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Investigation of Wasteful Activities Using Lean Methodology: In Perspective of Kazakhstan's Construction Industry

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Abstract: Like many other countries, the presence of wasteful activities is very common in Kazakhstan's construction industry. This severely affects the productivity of construction processes. Lean methodology maximizes the value of a process by minimizing wasteful or non-value adding (NVA) activities. This study aims to explore and quantify the impact NVA items on construction productivity. Several observations were made for construction processes in Astana, Kazakhstan to investigate and quantify various types of wasteful activities. Moreover, a survey was conducted to examine the general understanding of wasteful activities and Lean methods within the construction industry in Kazakhstan. In terms of wasteful activities, a similarity was found between the observed construction processes and survey results. Furthermore, apart from the commonly found seven types of wasteful activities, some other sources of waste, such as "preparation" and "break", were found from the observations. Finally, wasteful activities were mapped with commonly used Lean tools, as found in the literature, so that productivity can be improved by minimizing NVA activities. From the mapping and the survey results, value stream mapping (VSM) was found to be the most effective Lean tool, since it facilitates increased visualization.

Keywords: value adding activities; non-value adding activities; Lean methods; productivity improvement; construction process

1. Introduction

The construction industry in Kazakhstan accounts for 6% of country's GDP and the annual spending on all construction work was increased from KZT 2667 billion to KZT 3258 billion ($7.4 to $9.05 billion) in the years of 2012–2016. Despite the huge economic contribution, construction projects in Kazakhstan, like many other countries, face challenges related to productivity, quality of work, lack of effective management, low competitiveness of construction companies, insufficient volumes of high-level output, etc. [1,2]. This is because construction projects are characterized by the complex correlation and coordination of different functions and a large number of people are involved in a project [3,4], which eventually delays different construction operations, leading to cost and time overruns.

Considering the importance of the industry, the president of Kazakhstan identified the construction industry among the main priorities for economic development and instructed launching new breakthrough projects with improved performance. The concept of performance improvement deals with maximizing product value and reducing non-value adding activities in the construction processes [5,6]. This concept is in line with Lean thinking that focuses on delivering product with maximum quality, minimum resources, and reduced time.

The idea of Lean thinking originated in Japan's car manufacturing industry. Its roots and basic principles are taken from the Toyota Production System [7]. Lean thinking was brought in to construction and termed Lean construction by Koskela in 1992 [8]. The main aim of Lean construction is to minimize all non-value adding activities related to resources and time in construction projects [9,10]. Literature reveals that there are seven types of non-value adding (NVA) activities or wasteful activities according to Lean thinking, as follows: Defects, motion, transportation, overproduction, over-processing, inventory, and waiting [11]. The reasons behind these NVA activities are waiting for work assignments or resources, poor communication and coordination, and incorrect execution of work [12]. As assessed in [13], time spent on NVA activities is different for different projects, especially for construction projects. On average, this number is just below 50% of the time.

The research on Lean construction is more focused on the theoretical part and less on the actual practice. Emmit and Jørgensen [14] stated that there is a need for quantitative data analysis to verify the described theory. Claus [15] proposed a measurement model to evaluate the maturity level of Lean construction in an organization, while Babalola et al. [16] found that Lean implementation in construction lagged behind the manufacturing sector. Moreover, Lean methodology implies collaboration, flow, and vision of the whole project [17], while the construction industry is fragmented in nature and represented by interim organizations [8]. Alkhoraif et al. [18] argued that the successful implementation of Lean management is limited in the small and medium enterprises (SMEs), despite the fact that the majority of construction companies belong to SMEs. Furthermore, Gadde and Dubois [19] stated the construction industry as a disjoint system where innovations can be difficult to apply due to project groups, decentralized organization, and the absence of long-term connections. Nevertheless, Lean project management has been widely researched and successfully implemented in many construction projects [20–22].

Despite the benefits that the Lean methods offer in terms of value generation, improving productivity by reducing material and time waste, improving communication, cost savings, etc. [22–24], low adoption of Lean management is seen in Kazakhstan's construction industries [25]. Moreover, to the best of authors' knowledge, no significant study has been done on Lean perception nor is any data is available about the benefit gained by implementing Lean methods in construction projects in Kazakhstan. It can be seen from the discussion that there is a gap between theoretical and practical knowledge of Lean construction, particularly in Kazakhstan. Therefore, this study aims to make a quantitative as well as qualitative analysis to identify and quantify wasteful activities at construction sites and provide management control to improve construction operations and processes. It is to be noted that Lean project management differs from conventional project management [22,26] and the organization system is important to the successful implementation of Lean methodology in construction, which is beyond the scope of this study. A separate study should be conducted to understand the investment organization system from Kazakhstan's perspective.

2. Research Design

The nature of research can be of three types, as follows: Exploratory, descriptive, or explanatory [27,28]. Exploratory research is useful when there is limited knowledge or experience for a research question or when there is a need to explore about a little-known phenomenon. Descriptive research is used to describe any characteristic or phenomenon, while the goal of explanatory research is to answer the question "why" and explain a phenomenon or provide justification(s) for something that happens. This research is exploratory in nature and investigates construction operations in Astana, Kazakhstan to improve the understanding of wasteful activities in construction projects as a means of construction productivity improvement.

A case study approach has been used, which allows the study of a limited system to understand a complex phenomenon within its real-life context [29]. In this research, the bounded system is specific construction sites.

Data Collection

As mentioned in Yin [30], observation is important to understand and obtain information about a phenomenon. Accordingly, a number of construction processes were observed in Astana, Kazakhstan to investigate and quantify non-value adding or wasteful activities in construction projects. A value stream mapping (VSM) tool [31,32] was used to collect data through observations. The observations were made on five types of construction processes from three construction sites. The construction processes were installation of an aerated concrete block, installation of a bracket, installation of a floor slab, wall painting, and tile cutting. Though the researchers had limited access to observe other construction processes, these are some typical construction processes found in many building construction projects. Moreover, the construction sites were chosen from the leading real estate companies in Kazakhstan.

In addition to direct observation, a survey was conducted as a qualitative assessment that provides a holistic approach to the study of non-value adding activities in construction operations and portrays an understanding of Lean construction. Generally, the survey questionnaire included the following:

- Questions about the participant's experience and roles in the project;
- Questions regarding knowledge of Lean methods;
- Questions regarding waste/non-value adding activities in construction process; and
- Questions regarding Lean tools.

The questionnaire was set in the form of multiple-choice questions, which consisted of several answers so that the participant could easily choose the most appropriate option (the detail of the questionnaire can be seen in Appendix A). Such types of questions save the participants' time. The questionnaire was created with the help of the website www.freeonlinesurveys.com and the link was sent to people working in the construction industry through instant messengers and e-mail. A total of 123 construction professionals received the questionnaire.

3. Results and Analysis

Among the five observed construction processes, three sets of sample data are shown in Tables 1–3 for two construction processes "installation of a floor slab" and "cutting tile". The process "installation of floor slab" involved 3 persons, 1 crane operator and 2 installation workers. Table 1 shows the timing of the details of work for the crane operator. Table 2 depicts the timing for both the installation workers by classifying them as value adding (VA), non-value adding (NVA) and essential non-value adding (ENVA) activities. As defined in [31,33], VA contributes to the transformation of a product or service to the end result, done right from the first try and the customer is willing to pay for it. Whereas, ENVA is supporting activities that promote to the execution of value-adding activities, but do not add value. Finally, NVA uses resources but does not create value.

By comparing the data of Tables 1 and 2, it can be seen that when the crane operator was working (VA or ENVA) both the installation workers were waiting for their turns to come (NVA) and vice versa. Therefore, a significant amount of time was NVA time, as can be seen in Figure 1, which shows percentage of VA, NVA, and ENVA for all three people. More than half of the time for each person contributed to NVA activities. This is because each of the workers was waiting for other co-workers throughout the construction process, as evident from Tables 1 and 2. This is a typical characteristic when a construction process involves multiple workers.

Apart from waiting, other types of NVA activities were observed in different construction processes, such as "searching for tools", "walking to bring bracket/block/tools", "cleaning/screwing /unscrewing handrail fitting", "painting for second time", and so on. Moreover, each of the construction process consisted of several ENVA activities that used a significant amount of time in that construction process. For example, Table 3 shows timings of details of work for the construction process "cutting tile" by categorizing VA, NVA, and ENVA. In this case, one-quarter of the time was spent on NVA activities (see Figure 2). This value is much lower than the earlier case since one worker was doing the work and, hence, not dependent on other co-workers. However, 36% ENVA activities were engaged in the construction process.

Table 1. Average data gathered from the VSM of the process "installation of a floor slab" for person 1 (crane operator).

No.	Detail of Work	Classification	Duration (s)	% Of Total Time
1	Lowering the crane boom	VA	22.5	15
2	Waiting while person 2 was walking	NVA	6	4
3	Waiting while person 2 and 3 were fixing the slab to slings	NVA	17	11
4	Lifting the crane boom	ENVA	14.5	10
5	Turning the crane boom	ENVA	16	11
6	Lowering the crane boom closer to the installation site	ENVA	10	7
7	Waiting while person 2 and 3 were laying the mortar	NVA	26	17
8	Waiting while person 2 and 3 were walking	NVA	17	11
9	Lowering the crane boom to the installation site	VA	6	4
10	Waiting while person 2 and 3 were positioning the slab	NVA	10	7
11	Waiting while person 2 and 3 were installing the floor slab	NVA	5	3
	Total		**150**	**100**

Table 2. Average data gathered from the VSM of the process "installation of a floor slab" for person 2 (installation worker).

No.	Detail of Work	Classification	Duration (s)	% Of Total Time
1	Waiting while person 1 was lowering the crane boom	NVA	22.5	15
2	Unnecessary walking	NVA	6	4
3	Fixing the slab to slings	ENVA	17	11
4	Waiting while person 1 was lifting the crane boom	NVA	14.5	10
5	Waiting while person 1 was turning the crane boom	NVA	16	11
6	Waiting while person 1 was lowering the crane boom closer to the installation site	NVA	10	7
7	Laying of mortar	ENVA	26	17
8	Unnecessary walking	NVA	17	11
9	Waiting while person 1 was lowering the crane boom to the installation site	NVA	6	4
10	Positioning of the slab	VA	10	7
11	Installation of the floor slab	VA	5	3
	Total		**150**	**100**

Table 3. Average data gathered from the VSM of the process "cutting tile".

No.	Detail of Work	Classification	Duration (s)	% Of Total Time
1	Searching for tools (pen and measuring tape)	NVA	5	2
2	Measuring the required size	ENVA	14	6
3	Marking the required size	ENVA	18	7
4	Cutting the required size	VA	57	22
5	Marking of openings	ENVA	15	6
6	Cutting of openings	VA	47	19
7	Grinding	ENVA	20	8
8	Transportation of tile	NVA	26	10
9	Discussion of work	ENVA	24	9
10	Unnecessary taking, waiting, and smoking	NVA	28	11
	Total		**254**	**100**

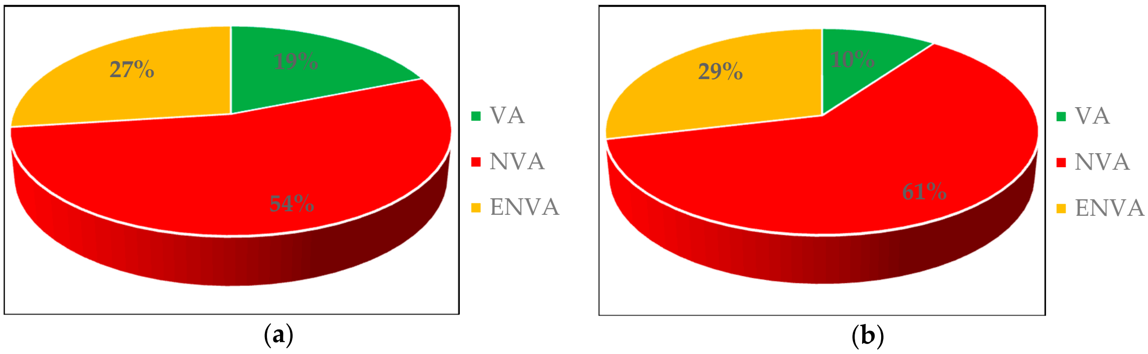

Figure 1. Summary of the VSM data of the process "installation of floor slab" (**a**) for person 1—crane operator, (**b**) for persons 2 and 3—installation workers.

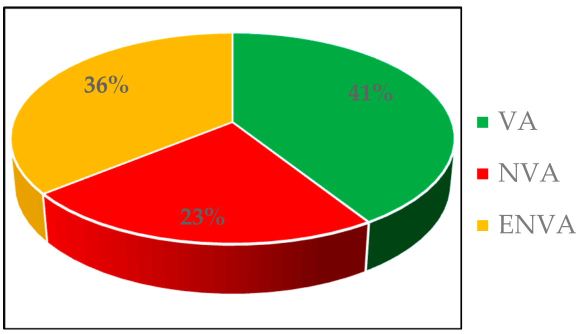

Figure 2. Summary of the VSM data of the process "cutting tile".

Similar classifications were made for three other construction processes and the percentages of VA, NVA, and ENVA activities are shown in Figures 3–5. A varying amount of NVA and ENVA were observed in these processes as well. Afterwards, a summary was made from Figures 1–5 by averaging the percentages of time for VA, NVA, and ENVA activities for all of the five observed construction processes. Figure 6 shows the average timing, in terms of percentage, for each type of activity. As can be seen in Figure 6, only 33% of the workers' time was spent on value adding activities. Nearly 41% of time was consumed in execution of essential non-value adding activities, which needed to be reduced. Additionally, about 26% of time was non-value adding activities, which should be eliminated.

Some variations can be found in the percentages of VA, NVA, and ENVA when comparing the results from observations made in Astana with those available in literature. For instance, a study conducted by Jens and Kristensson [34] found 44% VA activities in construction process, while the percentages of NVA and ENVA accounted for 36% and 20%, respectively. On the other hand, Mossman [35] assessed that the volume of NVA activities were in the range of 55%–65%. VA accounted for only 5%–10%, while the remaining 30%–35% were ENVA activities. Comparing the observed results in Astana and the conducted survey results, similarities can be noticed.

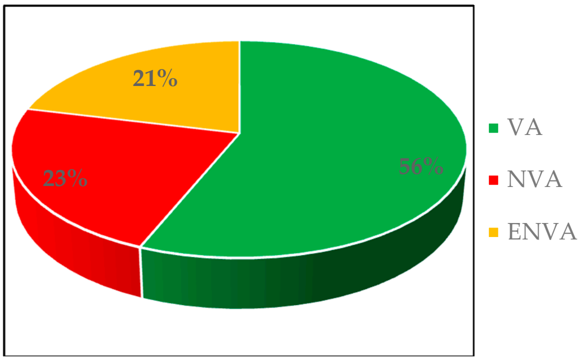

Figure 3. Summary of the VSM data of the process "installation of an aerated concrete block".

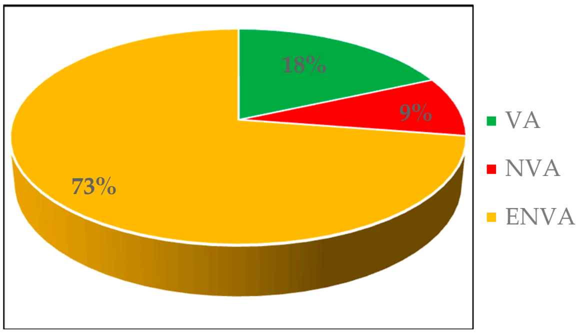

Figure 4. Summary of the VSM data of the process "installation of a bracket".

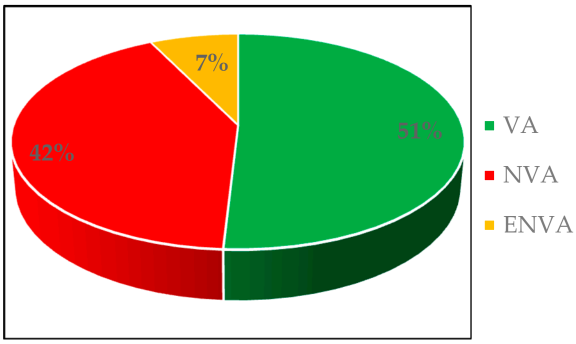

Figure 5. Summary of the VSM data of the process "painting of a wall".

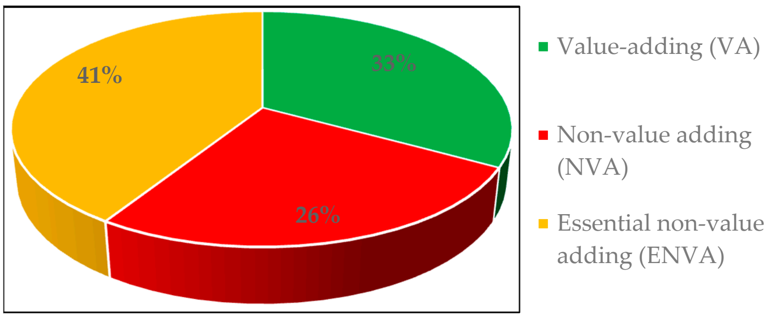

Figure 6. Average of each activity classification type for all observed construction processes.

Survey Results

The survey questionnaire was sent to 123 construction professionals. The survey received 28 responses with a 23% response rate. It can be seen from the responses received that all the participants were familiar with Lean methodology. This indicated that persons who were aware of Lean methodology participated in the survey. This was also indicated by a low response rate. Therefore, it was not possible to categorized responses based on the respondents' familiarity with Lean methodology.

Figure 7 shows the distribution of the work departments of the respondents, which shows that a wide range of construction professionals, including managing directors, project managers, heads of construction sites, site engineers, surveyors, foremen, and others, answered the survey questions. The majority of the participants were involved in the field of construction and were aware of wasteful activities in the construction process. Moreover, the working experiences of most of the participants were found to be from 1 year to more than 10 years. Therefore, the obtained survey results can be considered as representative.

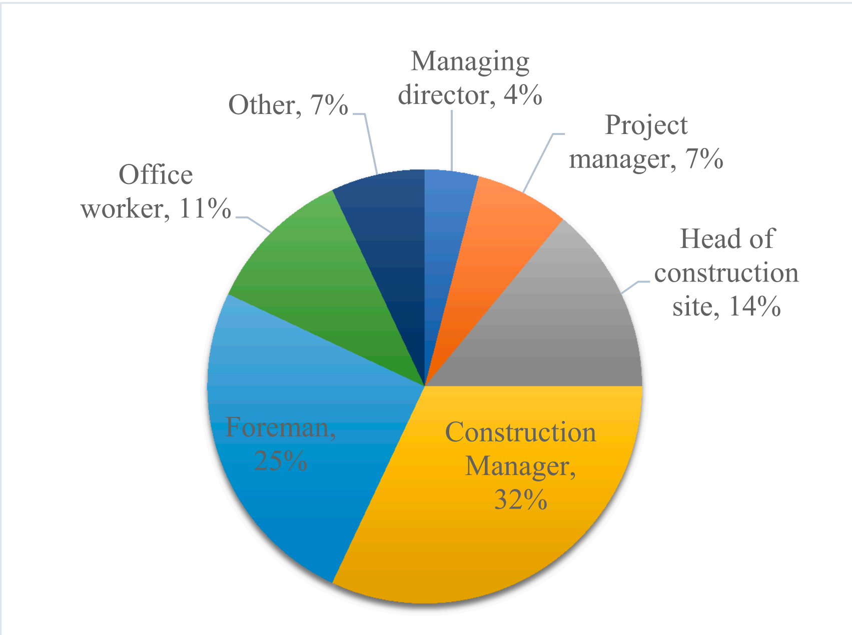

Figure 7. Working departments of the respondents.

In response to the question about effectiveness of the Lean methodology, 82% of the respondents agreed that Lean method is effective or very effective in improving construction operation, while the remaining respondents indicated that it has little effect in reducing wasteful activities (see Figure 8). While one can argue about the effectiveness of the Lean method to improve construction processes in Kazakhstan, the survey results indicate that the construction professionals have a positive attitude about the usefulness of Lean methodology.

Regarding the percentage of non-value adding activities within a construction operation, a significant number of participants (about 57%) indicated that there are 10%–30% wasteful activities in the construction process (see Figure 9), which is very close to the observed results in actual construction sites.

The next question on the survey was about the types of wasteful activities that are common within the construction operation. In this case, the participants were asked to choose from the seven types of wasteful activities (without considering their frequency of occurrence) as they observed in their construction projects. As can be seen in Figure 10, 75% of the participants indicated defects or correction waste as the most frequent, followed by waiting time, motion waste, transportation waste, and others.

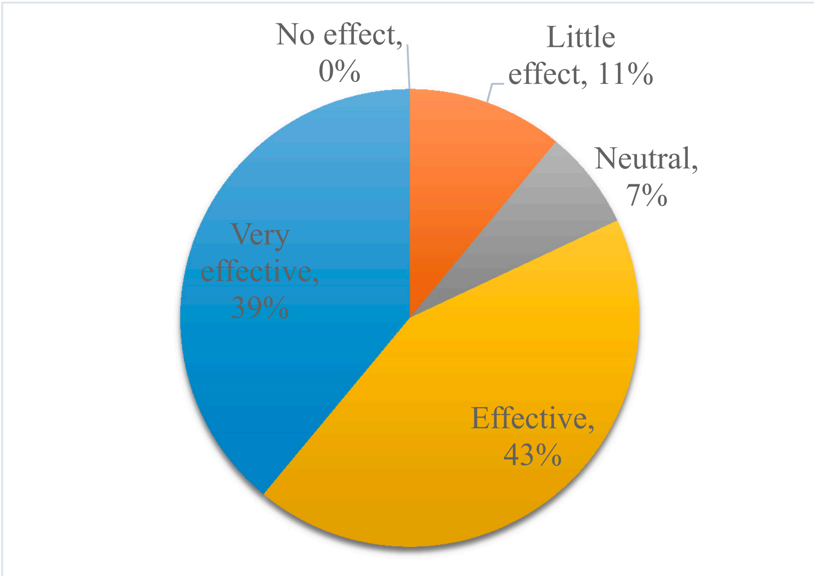

Figure 8. Percent response regarding the effectiveness of Lean methodology.

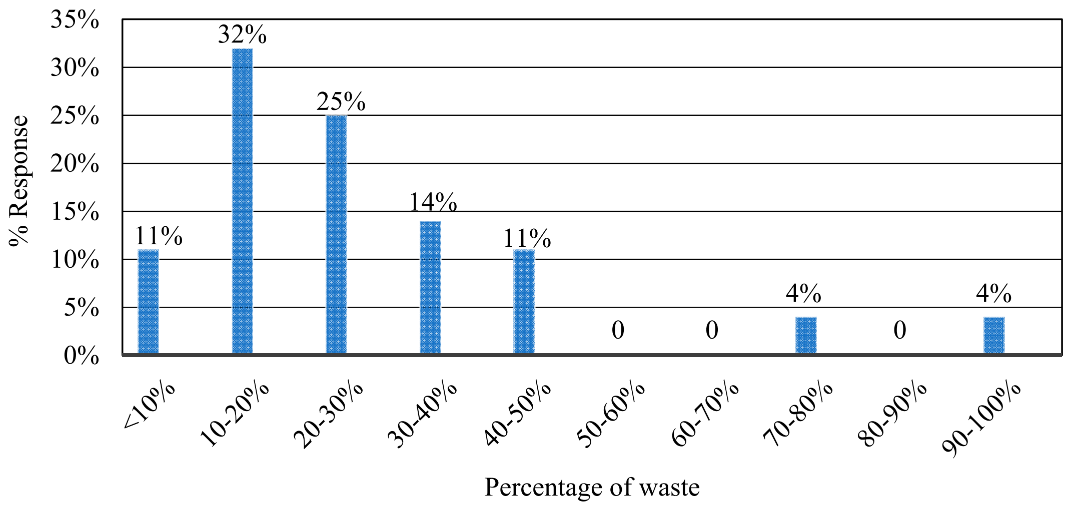

Figure 9. Percentage of responses regarding the amount of waste which can be found during construction.

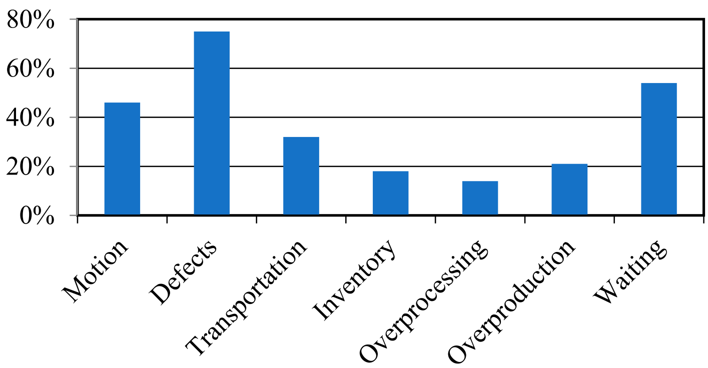

Figure 10. Percentage of responses regarding the most common type of waste which can be found in construction.

In the next part of the survey, the participants were asked to rate each of the wasteful activities in terms of their frequency of occurrence in a five-degree Likert scale (never, rarely, occasionally, frequently, and very frequently). From the responses, the types of wasteful activities were ranked based on the Relative Importance Index (RII), as can be seen in Table 4. The table depicts that 'waiting' was the most frequently occurred wasteful activity followed by 'defect', 'motion', 'transportation', and so on. A survey conducted by Ismail and Yosuf [36], in the Malaysian construction industry, also found that defects and waiting time were the major contributors to NVA activities.

Table 4. Relative Importance Index (RII) and Ranking for waste type.

Waste Type	RII	Ranking
Waiting	3.71	1
Defects	3.61	2
Motion	3.54	3
Transportation	3.04	4
Over-processing	2.93	5.5
Overproduction	2.93	5.5
Inventory	2.79	7

The wasteful activities, as found from the observations of the five construction processes, portray a similar trend to the survey results. According to the observations, 'waiting' and 'motion' were among the most frequent wasteful activities, followed by 'transportation', 'inventory', and 'over-processing'. However, 'defects' and 'overproduction' were not found in any of the five observations. The observed wasteful activities, which were identified as NVA activities, were categorized according to the types of waste and are presented in Table 5. As can be seen, waiting was observed in terms of waiting for other co-workers when a person was performing his/her work. On the other hand, motion waste was also observed as the prevailing type. A great amount of time was spent as motion waste while workers were searching for tools and materials. In most cases, the materials were stored in one place while the work was performed in another place and the workers were not sure about the type and/or the amount of material/tool needed for their work.

Another wasteful activity was found to be transportation waste. It was observed during the process of cutting a tile. Although the transportation waste was ranked 4th according to the survey result (see Table 4), in order to fully observe transportation waste it is necessary to focus on the external flow at construction sites, such as local material suppliers, poor job planning, inaccurate logs on vehicles and equipment, and so on.

The next type of waste identified from the observations was improper inventory. During the observations of construction sites, it was found that a lot of material and many tools were stored in one place from where workers spent some time to find his/her required tools or material. The results of the survey showed that participants noted this type of waste as not so common, but encountered nevertheless.

Over-processing waste occurred when the worker was painting the wall a second time. This activity does not match with the concepts of VA or ENVA activities. Although the work was done right the first time (in this case painting), it was the worker's intention to paint it for the second time.

Two types of waste, which were not observed in the five construction processes, were defects and overproduction waste, as mentioned earlier. The waste in the form of defect occurs when actions are needed to repair or redo the accomplished work. Among the five construction processes, there was no such case where an activity was performed incorrectly the first time, nor there was a need for additional work. On the other hand, overproduction waste is about producing more than it is required or demanded. Nevertheless, during this research investigation, there was no such case recorded and none of the investigated processes included work that could be overproduced.

Table 5. Type of wasteful activities in the construction processes as identified from observations.

Type of Wasteful Activity	Activity Description
Motion	Walking to bring a block Walking to bring a leveling tool Walking to bring a perforator Walking to bring a bracket Walking to bring a key Unnecessary walking
Defects	Not observed
Transportation	Transportation of a tile
Inventory	Too much tools and materials Searching for tools (pen and measuring tape)
Over-processing	Painting second time
Overproduction	Not observed
Waiting	Waiting while person 2 was walking Waiting while person 2 and 3 were fixing the slab to slings Waiting while person 2 and 3 were laying the mortar Waiting while person 2 and 3 were walking Waiting while person 2 and 3 were positioning the slab Waiting while person 2 and 3 were installing the floor slab Waiting while person 1 was lowering the crane boom Waiting while person 1 was turning the crane boom Waiting while person 1 was lowering the crane boom closer to the installation site Waiting while person 1 was lowering the crane boom to the installation site

Apart from the seven types of wasteful activities, as found in the literature, other non-value adding activities were identified during the observations. For example, the activities of "unnecessary talking, waiting, and smoking" can be categorized as "break waste". Moreover, there were other activities like "screwing/unscrewing handrail fitting" or "cleaning handrail fitting" which did not add value to the final product. These activities do not fall into the seven types of defined wasteful activities. Accordingly, such NVA activities can be classified as "preparation" waste. A study conducted by Arleroth and Kristensson [34] also identified similar waste categories by observing construction processes in Sweden.

To minimize the wasteful or non-value adding activities in the construction processes, Lean tools such as value stream mapping (VSM), increased visualization, 5S (Sort, Set in order, Shine, Standardize, and Sustain), and the Last Planner System are well known in the literature. These tools are mapped with the different types of observed wasteful activities and are presented in Table 6. The table shows a summary of observed types of NVA activities that can be improved with different Lean tools.

Table 6. Observed waste types that can be improved with 4 Lean tools.

	Motion	Transportation	Inventory	Over-Processing	Waiting	Preparation	Breaks
Value Stream Mapping	√	√	√	√	√	√	√
Increased Visualization	√	√	√	√	√	√	
5S	√	√	√	√	√	√	
Last Planner System	√	√	√	√	√	√	√

The survey respondents also showed positive attitudes regarding the effectiveness of these Lean tools. The last question of the survey was to evaluate the effectiveness of the abovementioned four commonly used Lean tools. Table 7 shows the ranking of the tools based on RII. As evident from the RII values, all the tools were found to be effective, though the tool 5S was ranked the 1st. However, by comparing Tables 6 and 7, out of these 4 tools, the VSM technique can be identified as the most prominent considering its ability to improve different types of wasteful activities and the survey ranking. Moreover, the VSM tool is found to be very useful for the examination of processes, identifying wasteful activities, and distinguishing them NVA and ENVA. After identifying each type of waste, it is possible to take further actions to eliminate/minimize unnecessary steps, create flow, and ensure the continuous improvement of the construction process.

Table 7. RII and Ranking for Lean tools.

Lean Tools	RII	Ranking
Value Stream Mapping	3.79	2.5
Increased Visualization	3.79	2.5
5S	4.04	1
Last Planner System	3.71	4

4. Conclusions and Discussion

Construction projects are characterized by low productivity that involves numerous wasteful activities in the construction processes. This study explored wasteful activities by means of Lean methods to improve productivity for construction projects in Astana, Kazakhstan. The method involved identifying and eliminating non-value adding activities in the construction processes. Several observations were made for some selected construction processes in Astana in order to categorize VA, NVA, and ENVA activities within a construction process and the percent of time for each activity type was quantified. It was found from the observations that the percentage of value-added activities contributed only 33%, while NVA together with ENVA activities occupied 67% of the total process time. Particularly, 26% of time spent on various activities were found to be pure waste, which came in the form of waiting, motion, transportation, inventory, over-processing, etc. Literature suggests that the time spent on ENVA activities should be minimized and that NVA activities should be eliminated. This minimization and/or elimination would eventually improve construction productivity.

A survey was also conducted as a qualitative assessment and to portray the perception of the construction professionals about Lean methods in Astana. Most of the survey participants indicated the presence of wasteful activities in the construction processes to be between 10%–30%, while the literature revealed the percentage of non-value adding activities to be between 36%–65%. Moreover, the frequency of different types of wasteful activities associated with construction processes showed a similar trend between the observed and survey results, where waiting and motion types of waste were found to be more frequent. In addition, apart from the seven types of NVA activities, as reported in the literature, other types of wasteful activities were found in the observed construction processes, which were categorized as “preparation” and “break” wastes.

This study provided a comprehensive understanding of Lean methodology for identifying and eliminating wasteful activities, so that productivity can be improved for the construction projects in Kazakhstan. Construction companies in Kazakhstan and other countries in the world can use the findings of this study to implement Lean method in their projects. Further investigations should be carried out to quantify the time and cost savings if the Lean method is used to improve construction productivity. Moreover, the company should carefully consider the necessary cultural changes within the organization to adopt the Lean project management approach for their projects.

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Appendix A

Questionnaire

1. Work experience in the construction industry

a. <1 year b. 1–5 years c. 5–10 years d. >10 years

2. Your position in the company

a. Managing director b. Project Manager c. Head of construction site
d. Manager e. Foreman f. Office worker g. Other

3. Are you familiar with Lean methodology?

a. Yes b. No

4. If you are familiar with Lean methodology, how do you assess the effectiveness of this methodology in construction on a scale of 1 to 5?

1 - not effective 2 - little effect 3 - neutral 4 - effective 5 - very effective

5. In your opinion, what percentage of total work time in construction operation is waste?

a. <10% b. 10–20% c. 20–30% d. 30–40% e. 40–50%
f. 50–60% g. 60–70% h. 70–80% i. 80–90% j. 90–100%

6. Which types of wastes are common in the construction industry? (You can choose several options)

a. Motion b. Defects c. Transportation d. Inventory
e. Overprocessing f. Overproduction g. Waiting

7. Please, rate the frequency of different types of waste which can be found in the construction operation, on a scale of 1 to 5.

	Never	Rarely	Occasionally	Frequently	Very Frequently
Motion waste	○	○	○	○	○
Defect waste	○	○	○	○	○
Transportation waste	○	○	○	○	○
Inventory waste	○	○	○	○	○
Overprocessing waste	○	○	○	○	○
Overproduction waste	○	○	○	○	○
Waiting waste	○	○	○	○	○

8. Please, rate the effectiveness of different Lean tools implemented in construction projects on a scale of 1 to 5.

	Not Effective	Little Effective	Neutral	Effective	Very Effective
Motion waste	○	○	○	○	○
Defect waste	○	○	○	○	○
Transportation waste	○	○	○	○	○
Inventory waste	○	○	○	○	○

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