Labor Waste in Housing Construction Projects: An empirical study

Abstract

Purpose - High-level labor waste is a major challenge in construction projects. This paper aims to identify, quantify and categorize labor waste in the context of Iranian housing construction projects.

Design/methodology/approach – This research uses a case study approach, with empirical data collected through direct observations and semi-structured interviews.

Findings – Having triangulated the findings from the literature review and empirical studies, a list of eight types of waste was derived for the thirteen observed laborers in ten case study projects. The empirical studies allowed the labor waste identified from the literature to be verified and refined by considering it in the context of the observed activities, and led to two new types of waste being identified which were not considered in the literature. Findings indicate that nearly 62% of laborers' time is spent on non-value adding activities. It appeared that 'unnecessary movement', 'waiting' and 'indirect work' make up the highest labor waste.

Research limitations/implications - This research focuses only on onsite resource flows in a housing construction site. It does not include offsite flows such as material delivery to site.

Originality/value - The findings have provided substantial evidence on type and amount of labor waste and provide a solid basis to stimulate construction actors to participate in reducing labor waste and improving productivity.

Keywords: Labor productivity, Labor waste, Waste measurement, Waste identification, Lean construction, Work sampling.

Article Classification: Research paper

Introduction

Construction is one of the largest players and employers in the worldwide economy. The global construction industry reached US$10.6tn in 2018 and is expected to reach US$12.7tn by 2022, with an average annual increase of 4.9 percent (Mike Betts, 2015).The industry makes up nearly 12 percent of the world's gross domestic product (GDP) reported as US$87.5tn in 2018 (Nasirzadeh et al., 2020). It employs between 5 to 11 percent of the workforce in most of countries (Buckley et al., 2016) and it is estimated to consume natural resources nearly 13 percent, equivalent to USD10tn of the global GDP each year (Chia et al., 2018). Despite this significance, the construction industry suffers from a high level of labor waste in comparison with other industries (Goulding and Rahimian, 2012; Tran and Tookey, 2011), and as a result, in some countries, the industry's productivity level is undergoing a weak or negative growth (Hasan et al., 2018).

In the Lean methodology, waste is referred to as anything that consume resources but adds no value to the final product (Womack James P, 1997) and it is often used interchangeably with the term "non-value adding activities" (Buzby et al., 2002). Labor waste is defined as any loss produced by activities carried out by labors; it creates direct or indirect costs but does not add any value to the product from the client point of view (Elghaish et al., 2020a; Formoso et al., 1999). The omnipresence and persistence of waste throughout the construction resource flows renders waste elimination fundamental for productivity improvement (Green and May, 2005; Vrijhoef and Koskela, 2000). It is argued that any improvement in reducing the labor waste can cause noticeable positive economic impacts (Koskenvesa et al., 2010) while continuing with such high level of labor waste leads to sharper rises in construction costs, adverse social implications and declining work for the industry (Ganesan, 1984).

Construction is characterized as a labor-intensive industry. Labor costs account for 30-50 percent of the total cost of projects and the bulk of work is performed manually (Enshassi et al., 2007; Jarkas and Bitar, 2012; Kolo et al., 2014), especially in developing countries (Chaturvedi et al., 2018). Therefore, it is argued that the level of labor waste plays a major role in construction productivity (Ghoddousi et al., 2014; Hamza et al., 2019; Hasan et al., 2018). Labor waste, as an unwanted byproduct, should be identified and made visible so as to be minimized (Denzer et al., 2015). Yet, waste is not easily detectable and is often hidden behind value-adding activities in diverse forms (Shingo, 1988), depending on the type of activities (Denzer et al., 2015).

Amongst construction practitioners, waste is typically conceived as the disposal of materials (Nikakhtar et al., 2015) and non-value adding activities are usually neglected (Koskela, 1992). As a result of this incomplete understanding of the concept of waste, productivity improvement is hardly achievable in the industry (Koskela, 1992). Also, current construction management practices have not been fully able to identify labor waste even though identification of waste is of utmost importance when it comes to productivity improvement (Li et al., 2019).

In particular, a review of the literature reveals that the existing scholarship does not establish a proper insight into the current state of labor waste in the Iranian construction industry and the opportunities for improvement. Given the importance of this industry for the Iranian economy, more accurate insight should be provided into labor waste identification and categorization, its impact on labor productivity (Achell and Bonet, 2013; Alwi et al., 2002a; Denzer et al., 2015; Formoso et al., 2015; Formoso et al., 2011), and on potential improvement efforts (Hajikazemi et al., 2017).

The aim of the research reported in this paper is to estimate the amount of labor waste in Iranian construction projects. The paper is structured as follows. First, the treatment of labor waste in the literature is discussed and the research gap identified. The research method adopted to collate and analyze data is described. The labor waste identified during the empirical studies is presented. The findings and contributions to knowledge are discussed. Finally, conclusions drawn from the research and areas for further research are presented.

Contextual Background

Labor waste in construction

Ramaswamy and Kalidindi (2009) define the Value-Added Activities as the main activities to transform raw materials to final product, meanwhile, the Non-added Value activities do not contribute directly to the transformation of raw materials to a final product and should be eliminated to reduce the waste (Javed et al., 2018). However, these 'non-added value activities are significantly important to support the implementation of value-added activities and sustain relationships among team members (Brooks et al., 2020).The Necessary waste can be identified as which are activities that may be wasteful, but critical and important to implement the operation (Arleroth and Kristensson, 2011).

Waste emerges in varying forms in different industries (Denzer et al., 2015). In construction, a proportion of waste is linked to this industry's high degree of complexity (Bølviken and Koskela, 2016; Elghaish and Abrishami, 2020; Rahimian et al., 2008), which makes it difficult to re-define and identify wastes in projects (Koskela et al., 2013). Waste in construction can differ from that identified in classical, standardized lists (Koskela et al., 2013), and therefore, waste defined for construction should fit the peculiar nature of this industry (Elghaish et al., 2020b; Koskela et al., 2013).

Eliminating or reducing the labor waste can lead to a significant improvement in productivity (Nikakhtar et al., 2015). Previous research show that activities in a production system can be divided into three generic categories, namely Value-Adding (VA), Non-Value-Adding (NVA) and Necessary Waste (NW) (Monden, 2011). VA activities have direct contribution to the final product whereas NVA activities (i.e. pure waste) are those unnecessary activities that consume resources but do not add any value to the final product (Shou et al., 2020). The NW category encompasses wasteful activities that pass no value to the end customer but they are necessary to enable value production (Denzer et al., 2015; Hines and Rich, 1997).

Many studies have studied the different factors of labor waste in developing countries such as Satchi and Temple (2009) which state that the productivity of labor in informal markets in developing countries is different from formal and institutional markets since their labors have substantial bargaining power. Enshassi et al. (2007) listed 45 factors that affect the labor productivity, these major factors are material shortage, lack of labor experience, lack of labor surveillance, misunderstandings between labor and superintendent, and drawings and specification alteration during execution. In addition, Hiyassat et al. (2016) studied the productivity drivers in Jordan and results indicate that the distrust between labor and management staff reduces the labor productivity. A similar study was conducted in Yemen by Alaghbari et al. (2019), the findings show that the lack of labor skills and misleading site leadership are substantial factors of labor waste in Yemen. Another study was conducted in Egypt confirms that competency of labor supervision, labor experience and skills and incentive programs are the main factors to improve labor productivity and minimize labor waste (El-Gohary and Aziz, 2014).

Table 1 summarizes the findings about the share of NVA activities and NW identified in previous studies.

Table 1. Share of waste in construction activities based on findings in previous studies.

Country of study	Type of work	Necessary Waste	Non-Value Adding Activities	Total Waste	Reference
Canada	Installation of drainage pipes	-	68%	68%	(Agbulos and AbouRizk, 2003)
Sweden	Housing construction	45%	35%	80%	(Strandberg and Josephson, 2005)
-	-	33%	27%	60%	(Orth et al., 2006)
-	Bricklayers, plasters, concrete-workers, painters and roof joiners	14%	33%	47%	(Alinaitwe et al., 2006)
India	Building construction	-	-	57%	(Ramaswamy and Kalidindi, 2009)
Scandinavia	Plumbing	50%	35%	85%	(Josephson and Björkman, 2013)
Norway	Electrical installation	28.10%	10.60%	38.70%	(Hajikazemi et al., 2017)

There are seven types of waste in the classic categorization. The list of categories includes defects, overproduction, inventory, over-processing, motions, transport and waiting (Ohno and Bodek, 2019). Arguably, this classification is perceived to be insufficient to deal with the full range of wastes presented in industries (Sutrisno et al., 2018). In the construction industry, Koskela (1992) identifies moving, waiting, and inspection as activities that must be minimized. Garas et al. (2001) group construction wastes into two fundamental components, namely time waste and material waste. Time waste includes waiting periods, stoppages, variation in information, rework, ineffective work, the interaction between various specialists and delays in planning activities; material waste includes over-ordering, over-production, wrong handling, improper storage, manufacturing defects, and theft or vandalism. Alwi et al. (2002b) describe the main categories of waste during construction as reworks/repairs, defects, material waste, delays, waiting, poor material allocation and unnecessary material handling. In another study, Koskela (2004) suggests 'Making-Do' as the eighth type of waste in construction. Making Do accounts for instances when an activity starts without having its standard prerequisites (e.g., materials, machinery, tools, personnel and external instructions) in place. Later, Senaratne and Wijesiri (2008) identify materials, delays, rework and defects as the common types of waste in construction. Table 2 summarizes the eight types of waste according to Lean methodology (Liker, 2004).

Table 2. Eight types of waste in the Lean methodology

Type of Waste	Description
Waiting	Laborers sometimes have to wait due to reasons such as equipment downtimes, stock-outs, unavailability of tools, supply chain interruptions, capacity bottlenecks, inspections, lack of instructions, avoidance of congestion in certain areas etc. In these situations, they usually stay idle until the problem is resolved.
Unnecessary movement	Any unnecessary motion by laborers during the course of their work, such as looking for or moving materials, parts and tools, unnecessary walking to find colleagues or inventory, and moving

	to unload the arrived materials.
Defects	Production of defective parts that do not meet the requirements including codes, specifications and/ or planned quality. It stems from multiple reasons such as inexperienced workforce, defective inventory, insufficient instructions, and deficient design.
Excess inventory	Excess finished goods and raw materials require longer lead time for unloading, storage, stock keeping, etc., and they increase defects as a result of improper storage which in turn, causes extra labor for taking correction actions such waste removals.
Unnecessary transport	Work which unnecessarily requires long distance transportation of materials
Overproduction	Producing goods and products that there are no orders for them
Over-processing	Carrying out unneeded measures to process the parts
Making-do	Starting an activity starts without having its standard prerequisites in place

Work sampling is the most commonly used method to measure labor waste through measurement of VA activities, NVA activities and NW at the individual or task level (Hajikazemi et al., 2017; Moohialdin et al., 2019). The method includes a series of instantaneous random observations of activities by collecting data at different intervals (Moohialdin et al., 2019; Robinson, 2010; Talebi et al., 2020). It is used to collate empirical data to understand how labor time is spent on different activities (Robinson, 2010), assess or improve productivity (Da Rocha et al., 2018; Hajikazemi et al., 2017; Mwanza and Mbohwa, 2016), identify improvement opportunities for productivity (Chang et al., 2015), and minimize waste (Hajikazemi et al., 2017). In construction, work sampling is a series of random and consecutive observations (Haugbølle et al., 2019). This method can be conducted by researchers with the knowledge of both construction and work sampling. However, it is better performed by an independent party to minimize the potential bias of in-house staff (Hwang and Lee, 2017). Work sampling is used in this study because the results of this method are applicable for measuring labor waste and investigate means to improve productivity.

Of note is that there are multiple definitions for productivity in the literature. In production, it is defined as the effective management of the facilities, especially in terms of labor and equipment (Chia et al., 2018; Miron et al., 2016; Mwanza and Mbohwa, 2016). In construction, the concept of productivity can be referred to as working hours required to accomplish a given unit of work (i.e. the amount of work performed by one labor per hour) (Al-Kofahi et al., 2020). Conventionally, organizations aim at maximizing the value-adding activities to improve their productivity. However, Lean Construction has changed the perception about productivity and suggests that it can be improved by minimizing the share of labor waste, also known as NVA activities (Buzby et al., 2002). This is the view adopted in this study, the ultimate goal of which is to identify, categorize and quantify NVA carried out by laborers to improve productivity.

Labor waste studies in Iran and gap in knowledge

Liker (2004) argues that tackling a problem by finding workable and suitable solutions first needs its characterestics to be identified. More specifically, developing a solution to minimize labor waste and improve productivity requires the identification, quantification and elimination of waste. Nevertheless, very little literature exists with the main focus on thoroughly collating labor waste in Iranian housing construction sites. A review of literature reveals that the definition of labor waste remain vague as most of the existing literature merely presents the participants' perceptions rather than identifying and quantifying labor waste through rich empirical data (Ghoddousi et al., 2014; Ghoddousi and Hosseini, 2012; Ghoddousi et al., 2015;

Miron et al., 2016; Nikmehr et al., 2017; Rad and Kim, 2018; Zakeri et al., 1996). None of the previous studies provides a quantitative measure of labor waste although this information is necessary in order to understand the magnitude of such challenge.

Research Design

The exploratory case study approach has been adopted for this research. This approach is used when exploring, describing and explaining a contemporary phenomenon within a real-world context, and achieving an in-depth understanding of real-world events (Sheikhkhoshkar et al., 2019; Yin, 2013). The purpose of the exploratory case study is not to only describe a phenomenon but also to explore underlying reasons as to how and why certain events occur within a real-world context (Eisenhardt, 1989; Seyedzadeh et al., 2017). The exploratory case study has been adopted for this study as it aims to answer 'how' and 'why' labor waste is occurred on housing construction sites. This exploratory research identifies the relationship between theory and construction project management practice, in order to inform practitioners and researchers.

Surveys are a common research method to identify reasons behind the occurrence of an event (Knight and Ruddock, 2009). However, using surveys does not necessarily lead to new understanding or in-depth verification of the reasons identified in the present literature (Rosenfeld, 2014; Ye et al., 2015). The case study approach in this research facilitates the collection of data in the context for which labor waste is experienced. In this research, literature is reviewed to gain a general understanding of labor waste. The empirical data is then collected from construction projects through direct observations on site and semi-structured interviews.

Rational for case selection

Appropriate case selection requires the selection of cases that are 'most likely' to satisfy the research aim (Brinkman, 2013). Purposive sampling was used to select cases and interview participants. Purposive sampling promotes the importance of conscious decision-making and is adopted when a small sample exists which must be informative (Saunders et al., 2016). Ten medium-sized housing construction sites in Tehran-Iran took part in the research with project footprints between 200 and 500 square meters. More than seventy hours of observations were conducted. Observations continued until data saturation was achieved, i.e., no new labor waste were found in the final stage of the observations. This implies that the selected cases were informative, and the adoption of purposive sampling ensured the selection of appropriate cases.

Data collection and analysis

Direct (non-participant) observation (O'leary, 2004) was conducted at the selected sites. During the observations, a detailed time-motion study using the work sampling method was adopted. Work sampling helped explore the various types of labor waste encountered on housing construction sites and also quantify the time that laborers spend on VA activities, NVA activities and NW. The observation period was two months, in which thirteen laborers performing seven different activities were observed. Construction activities during work sampling were classified into the three categories of VA activities, NVA activities, and NW. For example, laying bricks, applying plaster over drywall, and installing electrical wiring are constructive and classified as VA activities. All types of identified NW were categorized as "indirect work". Indirect works (e.g. inspection, measurement, unpacking materials) are needed to move the work forward but add no value to the end product. A decimal minute-stopwatch was used to record the time taken to perform each task with high level of accuracy. The name of activities and associated time were then recorded in data protocol form. An example of a filled data protocol is presented in Table 3. The careful approach taken during the observations ensured the accuracy of the data collected. The authors who collected the data attempted to carefully distance themselves from the participants on site and only engage in a small talk before the workday. This was due to (1) social distancing requirements, (2) the need to reduce the negative effect of laborers trying to produce more desirable results, and (3) the need to avoid causing anxiety to the laborers.

Table 3. An example of a completed data protocol for a plumber.

Observation 1 (Plumber)			
General Category	**Observed Actions**	**Time**	**Percentage**
Value-adding activities (VA)	Plumbing	2:57:17	51.03%
Necessary Waste (NW)	Measuring	0:29:17	8.43%
	Preparation	0:12:59	3.74%
	Inspection	0:05:13	1.50%
Non-value Adding activities (NVA)	Walk to material and tools	0:06:18	1.81%
	Looking materials and tools	0:14:52	4.28%
	Moving materials and tools	0:08:34	2.47%
	Handling materials and tools	0:42:18	12.18%
	Small talk	0:07:30	2.16%
	Unpermitted break	0:11:34	3.33%
	Sanitizing hands and cleaning up equipment	0:08:17	2.38%
	Waiting for other colleagues to avoid congestion	0:05:55	1.70%
	Problem-solving discussions	0:17:20	4.99%

Nine semi-structured interviews were then conducted to attain opinions of practitioners in the industry (Brinkman, 2013; Talebi, 2019) on the type of waste existing in construction activities in Iran. The interviewees were from high profile Iranian construction companies or universities. The interviewees were (1) three site engineers (Interviewees 1-3), (2) three project managers

(Interviewee 4-6), and (3) three construction academics (Interviews 7-9). The selection of the interviewees was on the basis of their expertise, willingness to participate and availability. Moreover, X interviewees were involved in one of the selected projects, that is, they were knowledgeable of the context of housing construction projects. The interview questions centered on seeking to understand the perception of labor waste on housing construction sites and how to identify it. Interviews were carried out face-to-face and took around 40 minutes each. The interviews were recorded, transcribed and translated to English. Content analysis was applied to the interview transcripts in order to identify the characteristics of labor waste. More specifically, content analysis was used to find the foremost facets of the data by interpreting the interview transcripts instead of simply referring to the number of times a topic is indicated (Fellows and Liu, 2015). Verbatim comments were included in quotations to better communicate the 'lived experience' of participants. Those quotations are modified for readability, without altering the meaning. Consolidating the findings from the literature, interviews and observations resulted in the identification of six different type of labor waste in housing construction sites.

Findings from the work-sampling observations

Table 4 and Figure 1 provide a summary of findings from the work sampling. It appears that results vary remarkably between laborers and between different types of construction activities. The percentage of VA activities varies between 16% and 58% whereas NVA activities range from 33% to 71%. NW was between 3% and 32%. The findings demonstrate that on average nearly 38% of the labors' time on sites is devoted to VA activities while 47% of the time is NVA activities. Moreover, NW accounts for 15% that needs to be minimized. Overall, it appeared that nearly 62% of the labor time is perceived to be waste.

Table 4. Summary of findings from the work sampling carried out for 13 laborers.

Labor No.	Value Adding Activities		Non-Value Adding Activities		Necessary Waste		Total	
	Duration **(h:m:s)**	%	Duration **(h:m:s)**	%	Duration **(h:m:s)**	%	Duration **(h:m:s)**	%
1	02:57:17	51	02:02:38	35	00:47:29	14	05:47:24	100
2	01:38:18	27	04:10:08	70	00:10:35	3	05:59:01	100
3	01:35:13	32	02:54:22	59	12:25:12	9	04:54:50	100
4	00:30:12	19	01:10:21	43	01:10:31	38	02:42:04	100
5	03:07:47	58	01:38:56	30	00:40:10	12	05:26:53	100
6	02:16:43	39	01:57:57	33	01:38:02	28	05:52:42	100
7	00:56:52	20	03:17:52	70	00:26:16	10	04:41:00	100
8	00:58:47	50	00:47:56	42	00:09:37	8	01:56:20	100
9	05:25:33	58	03:02:15	32	00:56:53	10	09:24:41	100
10	00:18:14	16	01:22:46	70	00:15:47	14	01:56:47	100
11	00:36:32	18	01:46:37	52	01:00:46	30	03:23:55	100
12	05:12:29	58	03:02:36	34	00:39:42	8	08:54:47	100
13	01:53:01	54	01:08:06	32	00:30:09	14	03:31:16	100

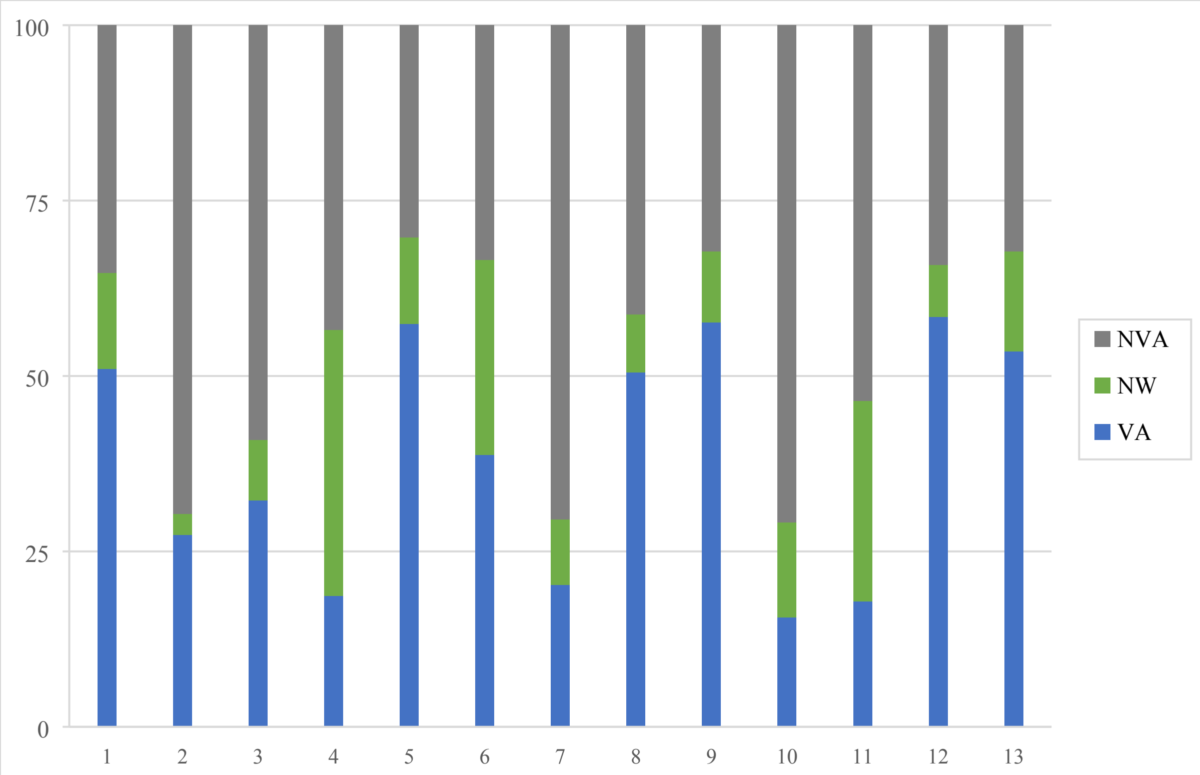

Figure 1. Share of Value-adding, Necessary Waste and Non-Value-adding activities in the collected data.

Findings from interviews

All participants in interviews believe labor waste largely exists throughout construction activities and causes cost overrun and schedule slippage. It was stressed that "there is always waste but it is very difficult to capture all of it" (Interviewee 3). "Several approaches work to reduce waste" and the issue that "some workers are on piece-work contracts" complicates the identification of waste (Interviewees 7). Furthermore, "no clear definition of waste exists and it is not sometimes easy to distinguish value adding activities from waste" (Interviewee 2). For instance, walking around the site can be considered as waste whereas sometimes it is necessary (Interviewee 5). It was pointed out that "the level of education and experience of crews play an important role" (Interview 8) and "it is easier to recognize the labor waste for a trained or experienced person" (Interviewee 9).

It appears that all interviewees consider waste mainly as the visible material wastage. The interviewees mostly indicated the issues causing labor waste (e.g. poor communication, weather condition) rather than identifying the types of labor waste incurred on site.

However, certain types of labor wastes were identified during the interviewees. A summary of the type of labor waste noted by each corresponding interviewee is found in Table 5.

Table 5. Labor waste identified during the interviews

Stated Labor Waste	**Corresponding Interviewees**
Waiting on colleague or material, Changeover time	1, 3, 4, 6
Excess inventory	1, 7
Lack of labor responsibility and motivation	2, 5
Unnecessary movement of people and material, Searching for colleague or material	3, 7
Damaged, lost, defected, or stolen inventory	7, 9

Results and Discussion

An in depth review of literature revealed a number of limitations of previous studies focusing on labor waste. Appreciation of these limitations, gained from the in-depth literature review should be considered as a contribution to theory. These limitations have obscured the labor waste somewhat, and more thorough study are needed prior to any attempt to develop solutions for reducing labor waste. To tackle the identified shortcomings, the case study approach was adopted, and quantitative data was collected using the work sampling method. Moreover, a list of labor waste for housing construction sites in Iran was created based on the findings from the literature and empirical studies.

It appears that the definition of labor waste is still vague in literature and among practitioners alike. Most of the existing literature is based on subjective views rather than empirical and quantitative data. In this study, VA activities, NVA activities and NW were identified during observations in ten case projects. Labor waste was then explored during nine semi-structured interviews with academics and practitioners who commonly deal with it. Therefore, this study contributes to existing theory by creating a better understanding of the characteristics of labor waste through rich empirical data.

The findings from the interviews and observations helped refine and verify the types of labor waste identified from the literature by contextualizing it by means of observed activities on construction sites. Two additional types of labor waste are proposed as a result. In this study, labor waste on housing construction sites is divided into seven categories, namely: (1) interrupted break or absenteeism, (2) indirect work, (3) waiting, (4) unnecessary movement, (5) defects, (6) excess inventory and (7) Making-Do. More specifically, 'unnecessary transport', 'over processing' and 'overproduction' are waste categories from the Lean Construction debates that were excluded from the final list as they were not observed in this study. It appeared that the work sampling method adopted in this study is unable to identify and quantity the Making-Do waste although it is evident that this type of waste is present.

'Interrupted break or absenteeism' and 'indirect work' have been proposed in this study as they stood out during observations. 'Interrupted break or absenteeism' is about taking rest breaks (e.g. lunch breaks) longer than entitled, or interrupting the workflow for personal reasons (e.g. unnecessary chatting with colleagues and private telephone calls). 'Indirect work' includes activities that are necessary for VA activities. While indirect works expend labor, time, and cost, they add no value to the final product (Elghaish and Abrishami, 2020; Talebi, 2014). Yet, while they are regarded as waste in the production system, they cannot be completely eliminated, and their absence leads to time lags or delays. Preparation of site, tools, materials and equipment, inspections and measurements, sanitizing and cleaning up tools, tidying up site, and unpacking materials are some examples of this type of waste.

The results demonstrate that on average 38% of the labors' time on housing construction sites is devoted to VA activities, whereas NVA activities consist of 47% of their time and NW accounts for 15%. Overall, nearly 62% of labors' time is waste underlying the need to take actions and reduce the labor waste. The quantitative measure of labor waste on housing construction sites is a contribution to both theory and practice.

Understanding what iss the most prevalent labor waste is a contribution to knowledge as it will help researchers and practitioners t prioritze when trying to tackle labor waste. Moreover, this research has adopted accurate time studies and used a clearer framework to classify construction activities (i.e. VA, NVA, NW), which differentiates this research from previous research.

8-Conclusion

The construction industry is criticized for high levels of labor waste and low productivity. The aim of this research was to identify, quantify and categorize labor waste in Iranian housing construction projects. A case study approach was adopted which used empirical collected data through semi-structured interviews and direct observations in ten case projects. Direct observations were used to identify and quantify labor waste. Semi-structured interviews were used to collect data from which the experience of practitioners and academics about labor waste could be captured.

The study confirmed that the eight types of waste discussed in the Lean Construction literature have a practical basis. Findings from the literature were combined with empirical studies to propose a list of seven types of waste for housing construction projects in Iran, namely: (1) interrupted break or absenteeism, (2) indirect work, (3) waiting, (4) unnecessary movement, (5) defects, (6) excess inventory and (7) Making-Do. Two types of waste not included in the prior body of knowledge in Lean were found, namely interrupted break or absenteeism and indirect work. The list is expected to give an insight into reasons behind the labor waste and low productivity across the industry.

During the interviews and review of extant literature, it was found that there is no clear definition of labor waste in the context of this research for house building sites,

By means of work sampling during observations, it was revealed that nearly 38% of the laborers' time on housing construction sites is spent on value adding activities, with 46% on non-value adding activities and 15% on necessary waste. This represents a significant amount of waste and suggests that around 62% of a laborer's time is devoted to waste while only 38% of time is spent on activities that add value from the point of view of the end customer. It appeared that 'unnecessary movement', 'waiting' and 'indirect work' make up the highest labor waste. The findings provide substantial evidence on the amounts of labor waste and provide a solid basis to stimulate construction actors to participate in reducing labor waste and improving productivity in the sector.

This study has three key limitations. Firstly, the empirical studies revolve around housing construction sites and future research may find more types of waste applicable to other types of construction projects. Secondly, this study was conducted in the Iran and may be affected by the particular characteristics of the housing construction there. These two limitations are partially mitigated as a result of reviewing the literature on labor waste in various types of construction projects conducted in different countries. Thirdly, the work sampling method is not capable of recognizing and quantifying labor wastes that are related to the process and human aspects such as Making-Do. Future research is needed to undertake additional studies into labor waste using technologies such as Radio Frequency Identification (RFID) linked into the Building Information Modelling (BIM).

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