPS) in JV projects.

f) Provision of physical space and co-location of the team; it was revealed that the availability of room for planning, controlling and co-location between teams is essential. The physical space was needed to have a visual board for the project, also it was seen that these rooms were close to the workspace.

g) Team integration and less parent company identity; the teams should ignore their parent company identity to create their responsibilities on the project. There is a strategy to share their emails, spaces, offices and every facility on the JV project. By doing this the teams will ignore their main company’s identity and work under the JV identity.

The study identified four blockers of Last Planner System (LPS), which could potentially hinder its implementation in JV contracts:

a) Poor promising.

b) Culture of old thinking and attitude among middle managers.

c) Lack of discipline and trust.

d) Resistance through procurement.

From the identified barriers and blockers of Last Planner System (LPS), the researcher concluded that human behaviours are the major problem for implementing Last Planner System (LPS).

Tezel and Aziz, (2016) after making ten visits to five different road (Highway) projects, managed to determine the benefits of 5S and implemented it on one of the highway construction projects (pilot project). It is important to mention that as shown in Figure 4, 5S refers to:

a) Sorting.

b) Setting-in-order.

c) Shining.

d) Standardizing.
After the implementation of 5S on the pilot project, from Table 2 the amount of time-savings needed to get every item from the warehouse by skilled and unskilled labours can be determined.
Table 2. Comparison between before and after 5S application on the pilot project

<table>
<thead>
<tr>
<th>Item</th>
<th>Before the 5S</th>
<th>After the 5S</th>
<th>Time savings after the 5S</th>
<th>Time savings after the SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batteries</td>
<td>97</td>
<td>57</td>
<td>37</td>
<td>29</td>
</tr>
<tr>
<td>Hammer</td>
<td>48</td>
<td>70</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td>Oil</td>
<td>111</td>
<td>80</td>
<td>40</td>
<td>27</td>
</tr>
<tr>
<td>Paint brush</td>
<td>87</td>
<td>67</td>
<td>63</td>
<td>26</td>
</tr>
<tr>
<td>Safety gloves</td>
<td>146</td>
<td>85</td>
<td>63</td>
<td>38</td>
</tr>
<tr>
<td>Safety goggles</td>
<td>75</td>
<td>80</td>
<td>56</td>
<td>38</td>
</tr>
<tr>
<td>Safety vest</td>
<td>136</td>
<td>60</td>
<td>60</td>
<td>42</td>
</tr>
<tr>
<td>Safety helmet</td>
<td>203</td>
<td>85</td>
<td>50</td>
<td>40</td>
</tr>
</tbody>
</table>


Heyl, (2015) presented a simulation game for road projects that was done twice; first using the traditional approach and then by using Lean concept. There is a comparison between the results, which were obtained from the two simulations. The following formula is used to calculate the required number of trucks needed:

\[
\text{Number of trucks} = \frac{P \times T \times S}{C}
\]

In this equation, P refers to Performance finisher, T: Circulation time, S: Safety factor and C: Capacity of truck (game roles are shown in Table 3). By decreasing the number of trucks used and improving the reliability of the supply, there was an improvement in the efficiency of the resources used. The results of the two simulations (Round 1 and 2) game are shown in Figure 5.
Table 3. Game Roles

<table>
<thead>
<tr>
<th>Role</th>
<th>Pers.</th>
<th>Task / Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck driver</td>
<td>8</td>
<td>Remote control of trucks; transport and unload of asphalt batches</td>
</tr>
<tr>
<td>Mixing plant</td>
<td>2</td>
<td>Operation of marble run and silo; measuring downtimes; responsible for delivery notes (log up and handing over)</td>
</tr>
<tr>
<td>Site worker</td>
<td>1</td>
<td>Acceptance of asphalt batches and delivery notes; responsible for asphalt paving; documentation of delivery notes; sort out defective material; measuring downtimes</td>
</tr>
<tr>
<td>Observer</td>
<td>&gt;0</td>
<td>Observing the gameplay; documentation of interesting incidents; ensuring compliance with rules of the game</td>
</tr>
<tr>
<td>Game Master</td>
<td>1</td>
<td>Introduction and explanation of roles, rules, gameplay and game elements; ensuring compliance with rules of the game; play of gameplay cards; moderation and control</td>
</tr>
</tbody>
</table>


Fig. 4. Results of the simulation games


Rodewohl, (2014) explained the requirements to apply the Lean concept to infrastructure projects; the process to integrate the project team into different project phases and the responsibility of the client in the application of the Lean concept in the project. These explanations were presented by studying six individual case studies using different methodologies as shown in Table 4.
Table 4. Used method in the six cases

<table>
<thead>
<tr>
<th>Research sources</th>
<th>Case I</th>
<th>Case II</th>
<th>Case III</th>
<th>Case IV</th>
<th>Case V</th>
<th>Case VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study of public project documents</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Individual interview with project manager</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual interview with project participant</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication via e-mail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: The presence of Lean Construction principles in Norways transport infrastructure projects, Norwegian University of Science and Technology, 2014.

The results that have been shown in this study can be summarized as follows:

a) Using Lean concept in infrastructure projects, there will be more focus on the wastes and so ways determined of how to remove them from the projects.

b) In the studied cases there was not a real integration between project parties, however, there was also no isolation in these cases for any member in the projects.

c) The client is responsible to understand the concept of Lean and be supportive to it during the different projects phases. So, the first step is to conduct training sessions in Lean concept for the project parties.

Kivistö, Ohlsson and Jacobsson, (2013) explains which lean principle is potentially applicable and determine the success factors needed to apply the Lean concept. This research is considered a qualitative study in which qualitative methods were used to respond to the research questions. By conducting a case study, the elements shown in Figure 6 were obtained.
Based on these elements, findings show that all Lean concept principles are suitable to be used in construction projects—especially road projects—and the success factors needed include applying the use of visual planning and applying Last Planner System.

Fullalove, (2013) presented the benefits and enhancements that occur because of using Lean concept in road construction projects. Using Planned Percentage Complete (PPC), Reason of Non-Completion (RNC) and visual management (5S) led to saving costs (around £78,000) for a project with a total cost of £365 Million. The followed actions took place:

a) More meetings were arranged between engineers and section engineers.

b) Engaging the sub-contractors to motivate them to finish their working activities on time.

Gaio and Cachadinha, (2011), further assessed the benefits and advantages of applying Lean concept in road projects. The study demonstrated that through the application of Lean concept to road projects wastes will be minimized or removed. By applying Just In Time (JIT), the material in stock will be reduced, using 5S concept the material will occupy less space, productivity will increase and the number of injuries of workers will decrease. By taking into consideration the concept of Total Productive Maintenance (TPM), the failure of the machines will be reduced.

Kahlen and Patel, (2011) presented a case study with the application of Lean concept; the results were summarized and analysed. The target of this study is to determine and list the factors that affect the rideability (rideability; the smoothness of the finished roads) of the highway construction projects and increase the supply chain efficiency to improve the rideability. Rideability is measured by using International Roughness Index (IRI); if International Roughness Index is high, this means the road is rough and rideability is low. The influencing factors and their results are:
a) Asphalt Temperature; hotter asphalt temperature produce lower IRI. However, cooler bitumen temperature produce lower IRI.
b) Work zone surface area; as the paving length increase per load, this produces lower IRI.
c) Layer thickness; thinner length produces lower IRI.

Jang and Kim, (2007) introduced a new measurement called Percentage of Constraint Removal (PCR) (its equation is shown below). The purpose of this study is to determine the correlation between this measurement and Last Planner measurements and to determine if this measurement can be represented in construction industry as workflow predictable.

\[
PCR = \frac{\text{Number of constraint free tasks when scheduling WWP}}{\text{Number of planned tasks at week (n)}^2 \times \text{Lookahead window}} \times 100
\]

Weekly Work Plan (WWP) will occur between week -1 and week 0. The purpose of this was determined by using three highway case studies. The study presented two phases; first phase of the projects used the traditional approach while in the second phase Lean Construction was used by applying Last Planner system (LPS). The findings show that there is no real relation between PCR and the improvement performance. The new measurement helped to determine if make-ready process was successfully done or not (main activities of make ready process are constraint analysis and constrain removal). Therefore, PCR could be reliable forecast for production process.

Farrar, AbouRizk and Mao, (2004) used simulation modelling on road project to show the improvement by applying Lean concept. The researchers used case study and made comparison between the model (in which Lean concept was used) and the real project (in which traditional concept was used). This study explained the studied road project that had the following categories:

a) Subgrade operations
b) Aggregate operations
c) Asphalt operations

To apply Lean concept to the simulation model the following steps were used in the study. After the below steps were taken the results were obtained as shown in Table 5:

a) Determine all the Non-Value Adding activities (NVA); candidates of improvement.
b) Assume that the duration of these activities equals "zero" to determine their significant effect on the project.
c) Run the simulation model.
d) Sort the Non-Added Value Activities (NVA) in their ascending order to determine which of them have the greatest impact.

e) Determine how to minimize the durations of Non-Added Value Activities (NVA).

f) Assume that the durations of material supply equals "zero" to determine the impact on delivering the material to the site.

g) Run the simulation model.

h) Determine the process to minimize the duration of delivering the material to site.

i) Determine the process to minimize the duration of Value Adding activities (VA).

j) Add buffers to the total duration of the activities. This will minimize the impact of uncertainties.

**Table 5: Comparison between real cases study (Traditional approach used) and simulated (Lean concept used)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Model Output</th>
<th>Actual Output</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Subgrade Production Rate (m²/hr)</td>
<td>624.7</td>
<td>620.7</td>
<td>0.64</td>
</tr>
<tr>
<td>Overall Aggregate Production Rate (tonne/hr)</td>
<td>337.9</td>
<td>355.1</td>
<td>4.8</td>
</tr>
<tr>
<td>Overall Asphalt Production Rate (tonne/hr)</td>
<td>290.8</td>
<td>298.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Paver Utilization Rate (%)</td>
<td>31.4</td>
<td>33.3</td>
<td>5.7</td>
</tr>
<tr>
<td>Paver Truck Change (%)</td>
<td>16.4</td>
<td>17.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Project Duration (hrs)</td>
<td>677.7</td>
<td>733.5</td>
<td>7.6</td>
</tr>
</tbody>
</table>


Table 6 summarize the previous studies that used Lean concept into road projects. From these studies by using Lean concept, improvements will occur in the cost and the duration for the road construction projects. However, some barriers prohibit applying Lean concept.

4. **CONCLUSION**

Pettersen, (2017); Kahlen and Patel, (2011) explained that Toyota Production System (TPS) established the lean concept after WWII in the production industry. TPS attempted to face the challenges that emerged in Japan during this period, and they sought better relations with their customers. Lean
concept has five principles; Value, Value Stream Mapping (VSM), Flow, Pull and Perfection, (Rodewohl, 2014). Some scholars in their work presented different barriers that could hinder the application of Lean Construction, (Gaio & Cachadinha, 2011; Heyl, 2015; Tezel, et al., 2016b; Farrar, AbouRizk and Mao, 2004). Among the mentioned barriers was the incorrect application of Lean Construction (Gaio and Cachadinha, 2011; Heyl, 2015; and Farrar, AbouRizk and Mao, 2004). In some cases, low interest from the different project parties as well as being intimidated to apply a new management tool to multi-million dollars projects acted as obstacles to the application of Lean Construction.

Kivistö, Ohlsson and Jacobsson, (2013) listed the three types of project durations, which are Value Adding (VA) and Non-Value Adding (NVA) activities (NVA; categorized into essential and non-essential activities). Lean concept categorized all the wastes that can occur into eight types of wastes. These wastes can be relevant to Non-Value Adding activities and especially non-essential activities because they can be removed and will result in more benefit for the activity duration.

Scholars listed some Lean tools that can be used in the construction industry, such as Last Planner System (LPS), 5S, Total Productive Maintenance (TPM) and Just In Time (JIT) concept (Gaio and Cachadinha, 2011; Pettersen, 2017; Tezel, et al., 2016a; 2016b; Jang and Kim, 2007; Tezel and Aziz, 2016). By applying these tools in the construction industry, more improvements in time besides increasing the value of Planned Percentage Complete can result (Tezel, et al., 2016a; Tezel and Aziz, 2016; Heyl, 2015). Using Lean concept in a case study leaded to make a cost saving by Fullalove, (2013). Farrar, AbouRizk and Mao, (2004) demonstrated the improvement in the production rates and the durations by using simulation game, which applied Lean concept principles.

REFERENCES


