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Practitioners' Perception on Relationship between Production Planning and Waste Occurrence in Construction Projects

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Abstract: Construction management has been suffering from many problems, which need to be solved or better understood. Most of construction projects have not achieved efficiency as expected. In this context, waste was also considered as a problem of efficiency decrease, and poor production planning was considered as a cause for waste. This study was conducted on the basis of waste concepts and production planning processes based on the philosophies of Lean Construction. A survey to find out the relationship between them was carried out through questionnaire, which was answered by experienced people in construction projects. The results have shown that frequency of wastes occurrence is quite high, and production planning processes are superficially performed in construction phase. There is a significant negative relationship between production planning and waste occurrence (r = -0.262). Weekly Work Plan (WWP) is the most dominant plan for waste control with seventeen in total of nineteen waste factors, and phase plan is the most dominant plan for two remaining waste factors. A case study was adopted to validate the relationship between production planning and waste occurrence. The results showed that the better the project was planned, the fewer the waste would occur on construction sites.

Keywords: Lean construction, Construction waste, Last Planner, Production planning, Vietnam

I. INTRODUCTION

Construction is the second largest economic activity accounted for proportion of 10.3% in GDP after agriculture (15.0%) in Vietnam. It is easily observed that this is due to Vietnam is a developing country. Many construction projects were built to cater the growing needs of population and economics in last decades. It is similar to other countries, especially in developing countries, construction projects in Vietnam have faced with many problems during implementation such as time and cost overrun, low productivity, poor safety, insufficient quality, lack of skilled workers, inferior working conditions, defective design, etc [24]. These problems cause a considerable waste for construction projects, and they have been reducing success of project. In practice, while a few large construction companies have begun to look into waste reduction and process improvement issues through several concepts like Lean Construction, most organizations are yet to address these issues [29].

Koskenvesa *et al.* (2010) have concluded that waste is not paid a lot of attention in the production planning and control processes, and it is considered as an accepted phenomenon in the Finnish construction industry [25]. Furthermore, from a lean construction perspective, Memarian and Mitropoulos (2012) have claimed that the production control practices achieve an accelerated schedule while minimizing waste and maintaining high level of safety [26]. Unfortunately, the traditional approach for planning production in construction industry frequently fails because it does not act over the difficulties related to input flows and also over the management of activities that normally do not aggregate value to the final product such as transportation, communication, waiting and inspection [11].

On the basis of research in the 1990s, Ballard and Howell have created a concept in planning and control called "Last Planner System" (LPS) to shield project from the uncertainty of work flows and to improve the predictability and reliability of construction production. LPS is defined as the last in the decision chain of the organization because the output of planning process is not a directive for a lower level planning process but results in production. Mossman (2012) indicated that LPS reduces waiting such as waiting for access, design information, materials and plant, waiting for the previous trade or design team to complete work. These are major sources of uncertainty, frustration and waste in projects. When one team is late delivering, follow-on teams are prevented from starting when they planned to and work ceases to flow [27]. In fact, it is easily seen that a construction project performed by correct plans is more effective than the one executed by incorrect or poor plans. Therefore, construction wastes, e.g., waste related to waiting for others to complete their work, waiting for materials and equipment to be delivered on site, defects due to unclear design, over-allocated workers, and materials damaged or lost due to long-time inventory, can be explicitly reduced if project planning and control are well prepared.

Based on above discussion, the research's goals consist of: (1) examine the current performance of production planning process and waste occurrence in construction

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projects; (2) explore relationship between production planning and waste occurrence based on respondent's perception; and then (3) assess the influence of production planning and control process on waste occurrence through case studies. The projects under construction phase have been selected. The viewpoint of analysis was based on the contractor's perspective. The research outcomes would serve the strategy for reducing waste through improvement of production planning and control process.

II. Literature Review

A. Waste in Construction

Nowadays, wastes (also known as non value-adding activities) are defined as "*any inefficiency that results in the use of equipment, materials, labor or capital in larger quantities than those considered as necessary in the production of a building*" [23]. Furthermore, Formoso *et al.* (1999) have also defined waste as "*any loss produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client*" [14]. In addition, Formoso *et al.* (2002) stressed the need to consider a broader view of waste that includes not only material waste, but also wastes related to other resources such as labor and equipment [15]. In practice, Christian *et al.* (1995) indicated that workers spend only approximately 46% of working time for the value-adding activities, and 54% for non value-adding activities from seven sites [9]. Ciampa (1991) showed even worse results that only 3% to 20% of steps add value, and their share of the total cycle time is negligible from 0.5% to 5% [10]. Koskela (1992) in United States revealed that cost of non-conformance constitutes 12% of project costs [23]. Eventually, Formoso *et al.* (2002) proved that the cost of waste was estimated to be 8% of total cost [15].

Under the philosophies of Lean Construction, nineteen waste factors were found from previous studies [1, 2, 14, 15, 24, 30, 32]. These waste factors were then classified into three groups as shown in Table I. The criterion adopted to make this classification was based on the way that wastes cause value loss for product. These groups are: (1) direct conversion wastes that pertain to manpower, materials and equipment when performing an activity; (2) non-contributory time wastes that pertain to time for waiting, idling and travelling; and (3) contributory time wastes that pertain to time for supervision, inspection, transport, instruction, and communication [14, 24, 30].

B. Production Planning and Control

One limitation of the old production planning and control technique, namely Critical Path Method (CPM), is the difficulty in sufficiently reflecting the site conditions, which practically change every day. In contrast, the LPS technique addresses such limitation by managing the daily work assignments [3]. It is a production planning and control tool used to improve the reliability of the workflow [4]. On the other hand, Kalsaas *et al.* (2009) have stated that LPS is a standardized procurement for project planning, evaluation and continuous learning to reduce variation during construction [22]. Furthermore, Hamzeh *et al.* (2011) have indicated that LPS is a system for production planning and control used to assist in smoothing variations in construction work flow, developing planning foresight, and reducing uncertainty in construction operations [19]. In detail, the system originally tackled variations in workflow at the weekly work plan (WWP) level, but soon expanded to cover the full planning and schedule development process from master scheduling to phase scheduling through lookahead planning to reach WWP. Fig. I shows the detailed LPS process in construction as proposed by Ballard [6].

TABLE I
NINETEEN WASTE FACTORS IN CONSTRUCTION PROJECTS

#	Group	Waste factors
X1	A	Over-allocated/ unnecessary equipment on site
X2	A	Over-allocated/ unnecessary materials on site
X3	A	Over-allocated/ unnecessary workers on site
X4	A	Unnecessary procedures and working protocols
X5	A	Material lost/ stolen from site during construction period
X6	A	Material deteriorated/ damaged during construction period
X7	A	Mishandling or error in construction application/ installation
X8	A	Materials for reworks/ repaired works/ defective works
X9	A	Accidents on site
X10	B	Waiting for others to complete their works before the proceeding works can be carried out
X11	B	Waiting for equipment to be delivered on site
X12	B	Waiting for materials to be delivered on site
X13	B	Waiting for skilled workers to be provided on site
X14	B	Waiting for the clarification and confirmation by client and consultants
X15	B	Time for reworks/ repaired works/ defective works
X16	B	Time for workers' rest during construction
X17	C	Time for supervising and inspecting the construction works
X18	C	Time for instructions and communication between engineers and workers
X19	C	Time for transporting workers, equipment and materials

Note: A: direct conversion waste; B: non-contributory time waste; C: contributory time wast

- *Master scheduling:* It is a front-end planning process that produces a schedule describing work to be carried out over the entire duration of a project. It involves project-level activities and identifies major milestone dates mostly in relation to contract documents and the owner's value proposition [31].
- *Phase scheduling:* It generates a schedule covering each project phase such as foundations, structural frame, or finishing. In a collaborative planning setup, the project team: (1) defines a project phase or milestone, (2) breaks it down into constituent activities, and (3) schedules activities backward from the milestone. After incorporating input from different project parties and identifying hand-offs between specialists, the team performs reverse phase scheduling back from important phase milestone [8, 17].
- *Lookahead planning:* It is the first step in production control and usually covers a six-week time frame. Lookahead time periods vary with the type of work being performed and the context. Activities are broken down into the level of production processes/ operations, constraints are identified, operations are designed, and assignments are made ready [4, 17].
- *Weekly work planning (WWP):* Also known as commitment planning, it represents the most detailed plan in the system, shows interdependence between the works of various specialist organizations, and directly drives the production process. At the end of each plan period, assignments are reviewed to assess whether they are complete or not, thus measuring the reliability of the planning. For incomplete assignments, analyzing the reasons for plan failure and acting on these reasons is the basis of learning and continuous improvement [6].

III. Discussion on Research Problem

Lean is a business philosophy for organizing and managing corporate processes including product development, design, production, operations, supply chain, and customer relationships to increase value and minimize waste [32]. Memarian and Mitropoulos (2012) have shown that lean construction practices, especially LPS, emphasize reliability of workflow in order to reduce waste and increase construction speed [26]. In the LPS, the primary means for achieving reliability is securing the directives (design, submittals and authorizations) and resources (materials, equipment and manpower) for the work assignments. Therefore, the LPS has been created to maximize reliability of the work/ material/ information flow to minimize waste in time or money in project processes and to maximize customer value [6].

Formoso *et al.* (2002) have summarized that a significant portion of waste is caused by problems which occur in stages that precede production such as inadequate design, lack of planning, flaws in the material supply system, etc [15]. There have been efforts in searching for new techniques and tools that can guarantee organizational competitiveness in the long run through the systematic decrease of losses and wastefulness, improvement of the production quality and improvement of the environmental and safety conditions [23]. But, most of studies tend to focus on the waste of materials, which is only one of the resources involved in the construction process. This seems to be related to the fact that they are based on the conversion model, in which material losses are considered to be synonymous with waste [15].

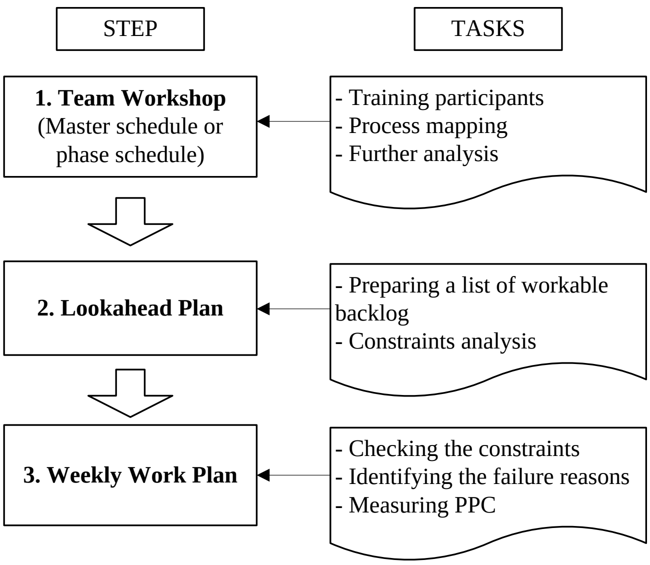

FIGURE I
BALLARD'S LPS IMPLEMENTATION PROCEDURE AND TOOLS

During the last ten years, there have been hardly any research findings published in the Vietnamese context on the incidence of waste in the construction industry, as well as the tool for reducing the effect of waste on project efficiency. In general, project managers are used to define the term "waste" as physical construction waste rather than the real concept of waste [23], and they tend to agree an acceptable level of waste in their construction site rather than finding solutions to reduce or eliminate the wastes [21]. This is due to they do not know clearly about what the principles and tools of Lean Construction are, but they have been trying to find better methods to perform the project with minimum possible level of waste.

In reality, large construction projects in Vietnam are always controlled by master schedule and WWP [21]. They are sometimes controlled by phase schedule and lookahead plan as well. Therefore, it is clearly that the idea in planning and controlling a project in the conventional viewpoint is basically similar to the new viewpoint of LPS. Here, the differences that need to explore are what course of action each process includes and how to use this process in practice. Then, when a process is improved significantly due to implementation of LPS, whether or not the waste will be reduced? Thus, the study here reported is the first survey about lean thinking in construction aiming to improve the current planning practice, and to provide a basis for the development of research in the field of Lean Construction in Vietnam.

IV. Research Methodology

A. Questionnaire Design

A questionnaire (in Vietnamese) consisting of nineteen numbers of question instruments which describe the possible impact of production planning process on waste occurrence on construction sites was designed. The nineteen waste factors are the results presented in the previous research [21]. The information regarding the current perspective of production planning and control system, waste occurrence, respondent's recognition of waste, and role of production planning process in reducing waste were also gathered through the questionnaire. This study has adapted the format of the estimate score sheet from previous studies. In questionnaire, the respondents were asked to rate the possible answer for a given factor according to their experience.

B. Data Collection

The data collection method includes two stages: (1) collecting data for the first two purposes of the study through questionnaire survey, and (2) collecting data for a case study as stated in the last purpose. The practitioners involved in the survey are identified through their company profile, and researcher's personal relationship. Data of each project were collected by one questionnaire according to its construction practice. The projects for sampling have been performing by construction companies in Ho Chi Minh City, Vietnam. The rule of questionnaire distribution was "one project, one questionnaire". As a result, a total of 51 copies of the questionnaire were distributed to the personnel in 51 construction sites. The study has then received 43 responses. After filtering these, only 40 responses were found to be usable.

Two high-rise buildings were then selected from forty projects above to be used as the case study. Formwork activity for a typical floor was chosen to investigate waste occurrence. In detail, one project has been fully performed by the planning and control process as mentioned in previous section; whereas, the other one has been performed by the poor or deficient planning process. In this study, a poor plan is plan that does not satisfy one of the following criteria: (1) do not foresee the correct sequence of activities; (2) do not foresee the correct quantity of services; and (3) do not guarantee that the planned job can be effectively accomplished [12]. The waste occurrences have been recorded by site engineer for both projects in three weeks.

C. Analysis Tools

The study has employed the mean analysis to explore the perspective of production planning system and waste occurrence. The Pearson-*r* correlation coefficient analysis has been used to explore the potential relationship between them by the statistical software SPSS 18.0. The cause-and-effect matrix has been adopted to connect the effective role of production planning process to each waste. A case study has been then analysed to validate the problem of waste reduction due to production planning and control processes were well performed.

V. Analysis and Findings

A. Respondents Profile

More than half (55%) of parties in the survey are contractors. Other parties consist of owners (17%) and consultants (28%). Regarding position of work, 15% of respondents are been project managers, 23% of those are been site managers, 33% of those are been QA/QC engineers and planning engineers, 29% of those are been site engineers. The quite large proportion of top and functional managers confirms the reliability of collected data for identifying waste problems on their construction sites. In terms of number of years involved in construction, majority (73%) of respondents have field experience of 3 to 6 years; whereas 12%, 7%, and 8% are respectively for less than or equal to 3 years, between 6 and 9 years, and 9 years or more. It would be better if the proportion of respondents whose experiences are 9 years or more can be increased. But, these ratios reflect the current phenomenon of Vietnam construction industry, that is a large amount of young practitioners have been graduated in recent years to meet the vast human demand, and they have got high positions in their organizations. The proportion of project types are: civil and heavy projects (20%), building projects (53%), industrial projects (15%) and others (12%). This implies that the study focuses mainly on building projects. Moreover, it reflects the specific characteristic in the growth of population and economics in a developing country is that building projects often need to be constructed larger than other projects.

B. Performance of Production Planning

Fiallo and Revelo (2002) have indicated that the functions of LPS include productive unit and work flow control, and completing quality assignments. In addition, it makes production easier to control the root of the problems, and to make timely decisions regarding adjustments needed within the operation in order to perform actions opportunely; thereby increasing productivity [13]. This study first reports the survey of the current performance of LPS process in construction practice. To do this, the respondents were requested to answer the “yes/ no” question for identifying the way that they used to plan and control production in their project. The results are shown in Table II.

Similar to other developing countries, the procedures at team workshop step in Vietnam construction industry include ‘training participants’, ‘process mapping’ and ‘further analysis’ are superficially performed with percent of agreement less than 70%. This indicates that the professionals in the industry have not paid much attention to this step, which is to establish long-term schedule including master schedule and phase schedule.

Normally, lookahead plan is made in the duration from two to six weeks before the date of construction. In this plan, the performance of classifying the works into work that can be done (workable backlog) and work that cannot be done is very low with 72%. But, the constraints analysis for the work that can be done in construction site is performed quite high with 86%. Ballard (2000) has stated that lookahead plan is a “beneficial bridge” that helps to connect between long-term schedule and WWP [6]. Therefore, the conventional planning processes are suffering from obstacles in making this bridge because lookahead plan is not fully performed or even ignored.

Eventually, checking the activity constraints again before execution is needed, but this procedure is performed quite low with 75%. In order to assess the effect of WWP, the percent plan complete (PPC) should be measured and analysed. The result shows that PPC is utilized quite much in the practice with 87%. This index helps the managers know number of uncompleted works in the previous week. Furthermore, the analysis on failure reasons for uncompleted work is performed quite low with 79%. Based on this analysis, the managers can make some corrective courses of action for the planned work in next weeks, as well as make the gradual improvement in managing a future project.

C. Occurrence of wastes

Lean construction is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value [7]. Before using any lean construction technique especially LPS to control waste in the practice, the frequency of waste occurrence should be first investigated. To do this, the respondents were requested to answer the “yes/ no” question to verify whether the waste occurs on their site. The results are presented in Table III.

It can be easily observed that six in total of nineteen waste factors have percentage of occurrence greater than or equal to 80%. These wastes include five waste factors in group B, and one waste factor in group C. Next, there are five waste factors that have percentage of occurrence greater than or equal 70%. Two among them belong to group A, two belong to group B, and one belongs to group C. Eventually, there are eight waste factors that have percentage of occurrence less than 70%. Those include seven factors of group A and one factor of group C.

These results demonstrate that wastes in workflow that pertain to time for waiting, idle, supervision, inspection, transport, instruction and communication often happen in construction sites. This causes the congestion of workflow in construction processes. Furthermore, most of professionals only know about wastes that pertain to materials and equipment for conversion activities. Therefore, finding a better way in planning and controlling production plays a very important role in making a smooth and predictable workflow in the face of high uncertainty in construction operations.

D. Correlative Analysis

Pearson-*r* correlation coefficient test was used to examine the relationship between independent variables and dependent variable. In this study, production planning is considered as a way to reduce waste occurrence. Thus, independent variable is production planning, and dependent variable is waste occurrence. The hypothesis can be stated as below:

TABLE II
PERFORMANCE OF PRODUCTION PLANNING PROCESS

#	LPS process	Yes (%)	No (%)
1	Training participants	55	45
2	Outlining process mapping for project performance	58	42
3	Conducting further analysis to understand clearly the requirements of project before execution	65	35
4	Making a list of workable backlog during construction	72	27
5	Analyzing constraints of activity before performance	86	14
6	Checking the constraints again	75	25
7	Analyzing failure reasons for an uncompleted work	79	21
8	Measuring PPC for weekly work	87	13

TABLE III
OCCURRENCE OF WASTE IN CONSTRUCTION SITES

#	Waste factor	Yes (%)	No (%)
X1	Over-allocated/ unnecessary equipment on site	65	35
X2	Over-allocated/ unnecessary materials on site	62	38
X3	Over-allocated/ unnecessary workers on site	61	39
X4	Unnecessary procedures and working protocols	63	37
X5	Material lost/ stolen from site during construction period	61	39
X6	Material deteriorated/ damaged during construction period	64	36
X7	Mishandling or error in construction application/ installation	68	32
X8	Materials for reworks/ repaired works/ defective works	75	25
X9	Accidents on site	71	29
X10	Waiting for others to complete their works before the proceeding works can be carried out	82	18
X11	Waiting for equipment to be delivered on site	83	17
X12	Waiting for materials to be delivered on site	85	15
X13	Waiting for skilled workers to be provided on site	72	28
X14	Waiting for the clarification and confirmation by client and consultants	84	16
X15	Time for reworks/ repaired works/ defective works	85	15
X16	Time for workers' rest during construction	74	26
X17	Time for supervising and inspecting the construction works	82	18
X18	Time for instructions and communication between engineers and workers	79	21
X19	Time for transporting workers, equipment and materials	67	33

Null hypothesis (H_0): Production planning (PP) has a relationship with number of waste occurrences (WO).

Alternative hypothesis ($H_A \neq H_0$): Production planning (PP) has no relationship with number of waste occurrences (WO).

The respondents were requested to answer the question assigned with value being 1 for "yes" and 2 for "no". The suggested production planning process includes eight items. Thus, the minimum value is 8 points, and the maximum value is 16 points. Similar to the wastes that include nineteen factors, the minimum is 19 points, and the maximum is 38 points. The collected data were statistically processed by SPSS version 18.0 with confidence interval of 95% (significance level $\alpha = 0.05$) and two-tail probability distribution. The results are shown in the Table IV and Table V.

It can be seen that the mean values from the respondent's feedbacks are 10.150 and 23.525 for production planning and waste occurrence respectively. This proves that production planning process is performed quite high, and waste problems occur quite high in construction projects. The Pearson-*r* analysis results show that there is a significant negative relationship between production planning and waste occurrence (r = -0.262) because the significance value (K = 0.006) is less than 0.05. Thus, the null hypothesis is not rejected. It means that when production planning is well performed, number of waste occurrences can be reduced. Based on this finding, further analysis of correlation between them can be carried out.

E. Cause-and-Effect Matrix

LPS offers a realistic way to collaboratively manage project-based production, enables issues to be identified and resolved before they become problem on-site and increases the chances that work will flow [27]. Therefore, planning plays a crucial role in managing the project. This study identifies the role of production planning process in controlling the waste on construction sites. The cause-and-effect matrix was employed to find out this role. The respondents were required to rate the schedule which has most influence on each waste based on their experience. The results are described in Fig. II.

The results show that WWP is dominant to waste control with at least 32.5% for seventeen in total of nineteen factors. Two remaining waste factors are mostly controlled by phase schedule, i.e., X1 with 35% and X4 with 37.5%. These indicate that WWP is currently the most important plan for controlling the waste in the

TABLE IV
SUMMARY OF DESCRIPTIVE STATISTICS

Component	Mean	Std. deviation	N
PP	10.150	1.902	40
WO	23.525	3.320	40

TABLE V
PEARSON-R CORRELATION COEFFICIENTS

		PP	WO
PP	Pearson coefficient	1	-0.262
	Sig. (2-tailed)	-	0.006
	Sum of squares and cross-products	141.100	-15.150
	Covariance	3.618	-0.388
	N	40	40
WO	Pearson coefficient	-0.262	1
	Sig. (2-tailed)	0.006	-
	Sum of squares and cross-products	-15.150	429.975
	Covariance	-0.388	11.025
	N	40	40

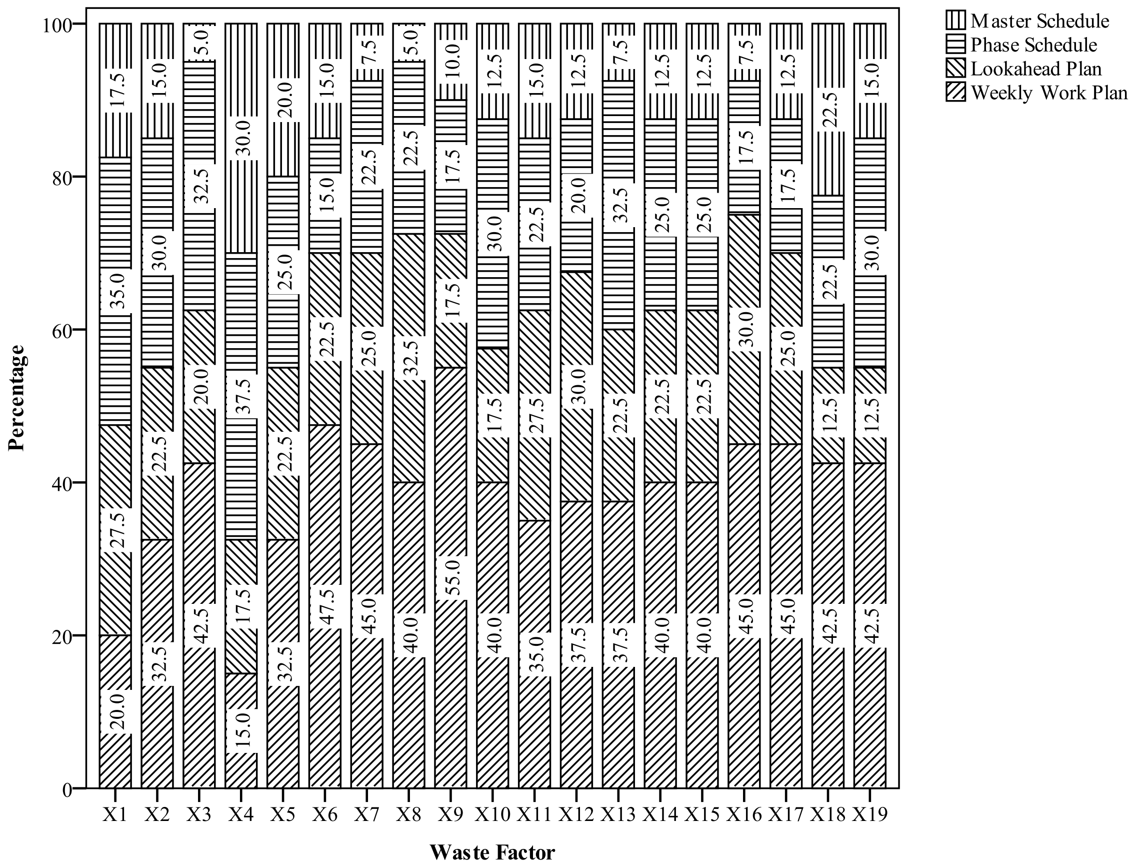

FIGURE II
CONNECTION OF PRODUCTION PLANS TO WASTE FACTORS

construction industry; whereas, lookahead plan and master schedule seem to be not an important plan. Unfortunately, lookahead plan is the central ideology of LPS when planning a project that shows what work can be done and what work will be done. Without looking in advance to the work that will be done, many problems maybe occur during construction phase. Furthermore, the master schedule is often made, but it does not play an important role in controlling the waste. From above analysis, a conclusion that can be stated in the current perspective of the Vietnam construction industry is that the longer the plan is made, the more difficult the waste is controlled. Similar to other countries, the personnel in Vietnamese context pay very much attention to WWP when performing a project.

VI. CASE STUDY

Previous studies have shown that there is no standard method to measure the waste in construction because the occurrence and effect of waste on project are very complex and irregular. Each different waste factor causes different level of waste for construction activities, and each different project type has different level of waste. It is even different from each other when performing the same task in two projects. For example, level of waste when performing concrete activity is completely different with rebar activity or formwork activity. The reason for this difference is derived from many sources. In this study, poor production planning and control is considered as a

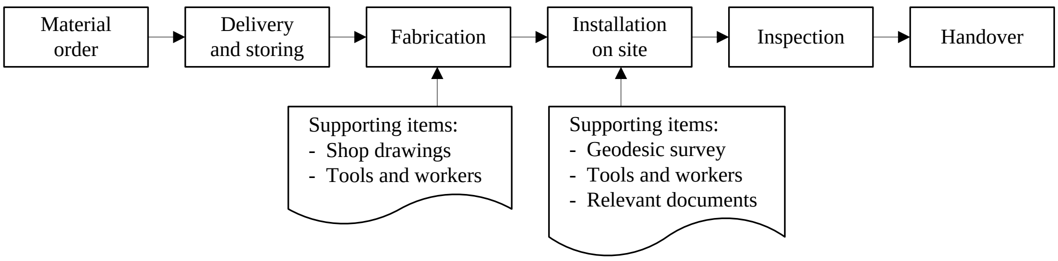

FIGURE III
CONSTRUCTION PROCESS FOR FORMWORK ACTIVITY OF BUILDING PROJECTS

TABLE VI
DESCRIPTION OF PROJECT PROPERTY AND PERFORMANCE OF PRODUCTION PLANNING

Description	Project A	Project B
General information		
Type of project	High-rise apartment	Resettlement building
Scope of work (m^2/floor)	4250.0	4400.0
Floor being executed	4^{th} floor	7^{th} floor
Duration of project completed (months)	18	21
Type of reinforced concrete structure system	Beam slab and wall	Beam slab and column
Investment sector (owner)	Private sector	Governmental sector
Reputation of contractor and consultant in construction market	Quite high	Medium
Performance of production planning		
Training participants	No	No
Process mapping	Yes	No
Further analysis	Yes	No
List of workable backlog	Yes	No
Analysis of activity constraints	Yes	Yes
Checking the constraints again	Yes	No
Measurement of percent plan complete (PPC)	Yes	Yes
Analysis of reasons for failure in WWP	Yes	No

source for waste increased. Therefore, in order to demonstrate the effect of production planning on waste, a case study has been adopted. The selected activity is formwork activity of two building projects. One project was totally planned and controlled by above mentioned process like LPS process, and the other project was by deficient or poor planning process. The basis to select these two projects was based on practical observation on the site, similar type and scope of project, and reputation of contractor in construction market. The construction process for formwork activity is shown in Fig. III. The description of the performance of production planning process in two projects is presented in Table VI.

Number of occurrences of waste were observed and recorded by a site engineer during three weeks. That was from April 8 to April 29, 2013 for project A, and from March 25 to April 15 2013 for project B. The reason for each waste occurrence was described according to plan and resource which were used to perform the formwork activity. The results of waste occurrence are presented in Table VII for project A and in Table VIII for project B.

In project A, most of waste occurrences in three observed weeks are contributory and non-contributory time wastes. Among them, X17 'time for supervising and inspecting the construction works' is dominant to waste occurrence. This is mainly due to two reasons: (1) the contractor himself always supervises his on-going works during construction to ensure that the work is being done with minimum of mistakes, and (2) the consultant himself checks whether or not the completed works follow the requirements as specified in the drawings and specification. The second most occurred waste belongs to X10 'waiting for others to complete their works before the proceeding works can be carried out'. Construction is a consequent chain of activities for the work on site; therefore, once any work is not completed as planned, the work flow will be probably interrupted. There are many reasons causing this incompletion such as unforeseeable weather conditions, design changes, poor plan and schedule, lack of supervision during construction, etc. This study solely considers waste occurrence due to poor or deficient production planning. Thus, level of waste can be reduced if resources and plans are well prepared. Finally, remaining wastes belong to X1 'over-allocated/ unnecessary equipment on site' (week 1), X14 'waiting for the clarification by client and consultants' (week 1), X7 'mishandling or error in construction applications/ installations' (week 2), and X15 'time for reworks/ repaired works/ defective works' (week 3).

Similar to project A, waste occurrences in project B are also dominated by contributory and non-contributory time wastes. X10 'waiting for others to complete their works before the proceeding works can be carried out', X12 'waiting for materials to be delivered on site' and X17 'time for supervising and inspecting the construction works' are the most occurrence of waste in all three observed weeks. This shows that these wastes are repetitive in week-by-week, and they can be classified into unavoidable wastes in the practice once the project is planned deficiently. There are two wastes that occur in two successive weeks including X2 'over-allocated/ unnecessary materials on site', and X11 'waiting for equipment to be delivered on site'. These two wastes are related to the plan of materials and equipment delivery for construction site. The appropriate reason to explain for this finding is the poor cooperation and communication between the contractor and the supplier/ seller. Due to this, construction process of an activity is mostly stopped, and it makes other proceeding activities cannot carried out as planned. Finally, remaining wastes happen individually in each week including X7 'mishandling or error in construction applications/ installations', and X18 'time for instructions and communication between engineers and workers' in week 1, X4 'unnecessary procedures and working protocols', and X14 'waiting for the clarification and confirmation by client and consultants' in week 2, and X8 'materials for reworks/ repaired works/ defective works' and X19 'time for transporting workers, equipment

TABLE VII
WASTE OCCURRENCE IN FORMWORK ACTIVITY OF PROJECT A

Week	#	Waste Occurrence	Detailed description
1	X1	Over-allocated/ unnecessary equipment on site	Work plan has not anticipated correctly number of cutters used to fabricate the formwork (4 nos.)
	X10	Waiting for others to complete their works before the proceeding works can be carried out	Workers who undertook the installation of the formwork of slab waited for others who undertook the fabrication of the formwork to finish their work due to lack of machine
	X14	Waiting for the clarification and confirmation by client and consultants	There was an unclear design between architectural and structural drawing that needed to be clarified, but the consultant replied to the contractor's RFI late two days comparing with commitment
	X17	Time for supervising and inspecting the construction works	Any work in construction site must be supervised by both contractor and consultant during performance, and must be inspected by the consultant after completion
2	X7	Mishandling or error in construction application/ installation	Formwork for kitchen area was installed with wrong high level due to the deficient drawing; therefore, it needed more time to complete the work
	X10	Waiting for others to complete their works before the proceeding works can be carried out	Worker who undertook the installation of the formwork of lift wall waited for geodesic engineers who undertook the location of the co-ordinate of wall to complete their work due to lack of equipment
	X17	Time for supervising and inspecting the construction works	*(Similar to week 1)*
3	X15	Time for reworks/ repaired works/ defective works	Due to the work plan has not been prepared well, the contractor needed much more time to correct the formwork following the requirements before it was inspected by the consultant
	X17	Time for supervising and inspecting the construction works	*(Similar to week 1)*

and materials' in week 3.

Table IX presents the comparison of waste occurrence in formwork activity between two projects above. It can be easily seen that X17 'time for supervising and inspecting the construction works' is the most common waste for both projects with three times of occurrence in three weeks. In overall, total number of waste occurrence in project B are 19 times greater than those of project A with 9 times. Therefore, it can be concluded that the project that is well planned will have less number of waste occurrences than the one that is poorly planned.

VII. DISCUSSION

There are no evidence that show the orthodox implementation of the tools and techniques of Lean Construction in Vietnamese context. This is due to Vietnam is a developing country; whereas, Lean Construction is a quite new way. However, the current practice shows that there are same ideologies and philosophies between them. The construction industry has been finding better solutions for its development. The difference found in this study is that the detailed procedures in each plan are superficially performed or even ignored, especially in lookahead plan. Therefore, in order to improve the project efficiency, the professionals should pay much more attention to this plan. This finding of the study can be used as a basis for prospective implementation of LPS in Vietnamese context.

Different from previous concepts, the current waste concept of Lean Construction is not only related to materials and equipment, but also related to time for transporting, idling, resting, moving, supervising and instructing. Some of these time wastes are not much recognized by the professionals in construction industry. Even they are considered as the necessitated time for the performance of construction activity. The results of this study have shown that the occurrence percentage for wastes that pertain to time for supervising, inspecting, instructing and communicating are quite high as shown in Table III. Furthermore, the results of case study in Table IX showed that 'time for supervising and inspecting construction works' occurs in both project A and B for all three observed weeks. This proves that the professionals often tend to accept them rather than trying to find reasonable solutions to prevent them from happening in construction sites.

Normally, many of required materials and equipment of project are ordered away from the date of construction to ensure that the sequence of activities is not interrupted, e.g., steel for roofing work, vinyl conductive tile for flooring work, pre-fabricated reinforced concrete pile for footing work, block tile for finishing work, etc. Most of these materials are analysed and planned in long-term schedule. But, the results of relationship analysis have indicated that WWP plays the most important role in controlling the wastes in conversion activities that are mostly related to materials and equipment. This difference is maybe due to the poor perception of the professionals to waste problems. They often pay attention to WWP as performing a project, or even they ignore to control the materials that have been planned in master or phase schedule.

VIII. CONCLUSIONS

Many attempts to reduce non value-adding activities have been made in the construction industry, but they seem to get less successful than expected. This makes contractors often have to pay a considerable amount for these activities. The implementation of lean construction techniques in a large number of projects, especially LPS, has provided a lot of empirical evidence of waste

TABLE VIII
WASTE OCCURRENCE IN FORMWORK ACTIVITY OF PROJECT B

Week	#	Waste Occurrence	Detailed description
1	X2	Over-allocated/ unnecessary materials on site	Ply wood sheets used for formwork activity of slab and beam in a floor area were over-allocated due to poor plan
	X7	Mishandling or error in construction applications/ installations	Workers incorrectly fabricated the formwork for one column comparing with the requirements due to wrong instruction
	X10	Waiting for others to complete their works before the proceeding works can be carried out	Formwork's workers waited for rebar's workers to install the rebar for three columns before they could continue to perform their work due to lack of worker. The workflow was interrupted in about 4 hours
	X11	Waiting for equipment to be delivered on site	The construction site waited for the seller one day to provide three small drillers comparing with the planned day.
	X12	Waiting for materials to be delivered on site	The construction site waited for the supplier to deliver nails and formwork sheets. It was delayed one day comparing with the planned day
	X17	Time for supervising and inspecting the construction works	Any work on construction site must be supervised by both contractor and consultant during performance, and must be inspected by the consultant after completion
	X18	Time for instructions and communication between engineers and workers	During construction, the foreman often requested the site engineer or site manager clarify design detail in the drawings
2	X2	Over-allocated/ unnecessary materials on site	U-shaped steel bars and tubular scaffolding were provided too many on floor. Most of them were even distributed messily and untidily. This made the performance of formwork activity for columns meets more difficult
	X4	Unnecessary procedures and working protocols	The consultant required the contractor himself inspects the work first to ensure that it meets the requirements before sending letter of inspection to the consultant
	X10	Waiting for others to complete their works before the proceeding works can be carried out	The formwork of lift core was not completed as planned; therefore, the formwork activity of beams and slab around this lift could not be carried out
	X11	Waiting for equipment to be delivered on site	Two small cutters used to fabricate the formwork were not delivered on time as stated in the order
	X12	Waiting for materials to be delivered on site	12 meter long U-shaped steel bars used to set out the formwork were not delivered on time as stated in the order (100 nos.)
	X14	Waiting for the clarification and confirmation by client and consultants	There was an unclear design between architectural and structural drawing that needed to be clarified, but the consultant replied to the contractor's RFI four days late
	X17	Time for supervising and inspecting the construction works	*(Similar to week 1)*
3	X8	Materials for reworks/ repaired works/ defective works	Due to scaffolding for an area of slab was installed incorrectly as planned; therefore, the consultant's supervisor required the contractor use some additional steel tubes to strengthen the loading capacity of the supporting system
	X10	Waiting for others to complete their works before the proceeding works can be carried out	Formwork activity for two staircases could not be performed due to geodesic engineers have not finished their work
	X12	Waiting for materials to be delivered on site	Workers waited for 200 Y-shaped tighteners of scaffolding for formwork installation of beams and slab to be delivered on the site so that the work could be started soon
	X17	Time for supervising and inspecting the construction works	*(Similar to week 1)*
	X19	Time for transporting workers, equipment and materials	Because the tower crane was busy for transporting rebar on the floor; therefore, transporting the formwork of columns was interrupted

TABLE IX
COMPARISON OF WASTE OCCURRENCE BETWEEN PROJECT A AND B

#	Waste Occurrence	Week 1		Week 2		Week 3		Total	
		A	B	A	B	A	B	A	B
X1	Over-allocated/ unnecessary equipment on site	✓						1	0
X2	Over-allocated/ unnecessary materials on site		✓		✓			0	2
X3	Over-allocated/ unnecessary workers on site							0	0
X4	Unnecessary procedures and working protocols				✓			0	1
X5	Material lost/ stolen from site during construction period							0	0
X6	Material deteriorated/ damaged during construction period							0	0
X7	Mishandling or error in construction application/ installation		✓	✓				1	1
X8	Materials for reworks/ repaired works/ defective works						✓	0	1
X9	Accidents on site							0	0
X10	Waiting for others to complete their works before the proceeding works can be carried out	✓	✓	✓	✓		✓	2	3
X11	Waiting for equipment to be delivered on site		✓		✓			0	2
X12	Waiting for materials to be delivered on site		✓		✓		✓	0	3
X13	Waiting for skilled workers to be provided on site							0	0
X14	Waiting for the clarification and confirmation by client and consultants	✓			✓			1	1
X15	Time for reworks/ repaired works/ defective works					✓		1	0
X16	Time for workers' rest during construction							0	0
X17	Time for supervising and inspecting the construction works	✓	✓	✓	✓	✓	✓	3	3
X18	Time for instructions and communication between engineers and workers		✓					0	1
X19	Time for transporting workers, equipment and materials						✓	0	1
SUM								9	19

reduction [5]. Similar to other developing countries, Vietnam construction industry has been also facing with many problems. The strategy of efficiency improvement for construction projects through eliminating the existing wastes can be gradually created. This study has considered the relationship between production planning and waste occurrence based on philosophies of Lean Construction. The main results of the study are as follows:

- The production planning processes are performed quite superficial. The most concerned problem is that the classification of work to set up a workable backlog is performed with only 72%, and the failure reason analysis for the weekly work to make a learning cycle is performed with 79%.
- Eleven in total of nineteen waste factors occurred in surveyed projects have percentage of response greater than 70%. Most of them are related to non-contributory and contributory time wastes such as time for waiting, transportation, communication, inspection and instruction.
- There is a significant negative relationship between production planning and waste occurrence (r = -0.062) because significance value is 0.706 greater than 0.05. The causal analysis results showed that WWP is the most dominant plan for seventeen in total of nineteen factors with at least 32.5%, and phase schedule is the most dominant plan for two remaining waste factors with at least 35%.
- A case study related to problem of waste occurrence and quality of production plan for formwork activity of two selected projects was analysed. The results showed that the better the project is planned, the fewer the waste will occur on construction sites.

It is recommended that all project parties, especially contractors, should clearly understand their responsibility to reduce waste occurrence on construction sites. Contractors need to know all useful information prior to making production plans such as required materials and equipment, people, budget, safety program, etc. An analysis of success-and-failure reasons in the previous similar projects should be conducted and highlighted. Owners and consultants need to know how to efficiently manage the contractor’s work. In summary, the mutual relationship between production planning and waste occurrence has been examined in this study. The results proved that the professionals in construction industry have not paid much attention to this relationship.

Although extensive efforts have gone into this study, limitations are unavoidable. The research team reviewed more than thirty papers to identify preliminary factors relating to wastes and planning process. However, the literature review can never be exhaustive. Thus, it should be possible to investigate more waste factors in order to accurately assess their impact on project efficiency. In general, the contribution of this study is to encourage practitioners to benefit from reducing waste due to production plans are well made before and during construction phase.

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