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Waste Management for Jordanian Industries Using Lean Management Principles

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Abstract
This paper is focused on managing waste that is generated by construction. Starting with expressing, how significant construction waste affecting project success, and then lean management principles were proven to be positively helping in keeping construction projects waste controlled. Where construction waste sources and causes were subcategorized under each main waste category that lean principles deal with. After that, adequate questionnaire was developed in order to collect data. These data were analyzed in order to determine the level of occurrence and significance for each waste type and to scientifically recommend the proper tools and techniques to deal with them, effective lean tools to be applied in Jordan according to waste sources that were determined.

Keywords: Performance Improvement; Construction Management; Lean management, Waste.

الخلاصة: تركز هذه الدراسة على إدارة النفايات الناتجة عن البناء. بدءًا من التعبير عن مدى تأثير نفايات البناء الكبيرة على نجاح المشروع ، ثم ثبت أن مبادئ الإدارة الرشيقة تساعد بشكل إيجابي في الحفاظ على السيطرة على نفايات مشاريع البناء. حيث تم تصنيف مصادر وأسباب نفايات البناء تحت كل فئة نفايات رئيسية تتعامل معها مبادئ العجاف. بعد ذلك ، تم تطوير استبيان مناسب لجمع البيانات. تم تحليل هذه البيانات من أجل تحديد مستوى التواجد والأهمية لكل نوع من أنواع النفايات والتوصية علميًا بالأدوات والتقنيات المناسبة للتعامل معها ، والأدوات الفعالة التي يجب تطبيقها في الأردن وفقًا لمصادر النفايات التي تم تحديدها.

1. INTRODUCTION

Construction waste has been identified as a very frequent issue in construction industry that causes an extra cost for projects that leads to cost overrun, in other words, it may cause construction projects to fail. John & Tied (2013) conducted a study found that construction waste was the reason for 21-30% of cost overruns. However, construction industry influences every country's economy, and in a developing country like Jordan with limited economical resources, cost is one of the most critical issues that may affect construction projects either to increase or to decreasing their overall productivity. Waste in construction consists of unwanted entities such as excessive materials, labors, equipment…. etc. these waste entities consume money, time and effort, and for one of these unwanted waste; material waste, it might contain hazardous substances, which shows the importance of reducing these materials. Even the disposal of these unwanted materials will not be enough, because an additional disposal costs will be involved in that case (Lingard, et al, 2000). Environmental issues such as air pollution would occur as well as a reason of disposing construction waste. However, eliminating and/or reducing construction waste needs to be approached by effective techniques, such as lean techniques, which are what this research aims to use.
Construction waste can be defined according to literature in different ways depending on its classification and recognition. Senaratne and Wijesiri (2008) found that delays, rework, excess materials and defects are some of waste classifications that were commonly mentioned by researchers. However, waste generated in the construction processes is named by researchers as "non-value-adding activities or non-physical waste" according to lean construction theory (Hosseini, et al. 2012). The same study emphasized that waste generated in construction projects is not limited to material waste, but also setup times, waiting times and transportation times are considered as major wastes as well. This explains the development of the term non-physical waste within the

construction processes. Waste with all its kinds mentioned above exhaust relatively high percentage of the overall project cost, besides the economical aspect, Tam, et al. (2007) stated that environmental problems are involved as well as a reason of construction projects material waste and by minimizing and recycling those economical savings and environmental benefits will be gained. In a lean thinking approach, construction waste was categorized by Hosseini (2012) in a way that each main category is classified in regards of its relation, Table.1 explains these categories and classifications.

Table 1 Waste categorizations Hosseini (2012)

Construction Site Waste	Waiting	Errors	Equipment wear and tear	Delay	Excess materials		
External Factors Waste	Excess materials		Safety costs		Clarifications needs		
Construction Processes Waste	Defects	Rework	Overproduction	Non value-adding work	Transport time	Unnecessary Inventory	Improper choice of methods

The main objective of this work is to implement some lean principles to eliminate and/or reduce waste generated within construction projects in Jordan. However, to achieve that, Jordan construction sector needs to be further studied, then to investigate and to categorize waste types, after that, causes and sources for each waste type needs to be mapped and rated based on the most occurrence in order to scientifically recommend and suggest the proper lean tools to be applied. Which as a result increase the project success.

2. WASTE AND LEARN MANAGEMENT PRINCIPLES

Lean principles are tools and techniques that are used for effective management were first started in Japan (Toyota, specifically) in the 1940s (Fujimoto, 1999) (Melton, 2005), later on, lean principles were developed in a suitable way to fit for the organizations as a whole, or even for each activity as individual (Kilpatrick, 2003). These principles were set to deal with the eight types of wastes:

1. Defects: defects waste resources in four ways, first, material waste. Second, labors effort that cannot be recovered. Third, labors are required to redo the service. Fourth, costumer complaints.
2. Transportations: delivering materials to its point of use instead of shipping materials from vendors to a certain location and after that to the place where they will be used. This lean tool is called Point-of-Use-Storage.
3. Waiting: refers to waiting for materials, equipment, information, tools, etc. one of lean tools deals with this waste is called Just-in-Time (JIT).
4. Non-Value-Adding Processes: can be described as reworking processes where work should be done from the first time correctly.
5. Excess Motion: the reasons for unnecessary motion are poor workflow, housekeeping, poor layout and poor planed work methods. Value Stream Mapping (VSM) technique is used to identify and to avoid this waste type.
6. Inventory: excess inventory spaces negatively impacts cash flow.
7. Overproduction: to produce and to make more than requested and demanded by customers. Lean principles suggest working upon a pull system.
8. Underutilized People: underutilization of creativity and abilities not only underutilization of physical attribute, where the main causes for this waste might be poor workflow and inadequate hiring.

Several lean tools and techniques were developed by many researchers through the past decades, Ansah et al., (2016) collected and explained these tools depending on previous studies. Table 2 describes some of these tools.

Table 2 Lean Tools and Techniques

5S	Concurrent Engineering	Check Sheet
Six Sigma	Construction Process Analysis	Pareto Analysis
Failure	Check Points and	Continuous Flow

Mode and Effects Analysis (FMEA)	Control Points	
Kaizen	Kanban (Pull System)	FIFO line (First In, First Out)
The Last Planner	Heijunka (Level Scheduling)	First Run Studies
Bottleneck Analysis	Time and Motion Study	Poka-Yoke (Error Proofing)
Visual Management	Total Productive Maintenance	Synchronize/Line Balancing
Work Structuring	Multi-Process Handling	5 Whys
Fail Safe for Quality	Daily Huddle Meetings	Preventive Maintenance
Statistical Process Control	Quality Function Development	Work Standardization
Setup Reduction	Schemes Suggestion	Just-in-Time (JIT)
Mapping (VSM)	Team Preparation	Muda Walk

Lean principles had proved its efficiency in effective management of systems, therefore, adopting these principles in construction is required. Lean principles can be approached in construction management in the following areas (Ogunbiyi, 2014); (1) Waste reduction, (2) Process focus in control and production planning, (3) End costumer focus, (4) Continuous improvements, (5) Cooperative relationships, and (6) Systems perspective.

3. RESERECH METHODOLOGY

According to JCCA there are 1640 contracting companies in Amman only. This represents 59% of total contracting companies in Jordan (Jordan Construction Contractors Association, 2014). Amman represents the general situation in Jordan, therefore the contracting companies in Amman is considered as the target population of this work. According to Cochran's (1977) the following sample size formula is used:

$$\text{No.} = \frac{\left[t^2 \times (p \times q)\right]}{d^2} \quad \text{……..(1)}$$

Where:

t: value of selected alpha level α 0.025 (1.96 for 95% confidence level)

p: percentage of selecting a choice expressed as decimal (which is equal to 0.5).

q: 1-p; (p) and (q) are estimates of variance.

d: acceptable margin of error for proportion being estimated (confidence interval expressed as decimals equal to = 0.1).

$$\text{No.} = \frac{\left[1.96^2 \times (0.5 \times 0.5)\right]}{0.1^2} = 96 \text{…….(2)}$$

However, as this sample size exceeds 5% of the population; Cochran's (1977) correction formula should be used to calculate the final sample size:

$$N1 = \frac{No}{\left(\frac{1+No}{N}\right)}, \quad N1 \approx 73 \text{ ……..(3)}$$

To address the construction waste management in the considered sample, A questionnaire is designed and developed. The questionnaire was simple, where all questions are straightforward and the researcher witness no need to translate or to clarify any information to the respondent. Before using the questionnaire it was reviewed,

then validated by two professors and one associate-professor from school of engineering at university of Jordan. Collected information is recorded, then statistically analyze SPSS software.

4. DATA ANALYSIS AND RESULTS

Table 4.1 demonstrates that "Underutilized people" has the highest level of occurrence and significance, 4.01 and 4.21 respectively. While the "Non value-adding Processes "waste type has the lowest level of occurrence and significance, 2.45 and 2.54 respectively. Similarly level of occurrence and significance for all waste types are shown in table 3.

Table 3 level of occurrence and significance for all waste types

Waste		Mean		Standard deviation	
No.	Type	Level of Occurrence	Level of Significance	Level of Occurrence	Level of Significance
1	**Defects**	2.92	2.91	1.19	1.32
2	**Transportation**	2.73	2.74	1.18	1.26
3	**Waiting**	2.66	2.63	1.15	1.21
4	**Non value-adding Processes**	2.45	2.54	0.96	1.07
5	**Motion**	3.37	3.17	1.07	1.16
6	**Inventory**	2.92	2.75	1.32	1.33
7	**Over Production**	2.72	2.60	1.33	1.23
8	**Underutilized people**	4.01	4.21	0.83	0.76

Roots of each waste type is identified, and the significance and the occurrence of each root is estimated using SPSS, assisting construction waste management in Jordan using lean principles is provided. Table 4, and table 5, shows the descriptive analysis SPSS output for roots of "Underutilized people" waste, and for "Non value-adding Processes".

Table 4 level of occurrence and significance for all root causes of "Underutilized People" waste type

Waste		Mean		Standard deviation	
No.	Type	Level of Occurrence	Level of Significance	Level of Occurrence	Level of Significance
1	**Ineffective planning and scheduling**	4.79	4.37	0.41	0.69
2	**Lack of weekly project evaluation meetings**	4.60	4.40	0.77	0.72
3	**Lack of periodic meeting among the management,**	4.50	4.13	0.51	069
4	**Inadequate instructions provided by supervisor**	3.87	3.99	0.46	0.74
5	**Lack of experience of craftsmen**	3.9	3.92	0.70	0.76
6	**Lack of team spirit among craftsmen**	4.02	1.06	3.90	0.96
7	**Lack of experience of supervisor**	4.08	3.85	0.97	1.02

Table 5 level of occurrence and significance for all root causes of "Non value-adding Processes" waste type

Waste		Mean		Standard deviation	
No.	Type	Level of Occurrence	Level of Significance	Level of Occurrence	Level of Significance
1	**Frequent revisions of drawing / design resulting in additional**	2.33	2.60	0.83	1.09

	work / rework				
2	**Make unnecessary inspection**	2.48	2.63	0.87	1.10
3	**Setup times**	2.13	2.35	0.72	0.91
4	**Entering the same data in more than one place on a form**	3.13	2.98	1.25	1.35
5	**Multiple approval levels for a small spending request**	2.48	2.44	0.85	0.96
6	**Multiple MIS reports**	2.15	2.27	0.77	0.87

Similarly level of occurrence and significance for all root causes of all other waste type are investigated.

In order to investigate if there is significant difference between general information filled by respondents and the results, Relationships between the sample characteristics and the eight waste type also have been investigated. For such purpose (González-Rodríguezet, et al., (2012), one-way ANOVA test has to be conducted. However, the assumptions of sample are independent as well as followed normal distribution, because it is more than 25 (Hozo et. al., 2005). The following relationship are investigated, then results are tabulated, as shown in table 6.

- Correlation between years of experience of respondent and waste type.
- Correlation between Job classification of respondent and waste type.
- Correlation between company classification and waste type.

5. CONCLUSIONS AND RECOMMOMNDATIONS

The results indicate that six out eight type of waste in Jordan construction projects have moderate level of occurrence and level of significance which are: Defects, Transportation, Waiting, Non Value-adding, Inventory, and Overproduction. Where the other two types of waste, namely; Motion and Underutilized people have high levels in both occurrence and significance of waste sources.

Table 6 Correlation in term of P-value, between Sample characteristics and waste type

Waste		P-value of					
No.	Type	Years of experience of respondent		Job classification of respondent		Company classification	
		Occurrence	Significance	Occurrence	Significance	Occurrence	Significance
1	Defects	0.23	0.27	0.062	0.78	0.502	0.514
2	Transportation	0.37	0.36	0.067	0.052	0.150	0.131
3	Waiting	0.43	0.44	0.062	0.068	0.219	0.184
4	Non value-adding Processes	0.31	0.29	0.064	0.066	0.507	0.524
5	Motion	0.27	0.28	0.071	0.074	0.099	0.124
6	Inventory	0.53	0.58	0.065	0.061	0.205	0.161
7	Over Production	0.38	0.34	0.074	0.079	0.383	0.379
8	Underutilized people	0.35	0.36	0.068	0.066	0.703	0.714

After subcategorizing main waste sources into roots, thirty-two roots of waste show a moderate level of occurrence and thirty-one of roots show a moderate level significance out of total waste roots which is forty-six. And seven roots of waste represent a high level of occurrence and significance, seven roots of waste represent a very high level of occurrence and eight roots of waste represents a high level of significance.

The category of underutilized people takes the first place in waste source with five roots classified as very high level of occurrence and three roots regarding the significance. In addition, two roots waste classified as high level of occurrence and four as high level of significance, therefore, more attention need to be given for these roots. The non-value-adding has the lowest rank in all waste sources with 2.45 and 2.54 for level of occurrence and level of significance, which classified in moderate level.

The one-way ANOVA test used demonstrate no statistically relationships between sample characteristics (in terms of experience, Job classification, and company classification) and the eight types of waste, Finally, Results indicate that the lean tool can address the most of crucial waste roots in Jordan construction industry.

It is recommended to pay more attention in minimizing and controlling Jordan construction waste from all parties not only by construction companies. Municipalities are recommended to take the role by hold workshops to increase the awareness of decrease total project cost. And focusing on lean tools are believed that they would handle the most waste roots in Jordan environment.

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