A LEAN MANAGEMENT APPROACH FOR POWER PLANT CONSTRUCTION PROJECTS: WASTES IDENTIFICATION AND ASSESSMENT

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ABSTRACT

This research addresses wastes in construction and erection processes in power plant projects. The main paper objectives are identification and assessment of the wastes, mainly in power plant projects. Accordingly, seven main groups of wastes are introduced and subdivided to 42 common wastes, and based on an opinion survey the most important and common wastes in power plant construction projects are identified and assessed. Moreover, importance of wastes in common and valuable compounded work packages and activities in construction and erection processes are investigated. Finally, some recommendations for reducing critical wastes in valuable work package are presented. The findings of this research could be used in power plant projects or any other construction projects for identification, assessment, and reduction of the wastes in construction processes.

KEYWORD: Value, Waste, Lean management, Lean construction, Power plant project, Waste in construction processes, Last planner system

INTRODUCTION

Nowadays with regard to limited large companies in terms of available financial funds and technical capabilities, finding solutions to an optimal application of existing funds is an important issue. Constructing power plants is among the projects which face such problems in different countries. The increasing demand for building power plants in order to supply required power and lack of public and private resources call for a new approach which can manage the project with the minimum resources to achieve the maximum efficiency. This purpose could only be achieved by determining the overall values in continuous productions from beginning to end of the project and identifying the flow to eliminate wastes which are defined as activities that consume time, resource and/or space but do not add value (Ohno 1988).

Over the past two decades, by entering lean management into the construction industry to reduce wastes in each process, many studies have been conducted on this issue. Many innovative techniques developed by different individuals can be used for lean production in such a way that identifies wastes and tries to eliminate or minimize them.

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To use principles of lean production in construction, there are a lot of limitations that are entirely due to the differences between two categories; Salem et al (2006) pointed to the most important differences as follow: (1) The final appearance: the final output of production is mobile and has the ability to move, but in construction we deal with a huge product that is not transferable. (2) On-site production: construction processes are not performed in fixed locations; in fact they are carried out in different places depending on the site location. On the contrary, production occupies a specific place and ultimately the final product is transferred. (3) One of a kind production: in production, we usually deal with certain types of products and we can create some standard units in which customization has no major roles, but in construction, depending on customer requests, we deal with unique and various products which are difficult to achieve a schedule and stable management. (4) Complexity: construction projects are inherently complex, unique, and dynamic systems that must rely on an initial design that involves a number of subassemblies with variable specifications (Bertelsen 2003). But in manufacturing, many components from different subassemblies can be easily managed because suppliers are selected early in the design phase. According to the mentioned differences, in order to apply the developed principles of lean production to construction more practically, at first these differences must be fully understood.

This paper aims to present a framework to find the most important wastes in construction processes of power plant projects in order to use minimum funds to reduce maximum waste of resources.

LEAN CONCEPTS

Lean thinking wave expanded greatly in 1996 with publishing a book by Womak and Jones called “Lean thinking’’. It was about the history of lean thinking and the work performed at Toyota. The stages and principles of lean thinking and lean management framework can be summarized as follows: (1) Specify Values: values can be defined only by the ultimate customer; (2) Identify the Value Stream: the Value Stream is all the actions needed to bring a product to the customer; (3) Flow: make the value-creating steps flow; (4) Pull: let the customer pull the product from you (Sell one; Make one); (5) Pursue Perfection: there is no end to the process of reducing time, space, cost and mistakes.

Due to considerable success of lean production principles, many attempts have been made to use it in other areas including construction industry. It was concluded that the lean principles acted as a catalyst and specified a range of projects (such as construction, commercial, industrial, etc.) and also the project characteristics (for example project definition, design, equipment, assembly, etc) and covered them by using the concept of lean management (Koskela 1992).

One important criterion of lean management is achieving the customer’s needs, which makes sense in lean production, but in construction, especially in massive construction, it cannot easily be achieved because construction does not deal with specific deliverables required by lean production. By considering the project deliverables in four interdependent groups: project definition, lean design, lean equipment, lean assembly (Ballard et al 1998), we can think of a series of deliverables during construction processes and regard deliverable recipients as customers and try to meet their needs.

A lot of research on applications of lean management in construction has been carried out. Among this research, we can point to the studies by Sacks and Goldin in 2006 and 2007. After studying various areas and principles of lean management in the construction sector, they were able to achieve the necessary changes in the value flow of construction projects, which could cause changes to the schedule from the perspective of normal class on lean management and reduce rework, wastes, and unfinished projects. They could also increase the firm's cash flow.

WASTES IN POWER PLANT CONSTRUCTION PROJECTS

By considering the process of production or construction as a process adding value to both information and material, existing activities and processes can be divided into add-value and not-add value. The processes and activities which consume time, cost, materials, equipments, etc., that do not add a value to construction or production are said to be not-add-values or wastes (Koskela 1992).

For the first time in 1988 Ohno classified major wastes in lean management into seven main categories: Over Production, Defects, Inventory, Transportation, Waiting, Motion, and Over Processing. These wastes found more developed concepts over time. Womak in 1996 added another category to these wastes and explained it in this way: Goods and services that do not meet the customer's needs. After that other types of wastes by other researchers were added, including: underutilization of people,

Wastes	Description
Over Production	Product that is more than required. Production much earlier than the time required (do something before it is actually needed). Manufacturing items for which there are no orders. Changes in the needs of the next delivery recipients (design changes).
Defect, Correction & Rework	Errors in the execution of required process that cause wastes in time, materials, etc., more than usual. Failure in machine tools and equipment due to incorrect use of them. Correcting incorrect and unnecessary processes. Reworks due to work interferences.
Inventory	A large number of under way processes in the construction or incomplete endeavor (or completed deliverables but not yet delivered). Possession of large and unnecessary quantities of raw materials that the capital still holds.
Transportation	Any mobility of materials that do not add to production values. Multiple transfers of data and information for final approval.
Waiting	Time wasted in the activities of employees and machines work due to bottlenecks and interferences, and capacity bottlenecks. Waiting for the information needs and customer requests or final approvals. Delays associated with stock-outs, lot processing delays, equipment.
Movement	Any physical movement or walking workers that keeps them from the work or causing delays in their work.
Over Processing	Additional steps in the production that is not required. Product with a number of features and quality over what the customer expected of the product. Unnecessary inspection.

Table 1: Description of seven main groups of wastes

complexity, etc. Ron Crabtree in 2011 named five types of hidden wastes: internal communication breakdowns, poor personal productivity and time management, ineffective meetings, knowledge disconnection, and lack of organizational focus on “add-value”. But they can be classified under the main seven categories by developing and completing their definitions. Table 1 provides definitions of seven main types of wastes.

According to definitions presented by Womak and Ohno and also more comprehensive definitions by Sarker in 2008, we can fully understand different types of wastes. Various researchers could partially work on types of wastes and bring out instances related to their research topic from them. Among these studies, we can point to G. Ballard et al in 2005, R. Sacks et al in 2007, and L. Ek. Anayake et al in 2000.

According to the aforementioned research and interviews with working professionals in power plant projects, and review of the common procedures used in power plant construction projects, at first 115 instances of wastes under the seven major categories were collected. After initial investigations and several meetings with experts, only 42 common wastes in power plant construction projects, with focus on construction and erection processes, were selected (see Table 2).

CASE STUDY

Here, a typical two-unit combined cycle power plant is studied as a case study. The main work packages and activities in construction and erection processes along with weight percents based on their estimated costs are shown in Table 3. For instance, in the Table, only one of the sub-islands in the project WBS is extended.

A series of common and valuable compounded work packages and activities with their weights, as well as their portion in the total project cost, are presented in Table 4. We assume that the value flow is followed in work packages and activities with more portions in the total project cost.

SURVEY CONDUCTION

An opinion survey, using a structured interview, was used to explore most important and common wastes in power plant construction projects in Iran. Survey participants included experts with experience in power plant construction projects.

The survey was divided into three parts. The first part comprised background questions about the respondents’ personal information. The second part dealt with frequency and importance of each of the 42 common wastes in power plant construction projects. In this part, respondents’ were asked to rate the frequency and importance of wastes. The third part investigated frequency of 7 main types of wastes in 11 common and valuable compounded work packages and activities in power plant construction projects, according to the respondent’s direct experience (see Table 4).

40 interviews based on the developed questionnaire framework were conducted with executive agents of main contractor, subcontractor, consultant and project management firms. The final data was considered sufficient for descriptive analysis.

SURVEY RESULTS

The Relative Importance Index (RII) (Sambasivan and Soon, 2007) method was applied to determine relative importance of frequency and importance of each waste.

Main Groups	Wastes	Code
Over Production	Additional maps (non-essential,impractical and excessively detailed)	101
	Construction surplus to planned requirements (added amount,ahead of schedule,higher quality than expected)	102
	Installation of equipment surplus to planned requirements (added amount,ahead of schedule,higher quality than expected)	103
Defect(Correction & Rework)	Errors in design and maps due to non-compliance with technical specifications,standards and codes;lack of adequate knowledge of customer requirements	201
	Errors in design and maps due to lack of adequate knowledge of customer requirements	202
	Correction & rework in design and maps due to changes in specifications and customer needs	203
	Mismatch between building plans and electrical-mechanical utilities;Not making necessary arrangements between maps	204
	Correction & rework due to mismatch and lack of necessary arrangements between building plans and electrical-mechanical utilities	205
	Mismatch between construction and technical specifications,standards,codes or needs of the subsequent costomer	206
	Incorrect methods of construction due to lack of knowledge,experience and required skills	207
	Correction and rework in construction due to non-compliance with design	208
	correction & rework in construction due to design changes	209
	Mismatch between installation of equipment and technical specifications,standards,codes or needs of the subsequent costomer	210
	Incorrect methods of installation of equipment due to lack of knowledge,experience and required skills	211
	Correction and rework in installation of equipment due to errors in construction	212
	Correction and rework in installation of equipment due to non-compliance with design	213
	Correction and rework in installation of equipment due to changes in design	214
	Fatal accidents and unsafe workplace due to non-compliance with HSE regulations in construction and	215
	Planning errors(correction and rework)	216
	Monitoring and controlling errors	217
Inventory	Supplying building materials surplus to planned requirements (added amount,ahead of schedule,higher quality than expected)	301
	Work in progress during construction more than scheduled tasks	302
	Not delivered construction or undergoing delivery process	303
	Work in progress during installation of equipment more than scheduled tasks	304
	Not delivered equipment projects or undergoing delivery process	305
Transportation	Unnecessary transportation to obtain technical approvals	401
	Unnecessary transportation to supply materials(administrative cycle to obtain documents out of/within the site,unneccessary transportation due to errors in site positioning)	402
	Unnecessary transportation to implement construction operations within the site due to errors in site positioning	403
	Unnecessary transportation to implement installation operations within the site due to errors in site positioning	404
Waiting	Waiting and delay in maps delivery	501
	Waiting and delay in maps approvals	502
	Waiting and delay in construction activities(efficiency of workers and equipment) due to work bottlencks within the site	503
	Waiting and delay in supplying construction materials	504
	Waiting and delay in installation activities (efficiency of workers and equipment) due to work bottlencks within the site	505
	Waiting and delay in supplying equipment	506
	Waiting and delay in planning and decision making	507
	Waiting and delay in monitoring and controlling for work delivery	508
	Waiting and delay in funding	509
Motion	Unnecessary movement and relocation of human resource and equipment associated with construction operations within the site	601
	Unnecessary movement and relocation of human resource and equipment associated with installation operations within the site	602
Over Prossesing	Additional processes in construction and installation that cause excessive use of raw materials,equipment,etc.	701
	Additional monitoring and controlling(checklists and excessive inspections in design stages,equipment supply,etc)	702

Table 2: Common construction and erection procedure wastes in power plant construction projects

The six point scale ranged from unimportant (0), very low (1), to very high (5) importance was adopted to calculate the relative importance index, using the following equation:

$$RII = \frac{\sum W}{A \times N} \qquad (1)$$

Where, W is the weight given to each factor by the respondents and ranges from 0 to 5, A is the highest weight which is considered 5 here, and N is the total number of respondents.

Item	Unit	Island	Sub Island	Activity	Civil Total Weight
Civil Works					100%
0	General				5.75%
0.1		General			5.75%
0.1.1			Site Mobilization		4.94%
0.1.2			Landscaping, Roads & Finishing		0.81%
1	Unit # 1				43.29%
1.1		Steam Turbine, Generator & Power House			12.23%
1.1.1			Steam Turbine & Generator		2.42%
1.1.2			Power House		9.81%
1.1.2.1				PWH - Excavation & Grading	0.50%
1.1.2.2				PWH - Building Foundation	1.48%
1.1.2.3				PWH - Steel Structure Supply & Trans.	3.30%
1.1.2.4				PWH - Steel Structure Erection	0.16%
1.1.2.5				PWH - Stages Civil Works	0.21%
1.1.2.6				PWH - Roofing	0.50%
1.1.2.7				PWH - Concrete Floor Slab & Trench	0.63%
1.1.2.8				PWH - Masonry	1.04%
1.1.2.9				PWH - Wall Sheeting	1.18%
1.1.2.10				PWH - Architectural & Finishing	0.81%
1.2		Heat Recovery Steam Generator			3.65%
1.3		Water & Steam Cycle			0.41%
1.4		Cooling System			23.73%
1.5		Transformers			0.51%
1.6		Power Supply (Electrical)			2.75%
2	Unit # 2				43.29%
3	Common				7.66%
3.1		Water Supply			2.39%
3.2		Balance of Plant (B.O.P)			5.27%

Item	Phase	Sub Phase	Total Weight
1	Engineering		10.00%
1.1		Engineering	10.00%
2	Procurement		28.00%
2.1		Tendering	2.80%
2.2		Supply / Manufacturing	22.40%
2.3		Transportation / Site Delivery	2.80%
3	Construction		62.00%
3.1		Civil	25.00%
3.2		Erection	32.00%
3.3		Commissioning	5.00%
Sanandaj WBS Total			100.00%

Item	Unit	Island	Sub Island	Activity	Erection Total Weight
Erection					100%
1	Unit # 1				44.95%
1.1		Steam Turbine, Generator & Power House			8.61%
1.1.1			Steam Turbine & Generator		0.69%
1.1.2			Steam Turbine		4.36%
1.1.3			Generator		2.61%
1.1.4			Power House		0.95%
1.2		Distribution Control System			2.91%
1.3		Heat Recovery Steam Generator			15.67%
1.4		Water & Steam Cycle			2.73%
1.5		Cooling System			10.26%
1.6		Transformers			0.65%
1.7		Power Supply (Electrical)			4.11%
2	Unit # 2				44.95%
3	Common				10.10%
3.1		Water Supply			5.40%
3.2		Balance of Plant (B.O.P)			4.70%

Table 3: The main work packages and activities of construction and erection processes of a typical two-unit combined cycle power plant

Code	Common And Valuable Compounded Work Packages And Activities	Weights (Portion In The Total Project Cost)(%)
1	Excavation & Grading	3.76
2	Building main Foundations & equipment Foundations	5.01
3	Steel Structure Erection	3.23
4	Erection of heavy equipment Such as Steam Turbine, Generator, Transformers and etc	6.52
5	Reinforcement , Formatting and Concrete Works	6.34
6	Wall Sheeting , Masonry,Architectural & Finishing	3.31
7	Install and Dismantle of climbing Forms	0.59
8	Install crane for cooling & install Overhead Crane for powerhouse	0.74
9	Roofing	0.81
10	X-Legs & delta construction & Positioning	3.44
11	Landscaping, Roads & Finishing	1.28
Total		35.01

Table 4: Common and valuable compounded work packages and activities

The waste value factor (WVF) is finally calculated by the product of relative frequency and important factors of each waste.

$$\text{WVF} = \text{Relative Frequency Factor} \times \text{Relative Importance Factor} \qquad (2)$$

Table 5 illustrates the frequencies and importance of wastes, as well as waste factors. In this Table the normalized values of each waste factor (WF) are computed by following equation (only the wastes with normalized value equal or greater than 0.4 are considered as critical wastes):

$$\text{Normalized WVF} = \frac{\text{WVF} - \min(\text{WVF})}{\max(\text{WVF}) - \min(\text{WVF})} \qquad (3)$$

Code	Relative Frequency Factor	Relative Importance Factor	Waste Value Factor (WVF)	Normalized WVF		Rank	Code	Relative Frequency Factor	Relative Importance Factor	Waste Value Factor (WVF)	Normalized WVF		Rank
101	0.30	0.49	0.15	0.00		42	**401**	0.46	0.65	0.29	0.29		28
102	0.40	0.60	0.24	0.18	0.11	39	**402**	0.46	0.59	0.27	0.24	0.23	36
103	0.31	0.72	0.22	0.14		41	**403**	0.43	0.61	0.26	0.23		37
201	0.52	0.77	0.40	0.51		14	**404**	0.37	0.63	0.23	0.16		40
202	0.44	0.82	0.36	0.41		18	**501**	0.57	0.86	0.49	0.68		4
203	0.53	0.74	0.39	0.48		16	**502**	0.72	0.84	0.61	0.91		2
204	0.59	0.83	0.49	0.68		5	**503**	0.58	0.74	0.43	0.56		9
205	0.55	0.81	0.44	0.59		7	**504**	0.65	0.84	0.55	0.79		3
206	0.35	0.81	0.28	0.27		33	**505**	0.56	0.78	0.44	0.57	0.67	8
207	0.41	0.79	0.33	0.35		22	**506**	0.53	0.77	0.41	0.52		13
208	0.44	0.76	0.33	0.37		21	**507**	0.53	0.81	0.43	0.55		10
209	0.46	0.76	0.35	0.39	0.42	19	**508**	0.51	0.75	0.38	0.46		17
210	0.30	0.81	0.24	0.18		38	**509**	0.72	0.91	0.65	1.00		1
211	0.36	0.82	0.30	0.29		26	**601**	0.45	0.65	0.30	0.29	0.29	27
212	0.40	0.72	0.29	0.28		31	**602**	0.44	0.66	0.29	0.28		30
213	0.41	0.71	0.29	0.28		29	**701**	0.41	0.69	0.28	0.26	0.26	35
214	0.39	0.76	0.30	0.30		25	**702**	0.44	0.64	0.28	0.27		34
215	0.35	0.89	0.31	0.32		24							
216	0.49	0.79	0.39	0.49		15							
217	0.52	0.86	0.45	0.60		6							
301	0.43	0.66	0.28	0.27		32							
302	0.43	0.73	0.31	0.33		23							
303	0.59	0.71	0.42	0.54	0.41	11							
304	0.47	0.72	0.34	0.38		20							
305	0.57	0.73	0.41	0.53		12							

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.889	**0.885**	**42**

Table 5: The frequencies and importance of wastes, as well as waste factors

As shown in Table 5, 18 critical wastes are highlighted. Respondents mentioned waiting and defect (correction and rework) as the critical groups of wastes in power plant construction processes.

The results of the third part of the interview which investigated frequency of seven main types of wastes in eleven common and valuable compounded work packages and activities in power plant construction projects are depicted in Table 6.

As shown in Table 6, results are obtained after applying cost values of each part on the main waste frequency in major activities in the power plant projects. It also represents important or critical parts of common processes for further investigations. To provide a normalized degree of importance for each waste in each main activity, all numbers are divided by the maximum number of each main waste in all activities.

According to the respondents' opinions and weights of work packages, the most valuable work packages are Concrete works, Building main foundations and Excavation (see Table 6).

Finally, to achieve the most important wastes in most valuable work streams, the following equation has been suggested which is the expanded form of Equation 2.

$$\text{Activity's WVF} = \text{Normalized}(\text{PRF} * \text{Activity's weight}) * \text{WVF} \qquad (4)$$

According to Equation 4, it can be concluded that some wastes that were not listed among the critical wastes including wastes related to "over production or over processing", should be considered in high-value compounded work packages such as "concrete" or "excavation and grading" work. On the other hand, some critical wastes may not be considered in some activities due to their low-values. For example, activity's WVF related to "errors in design", in concrete works is equal to 0.41 and ranks 18th, while this value for "waiting for materials", in steel structure erection, is equal to 0.40 and ranks 3rd. Hence "errors in design" in concrete works is more important than "waiting for material" in steel structure erection.

		value	Percent Of relativle Frequency (PRF)							Normalized (PRF × Value)						
Code	Common and valuable compounded work packages and activities	Weights (%)	Over production	Defect	Inventory	Transportation	Waiting	Motion	Over Processing	Over production	Defect	Inventory	Transportation	Waiting	Motion	Over Processing
1	Excavation & Grading	3.76	21.37	10.23	9.80	9.56	9.64	13.30	15.57	1.00	0.52	0.52	0.42	0.49	0.68	0.70
2	Building main Foundations & ...	5.01	9.71	9.77	9.80	7.65	9.64	10.98	12.29	0.61	0.66	0.70	0.45	0.65	0.75	0.74
3	Steel Structure Erection	3.23	11.66	12.09	10.46	11.47	11.67	13.30	13.11	0.47	0.53	0.48	0.44	0.51	0.59	0.51
4	Erection of heavy equipment Such as ...	6.52	2.91	4.65	4.58	4.46	7.11	5.20	3.28	0.24	0.41	0.42	0.34	0.63	0.46	0.26
5	Reinforcement ,Form working & Concrete Works	6.34	12.63	11.63	11.11	13.38	11.67	11.56	13.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	Wall Sheeting , Masonry,Architectural & ...	3.31	9.71	12.09	10.46	11.47	10.66	9.83	13.11	0.40	0.54	0.49	0.45	0.48	0.44	0.52
7	Install and Dismantle of climbing Forms	0.59	5.83	8.84	7.19	7.65	5.58	5.20	5.74	0.04	0.07	0.06	0.05	0.04	0.04	0.04
8	Install crane for cooling & install ...	0.74	2.91	6.05	7.84	6.37	7.11	6.94	1.64	0.03	0.06	0.08	0.06	0.07	0.07	0.01
9	Roofing	0.81	5.83	7.91	9.80	8.92	9.14	7.52	4.10	0.06	0.09	0.11	0.09	0.10	0.08	0.04
10	X-Legs & delta construction & Positioning	3.44	6.80	5.12	6.54	6.37	6.60	5.20	6.56	0.29	0.24	0.32	0.26	0.31	0.24	0.27
11	Landscaping, Roads & Finishing	1.28	10.68	11.63	12.42	12.74	11.17	10.98	11.47	0.17	0.20	0.23	0.19	0.19	0.19	0.18
	Total	35.01	100	100	100	100	100	100	100							

0.30	<	valuable	<	0.50
0.50	<	very valuable	<	0.70
0.70	<	critical		

Table 6: Frequency of seven main types of wastes in eleven common and valuable compounded work package and activities

As an example, the result for waiting waste group is illustrated in Figure 1. According to Figure 1, the Waiting group is the most important group in seven groups of wastes and also the most valuable and common part. This group of waste in the "reinforcement, form working and concrete work" highly affects the final cost.

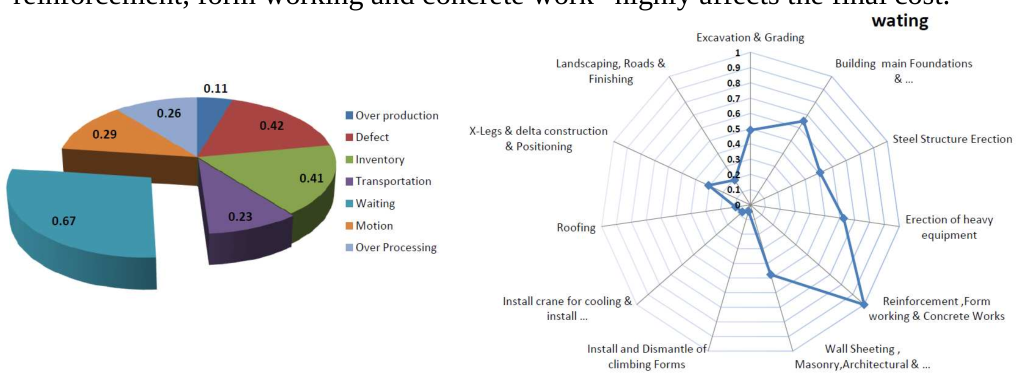

Figure 1: Normalized WVF of waste groups (left), and Waiting waste WVF in common and valuable compounded work packages and activities (right)

LEAN STRATEGIES TO REDUCE WASTES

As observed, waiting for financing, materials procurement, implementation of activities, etc. are the most critical wastes. These problems are mostly due to lack of proper activity planning according to financial guarantees and cash flow during the project, which can be somehow improved by correcting the planning procedure. The last-planner method (Ballard 2000 and 2004) is one of the planning improvement strategies. The last-planner is a person or group who is responsible for planning and organizing the implementation of work in order to improve the work stream and control the construction units. In such an implementation method, the reverse-plan-schedule, six-week-look-ahead, weekly-work-plan and the percent-plan-completed, limitations analysis and variance analysis create an effective framework in pull scheduling program (Ballard 2004).

One of the main problems which most of the critical wastes result from includes lack of communication and coordination among existing working groups in power plant projects. They cause problems such as mismatching maps, difficulties in getting approvals, failure to meet the needs of customers, etc which could be solved with the help of people with good experience in the construction of power plants (according to first-run-studies by Salem et al 2005). This technique has been designed based on the "Plan, Do, Check, Act" cycle which in fact includes a method depending on the experience of group members and matching it with any specific projects aiming to increase productivity and reduce common problems. Also, the huddle meeting technique will greatly help resolve the wastes by holding regular 10 minute meetings between supervisors and foremen at the beginning of every day (Salem et al 2006).

One useful technique for reducing errors in control and supervision includes using fail-safe-for-quality method. This technique is based on potential diagnosis and declaring the failure instead of inspection and quality control after doing the work to prevent errors and inconsistency (Salem et al 2005). Obviously this method is less costly than conventional methods, as well as being capable of resolving common errors in control and supervision. This technique is based on familiar and popular concept of poka-yoke in lean production and its purpose is to make the process unerring.

CONCLUSION

The objective of this research was to identify the main wastes in power plant construction projects, try to analyze them and suggest some identified lean strategies to reduce them. Primarily a literature review was conducted to explain how to put forward lean philosophy and apply it to construction. In the next stage, based on lean principles in power plant construction projects, 7 main groups of wastes were introduced and subdivided to 42 common wastes in construction and erection phases. Based on an opinion survey, using 40 structured interviews, the most important and common wastes in power plant construction projects were identified. As a result, "waiting and delay in funding", "waiting and delay in maps approval", and "waiting and delay in supplying construction materials" were the top three ranks of identified wastes. Moreover, importance of wastes in common and valuable compounded work packages and activities were investigated. Finally some recommendations for reducing critical wastes in valuable work package were presented.

The presented method in this study is a simple and practical method for assessing important and waste points of construction projects for greater emphasis on their investigation and it has the ability to be generalized to all construction or installation projects.

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