CONSTRUCTION SITE WASTES (NON-PHYSICAL) CATEGORIZATION IN ADDIS ABABA BASED ON LEAN CONCEPT

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ABSTRACT

Waste in the construction industry has been the subject of several research projects around the world in recent years. One of the effective methods of wastage reduction is the application of lean approach to construction industry. Lean construction is a result of the introduction of a new form of production management. In general, project managers tend to conceptualize "waste" as physical construction waste only, but there are noticeable wastes in the construction processes which are named "non-value adding activities" by lean construction theory. In addition to stressing on the physical waste, lean thinking specifically pays lots of attentions to the waste produced over a construction process. Waiting time, non-value adding (NVA) works and material transportations are categorized in this group.

This article is focused on categorizing construction site activities based on lean concept on selected six construction sites. These activities include rebar work for slab, formwork for column and concrete cast for slab. Video data collection method was mainly used to conduct the study. Video data collection required to be entered into spreadsheets so that the necessary tabular results could be generated. The results of the case studies showed that, a significant portion of crew working hours was spent on NVA activities. Among the NVA activities, waiting time took the largest share, indicating interruption of flow in the work process. The results of the study further pointed out that, time spent on non-value adding but required activities (NVAR), like temporary work and supporting activities can also be minimized by using better technologies (materials and equipment).

Keywords: Construction site waste, lean construction, lean thinking, non-value adding (NVA), non-value adding but required (NVAR) and value adding (VA).

INTRODUCTION

The construction industry in Ethiopia has been developing substantially over the last two decades. Recent studies indicated that the GDP contribution of the construction industry has been raised to 5.6% and approaches to the sub-Saharan average of 6% [1]. Despite the construction industry's significant contribution to the economy of developing countries and the critical role it plays in their countries development, the performance of the industry remains generally low [2]. However, in recent years, new construction technologies and methods have emerged. The newest methods of construction are expected to improve efficiency, performance and reduce construction waste [3].

LITERATURE REVIEW

It has been understood by many that construction industry has been suffering enormously from a serious drawback, which is "waste". During the past decades many researchers tried to categorize construction sites wastes in many ways. However, almost all of the researchers follow similar approach. Excess materials, delays, rework and defects are those waste commonly mentioned by researchers [4]. Another broader definition of waste is to include not only material waste but also waste generated in a construction project such as waiting time, transportation time, and etc. [5]. This issue of non-physical waste within construction processes is the basis of waste concept from one of the innovative approaches called "lean construction", which was introduced to construction industry in the 1990s based on a successful manufacturing theory, i.e., lean production [6].

History of lean production

The term lean production was coined by Womack et al. to define the Japanese production system developed by Toyota Production System (TPS) [7]. The foundations of lean production were developed in post–World War II Japan, when the Japanese manufacturing industry underwent a complete rebuilding [8]. The TPS was inspired by Fords mass production system, but deeply deviated from it to suit the sociopolitical and economic reality in Japan after Second World War [7]. Unlike Ford, Toyota operated in a small country that was suffering from the devastating effects of the war [7, 9]. Toyota then made the strategic decision to focus its manufacturing efforts not on massive volumes of a product but, rather, on many different products in smaller volumes since it greatly reduced the carrying costs required for huge inventories, and the cost of rework was reduced because defects showed up instantly in smaller batches [8]. Toyota also managed to reduce the amount of time required for machine setup from an entire day to three minutes, a task that enabled Toyota to increase the flexibility of its production lines as well as reduce production times. Lean production, as the TPS, aims at maximizing customer value while minimizing waste [10, 11].

The five lean principles

In 1996, Womack and Jones presented a set of five principles (value, value stream, flow, pull, and perfection) that are present in a Lean system and they set these principles as Lean Thinking [12]. These are briefly summarized as follows.

a. Value

The first principle of lean thinking starts with specifying value to a customer. This implies identifying the client's needs and expectations of a product or service. As defined by Ohno, waste is anything that consumes resources but does not add value to the product or service from the clients' point of view. The counter part of value is waste [13]. Ohno identifies seven types of waste that can be found in a production process [10]. These seven types of waste are mentioned as follows;

- Overproduction or the production of items not required and which accumulate as inventory;
- Time on hand or waiting for inputs from other activities;
- Transportation of parts, materials or equipment;
- Over processing;
- Stock on hands or inventory;
- Unnecessary movement of workers and
- Producing defective products.

b. Value stream

The second lean thinking principle is to identify the value stream. The value stream is all the specified actions that are required to bring a specific product (a good, a service, or a combination of the two) from the conceptual stage until it is delivered to the final customer [14]. Value stream analysis shows three types of actions occurring along the value stream [15]. These are;

i. Value adding activities (VA): e.g., Assembling engine, tightening a bolt
ii. Necessary but not value adding (NVAR): e.g., Inspecting welds to ensure quality
iii. Non-value adding (NVA): e.g., Products, equipment or people that must wait because of poor scheduling or unbalanced crew size and unnecessary movement of materials.

c. Flow

The third principle in lean thinking is to create continuous flow of value creating steps. This is an important step in the whole process of implementing lean.

This step requires a new way of doing things which is completely different from traditional batch thinking [15]. The goal of flow principle is based on redefining the work of functions, departments, and firms so that they can make positive contribution to value creation and to speak to the real needs of employees at every point along the stream [13].

d. Pull production

The fourth lean thinking principle is to implement pull, i.e., trigger production based on actual demand and conditions. Toyota follows pull, this means production starts only after an order is placed by customer. Traditionally, each department or company optimizes their own processes or services to produce as much as they can, as fast as they can, and pushes their products or services downstream without considering what the customer really wants at the time of production or what the actual demand is [10, 12].

e. Perfection

The last principle used to implement Lean Thinking is to seek perfection, or kaizen, the Japanese term for continuous improvement, through a Plan-Do-Check-Act (PDCA) cycle [9]. According to Womack & Jones, the most important stimulus to perfection is transparency – making entire value stream visible to everyone; subcontractors, suppliers, assemblers, distributors, customers, and employees, all of them can see everything; making value stream visible in such a way, make it easier to discover ways to create value and prevent waste [13].

Lean in construction

Lean construction has been defined in several ways as the concept continues to evolve. [16] lean construction refers to the application and adaptation of the underlying concepts and techniques of lean production as a new philosophy of production for construction. The Construction Industry Institute (CII) has defined lean construction as “the continuous process of eliminating waste, meeting or exceeding all owner requirements, focusing on the entire value stream, and pursuing perfection in the execution of a constructed project” [17]. [18] described lean construction as “a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value for the customer (both internal and external)”.

Lean Construction Elements and their benefits

Lean production has several tools and techniques that have evolved since the beginning of its application in the construction industry. Lean construction has been identified as trying to develop a list of the most prominent and exhaustive tools and techniques that are being implemented in today’s construction industry and that might also impact performance practices. Some of the tools related to the topic of study are: TFV theory, last planner, just-in-time and lean project delivery system.

The implementation of such lean tools and techniques had significantly reduced waste and improved performance in construction projects [15]. [19] lean construction has identified several benefits when applying lean principles in construction which include; reduce sharing of non-value adding activities, increase the output value through systematic construction of customer requirement, reduce process variability, reduce cycle times, Simplify by minimizing the number of steps parts and linkages, increase output flexibility, increase process transparency, focus on complete process, build continuous implement into the process and balance flow improvement with conversion improvement and benchmarking.

Gap Identification

In Ethiopia, limited researches were conducted on construction site wastes. However, all the researches follow similar principle by focusing on physical (material) wastes generated on construction sites only [20, 21, 22]. So far, no clear attempt was made to incorporate wastes generated on construction project sites such as waiting time, transportation time, and unnecessary movement and so on.

This issue of non-physical waste within construction processes is the basis of waste concept from lean construction approach.

METHODOLOGY

In this research, a total of six case studies were conducted at six selected construction sites. The construction sites were selected based on the years of working experience and types of technologies (material and equipment) used by the companies. Video data collection method was mainly used to conduct the study. Video data collection required to be entered into spreadsheets so that the necessary tabular results could be generated using excels for each job.

Data Collection Procedure

Table 1; bellow is an example of one of the data sheets used for rebar work. After viewing the videos several times, it was required to use a stopwatch and a data sheet.

ANALYSIS AND DISCUSSION

In this part the selected construction site activities were identified, categorized and discussed in detail based on lean concepts. Two cases focus on rebars work for slab, two cases focus on formwork for column work and the remaining two consecutive cases focus on concrete work for slab.

Case Study No.1 and No.2: (reinforcement bar work for slab)

Case Study No.1

The project was for one of Addis Ababa's sub-city G+7 office buildings. The total built up area of the building is 627 m^2. Rebar work is highly repetitive by nature; subsequently rebar work for 145.69 m^2 was only observed. Eight workers were engaged for placing 2,552.34 kg-diameter 10 mm Bar. The reinforcement bars were cu and bent on construction site and delivered to actual working site by using both tower crane and rebar workers.

Table 1:Data analyzing sheet

Name of the company, A						
Field classification sheet 1				***Case study No 1***		
Person or Equipment entire group cycle time				***Date 2/29/19 (Day One)***		
No	**Worker**	**Member classification**	**Activity**	**Time at activity**	**Activity classification**	***Waste classification***
1	Rebar worker one	Rebar for slab	Adjusting rebar position	00:00:21	NVAR	Material positioning
2	Rebar worker one	Rebar for slab	Checking rebar alignment	00:01:20	NVAR	In-process Inspection
3	Rebar worker one	Rebar for slab	Cutting and tying steel wire	00:01:49	VA	Value adding
4	Rebar worker one	Rebar for slab	Rework	00:00:59	NVA	Extra processing

Subcategories of activities based on lean concept

In general terms, inefficiencies are classified as one of three types: inefficiency due to waste (NVA activities), inefficiency due to work that does not directly contribute value to the work (NVAR activities) and inefficiency due to poorly designed work processes (ineffective VA activities) [9]. Table 2 shows inefficiencies due to VA, NVA and NVAR activities.

The reinforcement bars were stored on site; as a result, some of the rebar workers were arranging the reinforcement bars according to their size. Time spent by workers on such activities were considered as being an inventory related activity i.e., NVA. The summary of each crew member's activity along with waste classification and actual time spent on VA, NVAR and NVA activities are shown on Table 3 along with Chart 1.

Table 2: Inefficiencies due to VA, NVA and NVAR activities

Activity classification	**Description**	**Example**
Value adding (VA)	Any activity that changes the shape, form, or function of materials or information to meet customer’s needs.	Assembling engine, tightening a bolt, casting concrete
Non-value adding but required (NVAR)	Activities that are required for construction operations yet have no permanent effect on the finished product.	Material positioning,
		In-process inspection,
		Temporary work and support activities (TWSA)
Non-value adding NVA (Waste)	Anything that takes time, resources or space but does not add value to the product or service delivered to the customer	Overproduction
		Waiting
		Unnecessary Transport
		Extra Processing (Rework, re-handling or defects)
		Inventory
		Motion
		Defects

Table 3: Typical result for rebar crew completing rebar work for slab section (case 1)

Activity classification	*Waste classification*	*Worker No 1*	*Worker No2*	*Worker No 3*	*Worker No4*	*Worker No 5*	*Worker No 6*	*Worker No 7*	*Worker No 8*
VA	***Value adding***	02:34:45	02:22:09	01:40:48	03:23:09	03:51:51	00:49:06	01:15:28	00:31:01
VA Total		02:34:45	02:22:09	01:40:48	03:23:09	03:51:51	00:49:06	01:15:28	00:31:01
NVAR	***In-process inspection***	01:02:11	00:10:14	00:06:18	00:57:48	00:15:51	00:27:52	00:53:58	00:06:25
	Material positioning	01:32:58	01:04:28	00:56:14	02:09:14	02:00:24	00:37:38	00:52:04	00:15:43
NVAR Total		02:35:09	01:14:42	01:02:32	03:07:02	02:16:15	01:05:30	01:46:02	00:22:08
NVA	***Waiting***	01:54:45	00:47:35	01:00:25	01:19:56	0:57:18	00:29:00	00:47:08	00:07:07
	Transport	01:36:12	00:06:18	00:40:05	01:30:57	01:22:37	00:14:28	00:26:53	00:12:10
	Extra processing	00:22:06	00:28:50	00:20:30	00:44:50	00:45:21	00:09:06	00:14:50	00:15:01
	Inventory	00:38:00	00:02:48	00:14:32	01:43:37	01:08:24	00:00:00	00:50:35	00:00:00
	Motion	00:42:33	00:17:10	00:33:24	00:25:31	01:23:53	00:13:08	00:34:22	00:18:21
	Defect	00:02:52	00:00:00	00:00:00	0:08:38	00:08:34	00:00:00	00:00:20	00:00:00
NVA Total		04:16:28	01:42:41	02:48:56	05:53:29	05:46:07	01:05:42	02:54:08	00:52:39
Grand Total		09:26:22	05:19:32	05:32:16	12:23:40	11:54:13	03:00:18	05:55:38	01:45:48

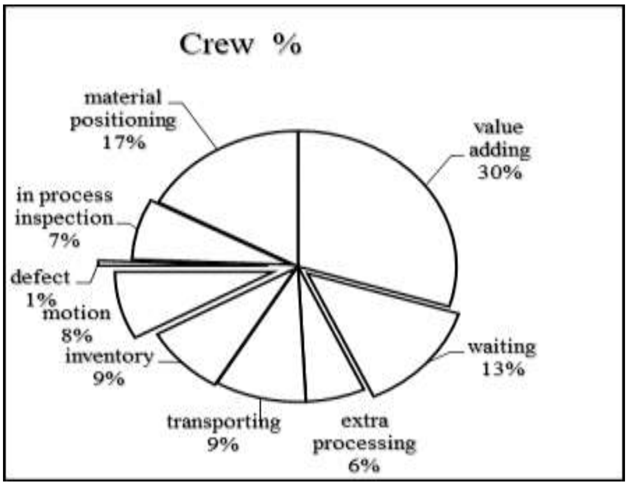

Chart 1: Typical result for rebar crew completing rebar work for slab section (case1)

The weighted average crew result shows that 30% of the working hours per slab section were spent on value adding (VA) activities, 24% of the working hours per slab section were spent on NVAR and the rest 46% was spent on NVA activities. Among the NVA activities waiting time took the largest share by holding 13%, this was due to waiting for delivery of reinforcement bar to site and waiting until inspections are performed by the resident engineer. Another 9% of the NVA was spent on unnecessary transportation of heavy weight reinforcement bars. Furthermore, 9% of the NVA was spent on sorting the reinforcement bars stored (inventory) on site according to their respective sizes. Additional 8% of the NVA was spent on unnecessary movement of the workers due to poor site layout. Another 6% of the NVA was due to extra processing which includes rework. Among the NVAR activities 17% was spent on positioning bottom and top bars and adjusting rebar positions, while the rest 7% was spent by inspection, measuring and marking rebar.

Case Study No.2

The project was a 1B +G+8 building for office purpose. The total built up area of the building is 504 m^2. However, rebar work associated with 98.45 m^2 was only observed for this research, following repetitive nature of the work. Eight workers were involved in order to place 2,320.06 kg-diameter 10mm bars. The reinforcement bars were cut and bent on the company's workshop, which is located outside the construction site and delivered to actual working site when needed in the amount needed. After being delivered to construction site, the reinforcement bars were transported to the actual working site by using both tower crane and rebar workers. The summary of each crew member's activity along with waste classification and actual time spent on VA, NVAR and NVA activities are presented on Table 4 and Chart2.

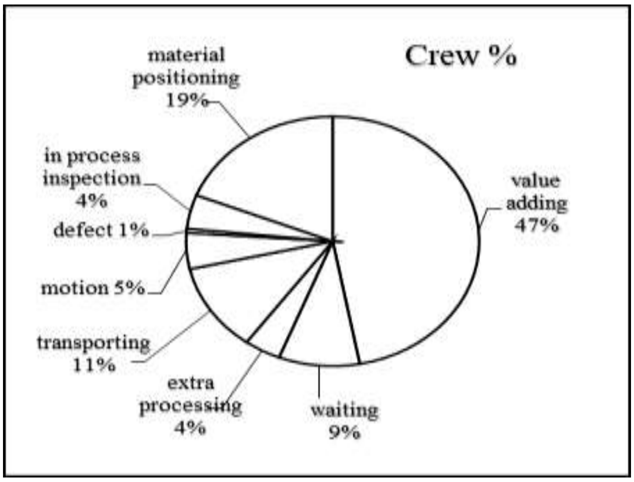

Chart 2: Typical result for rebar crew completing rebar work for slab section (case2).

The weighted average crew result shows that 47% of the working time was spent on VA activities, 23% of the working hours were spent on NVAR and the rest 30% was spent on NVA activities. Amongst the 30% of the NVA activities, 9% of the time was spent on waiting for inspection and delivery of materials; this also took a prime share among the others.

Table 4: Typical result for rebar crew completing rebar work for slab section (case 2)

Activity classification	*Waste classification*	*Worker No 1*	*Worker No2*	*Worker No 3*	*Worker No4*	*Worker No 5*	*Worker No 6*	*Worker No 7*	*Worker No 8*
VA	***Value adding***	01:32:55	01:54:18	01:40:56	01:04:15	01:20:28	01:31:15	01:35:42	01:32:27
VA Total		01:32:55	01:54:18	01:40:56	01:04:15	01:20:28	01:31:15	01:35:42	01:32:27
NVAR	***In-process inspection***	00:16:14	00:07:59	00:04:33	00:14:23	00:02:00	00:05:48	00:16:27	0:00:59
	Material positioning	00:25:25	00:21:17	00:32:19	00:46:47	00:50:45	00:43:44	00:31:53	00:43:09
NVAR Total		00:41:39	00:29:16	00:36:52	01:01:10	00:52:45	00:49:32	00:48:20	00:44:08
NVA	***Waiting***	00:14:58	00:20:01	00:17:55	00:28:59	00:12:07	00:14:08	00:14:18	00:16:27
	Transport	00:35:45	00:20:40	00:26:51	00:25:05	00:15:05	00:18:19	00:18:37	00:17:26
	Extra processing	00:11:20	00:05:53	00:03:08	00:06:35	00:13:05	00:02:49	00:03:37	00:16:21
	Inventory	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	0:00:00
	Motion	00:13:52	00:10:30	00:06:45	00:10:24	00:07:59	00:13:39	00:03:51	00:05:53
	Defect	00:00:49	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:03:36	00:04:00
NVA Total		01:16:44	00:57:04	00:54:39	01:11:03	00:48:16	00:48:55	00:43:59	01:00:07
Grand Total		03:31:18	03:20:38	03:12:27	03:16:28	03:01:29	03:09:42	03:08:01	03:16:42

Another 11% of the NVA was spent on unnecessary transportation of heavy weight reinforcement bars by the workers. In addition, 5% of the NVA was spent on unnecessary movement of the workers. The rest, 4% of NVA was spent on extra processing i.e., rework. Among NVAR activities material positioning including positioning bottom and top bars and adjusting rebar's position took 19%, while the rest 4% of NVAR was spent on in-process inspection i.e., inspection, measuring and marking bars.

Discussion on rebar work cases (case study No.1 and No.2)

Rebar crew at case study No.2 performed 17% more on VA activities as opposed to case study No.1. In addition, company at case study No.2 saved 8% of the working time spent on inventory related activities by separating the rebar bending and cutting place from the actual construction site, this as a result, also reduced waste associated with unnecessary movement of workers. On the other hand, in both companies, waiting time for inspection and delivery of materials took considerable amount of time; implying an interruption of flow in the work process.

Case study No.3 and No.4: (formwork for Column)

Case Study No.3

The project was a G+8 building for multi-use purpose. The total built up area of the building is 600 m^2. During the time of conducting the case study the building reached 2^{nd} floor. There are a total of 30 columns in the floor, however 8 columns with a size of ($600mm \times 600mm$) were only observed for this study. The company used plywood for formwork preparation. Eight carpenters were observed, during preparing the formworks. The summary of each crew members' activity along with waste classification and actual time spent on VA, NVAR and NVA activities are shown on Table 5 and on Chart 3.

Table 5: Typical result for carpenter crew each completing formwork for column(case3)

Activity classification	*Waste classification*	*Carp No.1*	*Carp No.2*	*Carp No.3*	*Carp No.4*	*Carp No.5*	*Carp No.6*	*Carp No.7*	*Carp No. 8*
NVAR	***In-process inspection***	00:07:08	00:11:26	00:20:07	00:05:25	00:08:40	00:31:03	00:17:10	00:12:59
	Material positioning	00:50:55	00:51:28	00:35:54	00:50:43	00:36:05	00:48:13	00:55:56	00:50:11
	TWSA	01:15:17	01:27:25	00:59:51	01:06:12	01:08:34	01:00:40	01:09:00	01:05:15
NVAR Total		02:13:20	02:30:19	01:55:52	02:02:20	01:53:19	02:19:56	02:22:06	02:08:25
NVA	***Waiting***	01:03:38	00:46:32	01:05:55	01:07:50	00:42:03	00:27:40	01:01:25	01:07:03
	Transport	00:00:00	00:00:00	00:06:36	00:02:16	00:00:00	00:04:52	00:05:00	00:00:00
	Extra processing	00:07:41	00:13:43	00:17:08	00:09:03	00:02:18	00:00:50	00:15:32	00:17:59
	Motion	00:00:00	00:00:00	00:00:00	00:00:00	00:14:41	00:00:00	00:12:47	00:18:13
	Defect	00:01:10	00:00:13	00:02:07	00:04:48	00:01:34	00:00:00	00:07:01	00:11:13
NVA Total		01:12:29	01:00:28	01:31:46	01:23:57	01:00:36	00:33:22	01:41:45	01:54:28
Grand Total		03:25:49	03:30:47	03:27:38	03:25:28	02:53:55	02:53:18	04:03:51	04:02:53

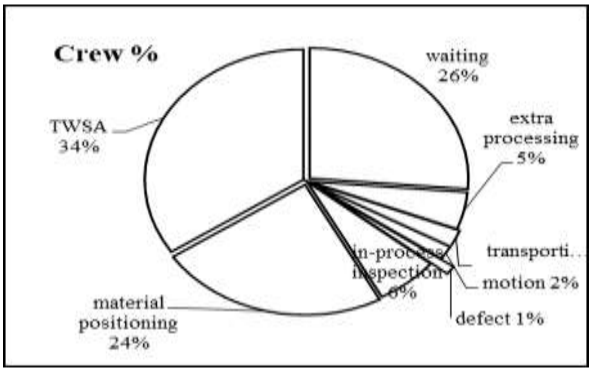

Chart 3: Typical result for carpenter crew each completing formwork for column (case 3).

According to the carpenters' crew result, 64% of the working hours per column were spent on NVAR activities. Among this temporary work and supporting activities (TWSA) took 34%, these activities include; erecting formwork and nailing horizontal and diagonal support. The other 24% of the NVAR was spent on material positioning i.e., positioning horizontal, vertical and diagonal support. The rest 6% of the NVAR was spent on in-process inspection i.e., plumbing and leveling, checking rebar alignment and by measuring and marking. On the other hand, NVA activities took 36% while waiting time consumed 26% of the working time; this was due to waiting for delivery of materials on site and waiting until the rebar crew complete their work. The fact that the plywood formworks were re-used several times, the carpenter crew was fixing defective formworks, this activity took 5%.

There were 38 columns on the floor, however 8 columns of (600mm×600mm) size were only observed for this study. The formworks used for the columns were modular type delivered from

Italy and are assembled on site. The summary of each crew's activity along with waste classification and actual time spent on VA, NVAR and NVA activities are shown on Table 6 and on chart 4.

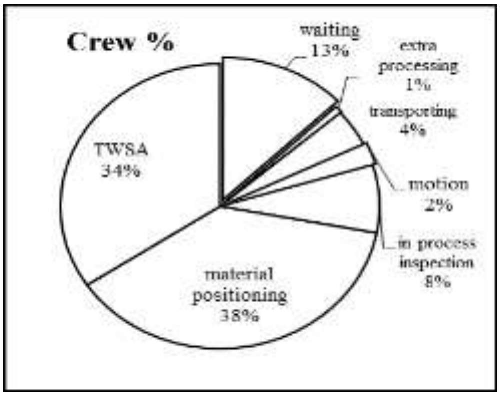

Chart 4: Typical result for carpenter crew completing formwork for column (case 4).

Table 6: Typical result for carpenter crew each completing formwork for column (case 4)

Activity classification	*Waste classification*	*Carp No.1*	*Carp No.2*	*Carp No.3*	*Carp No.4*	*Carp No.5*	*Carp No.6*	*Carp No.7*	*Carp No. 8*
NVAR	*In-process inspection*	00:10:40	00:06:21	00:03:58	00:03:25	00:12:38	00:11:36	00:13:22	00:16:29
	Material positioning	00:48:56	00:38:44	01:01:50	01:04:41	00:44:18	00:42:30	00:49:12	00:33:23
	TWSA	00:39:01	00:37:15	00:42:07	00:37:58	00:55:11	00:50:43	00:47:48	00:39:37
NVAR Total		01:38:37	01:22:20	01:47:55	01:46:04	01:52:07	01:44:49	01:50:22	01:29:29
NVA	*Waiting*	00:14:48	00:18:53	00:11:32	00:15:24	00:13:28	00:17:13	00:17:29	00:21:47
	Transport	00:00:00	0:14:32	00:03:45	00:07:14	00:00:00	00:01:29	00:11:50	00:03:45
	Extra processing	00:00:00	00:00:00	00:18:19	00:02:22	00:00:00	00:00:00	00:02:22	00:00:25
	Motion	00:02:15	00:00:43	00:00:00	00:02:33	00:06:43	00:08:03	00:02:47	00:02:33
	Defect	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00
NVA Total		00:17:03	00:34:08	00:18:19	00:27:33	00:20:11	00:26:45	00:34:18	00:28:30
Grand Total		01:55:40	01:56:28	02:06:14	02:13:37	02:12:18	02:11:34	02:24:40	01:57:59

Case study No.4

The project was a 2B+G+8 building for apartment use. The total built up area of the building is 1070 m^2. There were two sections in the building, the case study focused on one of the sections. The selected section has a total area of 507 m^2. The building reached 4^{th} floor when the study was conducted.

The weighted average crew results show that 80% of the carpenters working hour per column was spent on NVAR activities while the rest 20% was spent on NVA activities. Among NVAR activities, material poisoning took 38%, these activities comprise of positioning the pins, wedge, zinc-coated distancing steel bars and props and adjusting formwork position. The other 34% of the NVAR was spent on TWSA, which includes; erecting formwork, locking formwork with pins and wedges, locking formwork with head arresters and tying timber support with wire.

The rest 8% of NVAR activities was spent on in-process inspection including checking for formwork alignment. Among NVA activities 13% was spent by transporting formworks to working site and waiting for confirmation order. While the rest 4% and 2% respectively were spent by unnecessary transportation and movement of workers. Due to the use of good quality of formwork (segmental formworks), defective work and rework was only 1%.

Discussion on formwork for column cases (case 3 and case 4)

The different mechanisms and materials used by the two companies showed an insight on how working hours spent on temporarily built and supporting activities (NVAR) can be shortened. Due to modular type of formwork used on case study No.4, working hours spent by the carpenter crew was less compared to case study No.3. Waiting time of carpenter crew at case study No. 4 was also 12% less, due to the same reason.

Furthermore, on case study No. 4, the probability of making defective works and reworks were almost none, owing to segmental formworks used, while on case study No.3, due to the regular reuse of plywood formworks, the probability of making defective work was 4% more.

Case study No.5 and No.6 :(Concrete work for slab)

Case study No.5

The project was in one of the renowned universities in Addis Ababa.

The project has five ongoing buildings for different uses. The case study focused on one of the buildings being constructed for students' laboratory purpose. It's a 3B+G+5 building with a total built up area of 457. 15m^2. Nevertheless, concrete work for slab work associated with 106.06 m^2 was only observed for this study. The company used ready mix concrete, delivered to site by mixing trucks, after then the concrete was placed through trailer pumps (small general pumps). There were 29 workers involved for placing concrete. Among the 29 workers, 9 of them were carrying concrete pipes hoses attached to the end and were placing concrete. Two crew each having 8 and 6 workers were placing concrete using shovel, the rest 6 masons were vibrating and finishing concrete. The summary of each crew member's activity along with waste classification are shown on Table 7.

Table 7: Typical result for entire crew completing concrete work for slab section in % (case 5)

Activity classification	*Waste classification*	*Concrete transporting crew*	*Concrete placing crew 1*	*Concrete placing crew2*	*Concrete vibrating and finishing (mason crew)*
VA	*Value adding*	0.00%	27.35%	37.48%	26.94%
VA Total		**0.00%**	**27.35%**	**37.48%**	**26.94%**
NVAR	*In- process inspection*	0.00%	0.00%	0.00%	4.11%
	Material positioning	17.57%	0.00%	0.00%	0.00%
NVAR Total		**17.57%**	**0.00%**	**0.00%**	**4.11%**
NVA (waste)	*Waiting*	27.94%	65.83%	59.14%	55.37%
	Transport	54.49%	0.00%	0.00%	0.00%
	Extra processing	0.00%	0.00%	0.00%	3.88%
	Motion	0.00%	6.82%	3.38%	9.70%
	Defect	0.00%	0.00%	0.00%	0.00%
NVA Total		**82.43%**	**72.65%**	**62.52%**	**68.95%**
Grand Total		100%	100%	100%	100%

The transporting crew spent 54.49% of the working hours per slab section on unnecessary transportation of concrete by carrying heavy weight concrete pipe hoses attached to the end. Another 17.57% was spent on adjusting concrete placing pipe's position, while the rest

27.94 % was spent on waiting until an empty concrete mixing truck was replaced by another loaded mixing trucks. Concrete placing crew No.1 spent only 27.35% on value adding activities i.e., by placing concrete using shovels while 72.65% was spent on NVA i.e., waiting until concrete was transported to site and until concrete pipe's position was adjusted. The rest 6.82% was spent on unnecessary movement of the workers. On the other hand, the concrete placing crew No.2 spent 37.48% by VA i.e., placing concrete using shovels, while the rest 62.52% was spent on NVA activities such as waiting until concrete was transported to site and until concrete pipe's position was adjusted. The rest 3.38% was spent on unnecessary movement of the workers. The mason crew spent only 26.94% on VA activities i.e., vibrating and finishing concrete, while 55.37% was spent NVA activities such as waiting until concrete was placed by concrete placing crew, and the rest 9.70% was spent on unnecessary movement of the masons.

Case study No.6

The project was a B +G+10 office building for one of the construction companies in Addis Ababa. The total built up area of the building is 552.15 m^2. However, concrete work for a slab associated with 134.52 m^2 was only observed for this study. The company used ready mix concrete and the concrete was placed by a means of power boom (remote pedestal booms). Only 9 workers were involved for placing concrete. Among the 9 workers, 2 of them were placing concrete by adjusting the hose attached to the boom ends with the aid of the remote-control guy, while 2 workers were placing concrete using shovels, and the rest 5 masons were vibrating and finishing concrete. The summary of the entire crews' activities along waste classification are shown on Table 8.

Table 8: Typical result for entire crew completing concrete work for slab section (case 6)

Activity classification	**Waste classification**	**Concrete placing crew No. 1**	**Concrete placing crew No.2**	**Concrete vibrating and finishing (mason crew)**
VA	**Value adding**	64.12%	67.69%	58.10%
VA Total		**64.12%**	**67.69%**	58.10%
NVAR	**In process inspection**	0.00%	0.00%	0.00%
	Material positioning	0.00%	0.00%	0.00%
NVAR Total		**0.00%**	**0.00%**	**0.00%**
NVA (waste)	**Waiting**	35.88%	32.31%	41.90%
NVA Total		**35.88%**	**32.31%**	**41.90%**
Grand Total		**100%**	**100%**	**100%**

Concrete placing crew No.1 spent 64.12% of the working time on VA activities while the rest 35.88% was spent on waiting until the pedestal boom change position and until the empty trucks are replaced by loaded trucks. Concrete placing crew No.2 on the other hand spent 67.69% on VA activities while the rest 32.31% was spent on waiting until the crew1 finish placing concrete. The mason crew spent 58.55% on VA activities by vibrating and finishing concrete while the rest 41.25% was spent on waiting until the concrete placing crew finish placing concrete.

Discussion on concrete work for slab cases (case 5 and case 6)

Concrete work case studies result showed that, methodologies used by case study No.6 acquired less time and number of workers than on case study No.5. On case study No.6 all the 9 workers were adding value to the work process while on case study No.5, among 29 workers only 20 workers were adding value to the work process. On case study No.5 waiting time of the concrete placing crew was twice more than it was on case study No.6, this was due to an interruption of flow in the work process due to various reasons i.e., waiting until vibrators are fixed, waiting until empty mixing trucks are replaced by loaded trucks and waiting until concrete pipes' positions are adjusted. Furthermore, on case study No. 5 significant amount of time was spent by workers, by pointlessly transporting concrete by means of carrying the heavy weight hose attached to concrete pipe ends of the trailer pump. However, on case study No.6, no time was spent on unnecessary transportation (NVA) of concrete by workers, due remote pedestal booms used for placing concrete.

Summary of the discussion

The result of this study pointed out that, the observed construction companies viewed construction site wastes in physical terms only and paid a lot of attention to material wastes generated on site. On the contrary, non-physical wastes which were generated on the construction sites such as waiting time, unnecessary transportation, unnecessary movement and defective works, which are named non-value adding activities by lean construction theory, were not given attention. Among these non-physical wastes, waiting time took significant portion of time; this is due to lack of organization in the work process, late delivery of materials and unnecessary allocation of laborers. Furthermore, in almost all of the case studies conducted, unnecessary transportation of construction materials to site by workers was also very common. Unnecessary movement of the workers like smoking, drinking and chatting with colleagues was also considerably observed in all of the case studies.

CONCLUSIONS

Based on the discussions made earlier, the following conclusions are drawn;

1. In all case studies conducted, working times spent on NVA activities took considerable amount of time. In addition, among the NVA activities, waiting time took the top share; indicating an interruption of flow in work process.
2. On the rebar work cases, the company at case study No.2 saved 8% of the working hours spent on arranging and categorizing reinforcement bars on site, by separating the rebar bending and cutting place from the actual construction site.
3. Waiting time of carpenter crew at case study No. 4 was 12% less as compared to case study No.3, due to readily available modular formworks. In addition, on case study No 4, the probability of making defective works and reworks were almost none, while on case study No. 3 due to continuous reuse of plywood formworks, time spent on rework reached 5%.
4. On the concrete work for slab cases, due to well -planned and organized crew on case study No.6, there was less waiting time and less interruption of flow in the work process. In addition, the company avoided unnecessary transportation (NVA) of concrete, by using remote pedestal booms for placing concrete. This in addition, reduced unnecessary movement of workers. NVAR activates like adjusting and changing concrete pipes position were also avoided due to the same reason.

RECOMMENDATIONS

1. The study strongly believes that, construction companies should take the first steps in understanding non- physical wastes; (overproduction, waiting time, transportation, over-processing, inventories, movement and making defective products) existing on construction sites, in order to maximize value to customers and minimize cost.

2. In order to avoid waiting time in the work process, the flow should carefully be planned starting from inception to completion and any interruption of flow in the work process should be avoided as much as possible.

3. Site layouts and working spaces should as well be planned to reduce wastes arising out of unnecessary transportation and movements of the workers. In addition, unnecessary transportation (NVA) of heavy weight materials like

reinforcement bar and formworks by workers should be reduced as much as possible, by using the available machineries and equipment efficiently.

4.Time spent on NVAR activities like temporary work and supporting activities (formwork) should be minimized by using better technologies (materials and equipment), in addition associated NVA activities like waiting time, defective works and re-works can also be minimized.

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