WORK-TIME WASTE IN CONSTRUCTION

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ABSTRACT

Purpose: To develop a method for measuring time waste in construction. A second aim is to quantify the wasted time, as it is assumed that some of the figures in the existing literature might be exaggerated for political purposes.

Research method: Theoretically informed case study and literature review.

Research findings: According to the “boss method” developed for this study, 5% of working time was classified as waste, whereas a more limited and detailed study identified waste as amounting to 17% of working time. However, if “personal time” is taken out of the equation, the detailed study shows 7% waste. Clearly, the more subdivided the data, the greater the amount of uncovered waste. The detailed study also shows that directly value-adding work amounted to 49% of the working time, and that supportive work amounted to up to 34%. The analysis based on the primary data is compared to a Swedish and an American study, whose figures for waste as a proportion of the working time are considerably higher. The figures for directly value-adding work are also radically lower in both of these studies. Some of the differences can obviously be ascribed to the type of work involved in the studies, and the applied methods of measurement. Comparisons to another Norwegian study as well as a Finnish one showed fairly good correspondence in terms of the uncovered proportion of directly value-adding work.

The main contribution of this paper: Contributes to the conceptualisation of time waste and gives empirical examples of waste.

KEY WORDS

Lean Construction, Waste, Work-time waste

INTRODUCTION

The elimination of waste is a core focus of lean production and construction; see for example Koskela (2000). Seven types of waste figure in the lean literature, namely overproduction, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting, and unnecessary motion. “Making-do” has later been added as an eighth type of waste (Koskela 2004). “Making-do” means that a construction task is started without all its standard inputs – such as materials, machinery, tools, personnel and external instructions – being in place. “Making-do” is conceived as the opposite of buffering, but both are responses to variability in production. In “making-do” tasks are started too early to maintain a high utilization rate or to avoid schedule slippage.

How can time be fitted into these classical Toyota categories? Overproduction, often in the shape of large batches, increases the throughput time. The category of unnecessary inventory covers the extra handling associated with relatively large

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batches. When defects occur, the production has to be repeated. In addition, the production process is destabilised in ways that can be measured in the shape of extra time. The extra handling required by unnecessary inventory can be measured as time in addition to other waste aspects. Inappropriate processing, understood as inadequate processes and procedures, is expected to be more time-consuming than processing which involves clear and well-understood production procedures. Excessive transportation, waiting and unnecessary motion all contain obvious aspects that can be measured in terms of time.

In terms of relating the categories of waste to production in construction, overproduction may be the most problematic one of the seven, since for the most part on-site production in construction is not a matter of serial production. Diekmann et al. (2004, 62) interpret overproduction as a category of waste that is relevant to construction in the following manner: "*Overbuilding a particular aspect of a project, either because it was over-engineered or a process was started before it was really needed"*. The latter aspect of this understanding seems to overlap with "making-do", whereas the over-engineering of structural design, for example, is a familiar problem within the construction industry. However, this phenomenon can also be classified as belonging to the waste category of "over processing".

What do we know about waste in building production, and perhaps particularly about time waste? This author was prompted by a series of more or less well-documented claims, often occurring in a context designed to motivate the audience/readers to accept that something needs to be done about the construction industry.

Time-waste in construction projects can be studied on various levels. In this paper the focus is on time-waste as it manifests itself among those who carry out the production at building sites, namely the skilled workers of the different trades. Underlying this study is a proposition that the estimates regarding wasted time and low productivity in the construction industry are often exaggerated and used politically to create the impression of a crisis in an attempt to convince people in the industry as well as the authorities responsible for allocating funds that something must be done – such as introducing lean construction. The objective of research, in contrast, should be to uncover facts without considering any potential agenda. The research question of this paper is, then: *How do we measure work-time waste at the production level in the construction industry?*

The method applied is a case study supplied by relevant literature. The case is Havlimyra oppvekstsenter, located in a district of Kristiansand municipality. The property developer, Skanska Agder, is responsible for a project that involves a total of 6800 square metres. This includes a nursery school/kindergarten, a school, and a unit earmarked for cultural purposes including a multi-purpose hall. The project represents a turnover of 140 million Norwegian kroner for the main contractor. Construction began in the autumn of 2008, and the completed project will be handed over to the owner in June 2010. The case has been a pilot project for the introduction of Last Planner (Kalsaas et al. 2009; 2010). A more detailed description of the method developed will be given below.

The following chapters contain a review of the literature on lost time. Next, two primary studies on lost time are presented and analysed. Finally, a conclusion is proposed in relation to the research question.

TIME WASTE IN LITERATURE

In a Swedish study Josephson and Saukkoriipi (2005) study the construction workers' use of their work time. Their example is from construction of housing and involved a trained observer following a group of construction workers for 22 days. The work time was divided into 1) directly value-adding work, 2) preparations, and 3) pure waste. The conclusion of their study was that directly value-adding work constituted less than 17.5% of the work time, while preparations constituted 45.4%, and waste 33.4%. The category of preparations covers the sub-categories of indirect work (all preparation within a few metres from the workplace, accounted for 25%), handling of materials (14%), and planning (6%). At 23%, waiting constituted the greatest share of the waste. The study also looked at the engineers and architects time use. One of the findings was that slightly less than 30% of the time was used for direct work

Skanska Norway uses a frequency method[2] to perform what the company calls productivity measurements (Thune-Holm and Johansen 2006), whose results show the construction site time-use of the company's own workers (skilled concrete workers and carpenters). The main categories are: 1) productive time, 2) indirect time, 3) change-over time, and 4) personal time. In short, the method uses a standardised form with a coarse WBS on one of the axes and work categories within the four mentioned main categories along the other. The observer or observers, who tend to spend a week or so on a project, pick 3-5 random registration points per hour. At these points the observers registers what each worker is doing according to the categories on the form. When the period of registration is over, the observations for each activity are added together, and percentages are worked out for the different activities. The productively used time among carpenters on four different construction projects was measured (ibid.) to be 59.4, 70.7, 70.2 and 50.7%. The two measurements of concrete workers' work time use quoted in the report gave the figures of 65.1 and 69.5% productively used time. No measuring is conducted during meal breaks. The authors point out that the method does not uncover anything about *how* the work is conducted. Furthermore, no distinction is made between productive and counter-productive work (rework). This contributes to the methodological difficulty of comparing different projects with one another. The measurements are primarily used by Skanska as part of a collaborative project with the company's in-house workers aimed at reducing indirect time.

Table 1: Value adding work, percentages (Diekmann et al. 2004)

Steel erection job	VA	NVA (Waiting)	NVAR
Project 1	32	60 (34)	9
Project 2	11	57 (24)	35
Project 3	10	67 (46)	24

Diekmann et al. (2004) provide a detailed focus on work-time use in a series of case studies. Among these are three studies of structural steel erection jobs. The method applied maps the work time of individual members of each crew. Each job has one or

[2] The National Institute of Technology, Norway, (Teknologisk institutt) provided Skanska with training in applying the method.

several crews. The main categories used are “value adding” (VA), “non-value adding but required” (NVAR), and “pure non-value adding” (NVA). This terminology is taken from value stream analysis; see for example Rother and Shook (1999). Table 1 shows some results from the three steel erection job studies. The shown results are weighted crew averages.

TIME WASTE AS INDICATED BY WORK TIME

The data was collected in March-December 2009 at the construction site for the Havlimyra oppvekstsenter project, a project already presented in the introduction.

THEORETICAL FRAMEWORK

Wasted time is understood as the time that is perceived by the skilled workers as useless, or as a wastes use of time. The concept is an attempt to quantify the difference between the situation when the worker has a perception of the work going well, and situations where he feels that “we didn’t get much done today”. The way skilled workers use their work time is also particularly interesting since it can be seen as a reflection of the project organization, production management and production planning function.

The time waste concept resembles technical time waste from the manufacturing industry, which is the time that is wasted due to waiting, poor equipment or other shortcomings over which the skilled worker has no control, affecting the effective production time. So-called personal time-waste is not included, however. This is the time it takes for the worker to meet his vital personal needs. Wasted time is conceptualised as originating from two main sources: 1) unnecessary fragmentation of the work, and 2) faulty execution.

Every time a worker is unable to finish a piece of work in a logical and natural manner, he has to return later to complete the job. Such fragmentation means that extra time is spent on motion and on rigging up and down. This may involve the moving and setting up of tools, fetching and moving of materials, having to study drawings again, etc. Such changes of workplace on the same project can be likened to “change-over time” and “set-up time” in manufacturing, and when the number of changes increases, so does the time-use. This has to do with economies of scale, as a minimising of such changes allows the workers to concentrate more consistently on similar tasks and thus to achieve advantages of scale. Too many changes of tasks also result from the phenomenon of “making-do”, which means that tasks are started without all the standard inputs – such as materials, machinery, tools, personnel, and external instructions – being in place.

Time for planning is understood as a condition for productive work and is registered separately. Underlying the focus on wasted time is an assumption that if the amount of wasted time is reduced, the costs are also reduced, and thus the productivity increases; see for example Suri’s (1998) elaboration on this line of reasoning in relation to lead times in production in general.

The following factors are included in the first category of waste: faulty work by others, unavailable workplace, missing drawings, missing materials and equipment, erroneous or missing information from management, and other. The point is to try to register the extra time-use resulting from changing of tasks due to the mentioned causes. In contrast, the second category seeks to capture extra time-use directly caused by errors, lack of coordination and insufficient drawings. A distinction is made between errors made by one's own team as opposed to errors picked up after others. Lack of coordination may mean that order in which the work is conducted is impractical, thus leading to additional work and extra time-use.

METHOD (THE BOSS METHOD)

The participants in the study were skilled concrete workers, carpenters (several crews), tinsmiths/ventilation fitters, electricians, plumbers, and painters. The method was called the boss method to describe the level of detailing in the collected data.

The data was collected on a weekly basis by the boss of each team. Each boss discussed wasted time with the other members of his team. In terms of the main contractor, the time tickets were used as a support in the data collection related to the firm's own workers (carpenters and concrete workers). In addition, there has been good and continuous contact between the bosses and this writer about the interpretation of what constitutes wasted time, and the classification of the different types of wasted time. These discussions have prompted many technical discussions that have helped in the process of learning how to identify the time that is wasted, not least as a result of fragmented work. Or as put by a carpentry boss: "*we are always busy working, we always find something to do, we never just wait around*". But such busy-ness, which we can identify as "making-do", may hide a great deal of wasted time spent rigging up and down, moving around, planning, solving problems, and so on – as confirmed through conversations with the stakeholders.

The contact with the bosses about wasted time was maintained by one person, and the same person transferred the registered data to a computer program. When receiving the data, this writer often asked questions about interpretations and causes, and in some cases wasted time was reclassified in order to achieve the best possible uniformity. After a few weeks' experience, some adjustments were made to the data form, which was expanded and pedagogically improved.

The collection of time-waste data has generated a great deal of engagement and involvement. The workers on piecework contracts have an interest in performing their tasks with the greatest possible continuity in order to achieve economies of scale in their work, which means a situation where the time-waste is minimised as much as possible. However, interest for this project was also shown among those who are paid on an hourly basis. When invitations were extended to participate in the Lean project, the electricity contractor's project manager said: "*this is something we want to take part in; it goes straight to the bottom line*".

FINDINGS

The data cover almost 30,000 man-hours, distributed between concrete work (25.7%), ventilation (5.8%), electrical work (10.5%), plumbing (12.9%), and carpentry (45.1%). Table 2 sums up the aggregated findings.

Table 2: Aggregated results, wasted time as % of working time

Time for planning	Time waste	Time waste due to work fragmentation	Performance-related time waste
4.6	4.7	3.2	1.5

Table 2 shows that the amount of time perceived as wasted by the skilled workers constitutes 4.7% of the total time for all of the involved trades taken together, of which 3.2% can be ascribed to fragmentation of the work and 1.5% to performance. 4.6% of the total work time is spent on planning. Progress meetings, which are an important arena for mutual coordination, represent most of this time-use. The large "remaining time" category of 90.6% cannot be analysed with the data from the boss method, and will be discussed further below.

The findings show that there are some differences between the trades, and that the electricity subcontractor has a noticeably lower proportion of wasted time than the other trades. Furthermore, the time waste due to fragmentation of the work is relatively large in the carpentry trade, whereas a relatively high proportion of the plumbing subcontractor's time-wasted is caused by errors.

The largest single cause of fragmented work registered is lack of materials and equipment. Carpenters in particular report this problem. They also have relatively large problems with the workplace being unavailable. Concrete workers have the greatest proportion of wasted time caused by errors made by others.

The data shows that the ventilation subcontractor had to deal with the challenge of inadequate and missing drawings. This finding corresponds with other observations. Another obvious finding is the amount of time spent by the plumbing subcontractor correcting errors, both their own and those made by others. Often, the time it takes to correct other people's errors can be added to the bill. Concrete workers also lose some time because of their own mistakes, and the electricians from the electrical subcontractor lose time because of mistakes made by others.

VALIDITY AND RELIABILITY

The cause of time-waste is the cause as perceived by the worker, whereas the root cause may be a different matter. Furthermore, for the most part the measuring method fails to capture the fact the design and project planning may lead to a construction method that is less than optimal. What is measured is wasted time given these paramount conditions, meaning that differences in time-use due to differences in project planning and design do not emerge. Neither does it emerge whether the workers have chosen smart solutions to their work within the existing framework conditions or not. However, we expect the influence of planning processes and management to emerge, as the registration model covers such factors as errors on the drawings and inadequate coordination.

The registrations of the boss study capture first and foremost wasted time that can be related to lack of flow in the work caused by unnecessary fragmentation of the tasks, and by work having to be redone for various reasons; cf. the discussion on "flow" in Kalsaas and Bølviken (2010). This means that waste in the shape of what Josephson and Saukkoriipi (2005) call "unutilised time" (personal needs, non-work related discussions, late arrival, early departure, extended breaks) is not included. Covering such categories of time-waste requires a more detailed method of measurement like the more micro-oriented analysis below. The category "waiting and interruptions" (ibid.) does not cover "non-work" caused by information or coordination errors (lack of materials, faulty equipment or lack of equipment, lack of tasks), waiting for someone else, waiting without any obvious reason, and re-location (motion between different tasks). These are categories that are for the most part covered by the boss method, albeit with the exception of waiting in the order of 5-10 minutes. Waiting is discussed in greater detail later. With regard to the time included in the category of meetings and planning, this primarily concerns the bosses's time-use on meetings and administration. The time spent discussing and studying drawings on the construction site cannot be captured with the data resolution used here.

Given these limitations we consider the concept validity to be reasonably good. Furthermore, we assume that the external validity is such that to a certain degree, the results can be generalised and applied to other construction projects of similar size and complexity, especially within the same culture (Norway). With increasing skills at using Last Planner and greater familiarity with the form of cooperation it involves, a reduction can be expected in the amount of time going to waste.

The greatest weakness of the method is found in the reliability of the data, as the different bosses and workers may have different interpretations of what constitutes wasted time. This applies both to the cause of the wasted time and the amount. We may therefore assume that the amount of time-waste caused by fragmentation of tasks is underreported. There are indications that this is indeed the case, especially concerning the subcontractor for electrical installations. In contrast, we consider the validity of the data pertaining to performance-related time-waste to be more reliable, as it is easier to relate to matters such as the correction of errors. Potential underreporting of errors because making mistakes may be embarrassing is not considered a problem: It is this author's distinct impression that everyone involved felt sufficiently confident that this data will not be used against anyone, and that the sole purpose is to gain knowledge that will be used as input for improvement work. We also consider the category of time spent on planning to be reliable within the chosen level of detailing, as the registration work requires little interpretation. An effort has been made to counterbalance the problematic aspect of the reliability of the data through seeking close and frequent contact and discussions with the foremen.

MICRO MAPPING OF WORKING TIME

In order to extent the study of working time and as an aid to evaluating validity and reliability, a detailed mapping of working time in the Havlimyra construction project was conducted. The workers were observed by students who made a registration every five minutes between 7 o'clock in the morning and 15.30 in the afternoon of how the workers were using their time. The data covers 11 working days. The observations involved electricians, plumbers and carpenters, who were observed for two, four and five days respectively. The electricians worked mostly with cabling, plumbers primarily lay pipes and mounted utility equipment, and the carpenters mostly mounted wallboards. Table 3 presents the aggregated data.

Most of the workers who were observed and interviewed had a perception that there had been a good flow to their work. One of the electricians felt differently, however, relating that: "*the flow was poor. Nothing went as planned. It was difficult to find something to do since ceiling work was being conducted where I was supposed to be working.*" Both of the electricians also felt that the day was different since they were leaving for the Alps on a business trip the following day. Altogether, the electricians spent less time, relatively speaking, doing direct work and more time "waiting", "cleaning up" and "reworking", and they had more "personal time".

Table 3: Proportion of work time (%)

	Elect - rician s	Plum-bers	Carpe n-ters	All crews
Direct work	19.3	54.6	56.6	49.1
Personal time	20.3	13.1	9.9	13.0
Coffee and lunch breaks	12.0	10.5	10.1	10.6
Handling of materials	6.8	10.3	10.5	9.7
Work planning and meetings	2.6	7.2	6.1	5.9
Waiting	20.8	0	0.4	4.0
Cleaning up	7.8	2.6	2.3	3.4
Reworking	10.4	1.3	1.5	3.0
Rigging	0	0.5	2.3	1.2
Unloading and unpacking	0	0	0.2	0.1
Inspection	0	0	0	0

Skanska Finland[3] has conducted several comparative case studies related to productivity. One of these studies addresses window installation on different storeys of the same high-rise building with the same team. In their detailed study of work-time, direct installation work varied from 57 to 68% of the total man-hours used. The increase in productivity was a result of various logistics improvements introduced to support the installation (windows packed by type vs. windows packed by apartment). The installation time was reduced by 140 minutes when the windows were packed according to which apartment they were to be installed in. The variations between the studies conducted in Finland and the study presented in Table 3 seem reasonable given that the Havlimyra project cycle was in its completion phase when the study was conducted. This means many small jobs having to be undertaken, which makes it difficult to achieve the good flow to the work that can be expected in the early phases of a project, when conditions probably allow for more continuous work on tasks and there is less competition between different trades for access to the workplace.

In the micro-study, waiting, at 4%, and reworking, at 3%, are perfectly clear contributors to time-waste. However, personal time makes the greatest contribution to time-waste in this limited study, with the underlying data indicating that the average figure for non-necessary personal time is as high as 10%, and with one trade in particular contributing to the high score. This brings the figure for wasted time up to 17%, suggesting that the more detailed the study, the greater the amount of waste it is likely to uncover. The boss method study does not have a category for personal time. Nonetheless, our figures are far lower than those exposed in Josephson and Saukkoriipi’s (2006) study, where waiting time alone constituted 23% of the working hours. Their work uses a different concept of waiting, however, with workers’ transitions between worksites (re-location) constituting a considerable share. This factor is part of the rigging time in the micro-study from Havlimyra (1.2%) and is

[3] Unpublished material created in 2009 by Logistics Manager Ulla Talvitie, Skanska Finland.

strongly related to waste due to fragmentation of the work in the boss study from the same place (3.2%). If figures of 17% waste and 49% directly productive work are used as a basis for the Havlimyra microanalysis, the working time spent on supportive work constitutes 34%. The share constituted by waste is probably somewhat underestimated, especially for handling of materials, which constitutes 9.7% of the time-use.

In terms of reliability the micro study is just an example, an empirical snapshot. One should be particularly careful about generalising the data regarding the electricians, as these are based on a very limited number of individuals who were observed during a working day out of the ordinary. A weakness of the micro-study is revealed by the fact that inspection takes a zero value. As the worker's own evaluation of their work is included in the category of direct work we need to study entire crews to secure sufficient data for the inspection variable, see Diekmann's approach. Furthermore, the data collection method might have led to changes in behaviour among the studied workers, but we interpret this potential problem as being limited in this case due to observations. Furthermore, the gathered data presented in Table 3 also indicate that there is room for more efficient usage of work time, and a significant amount of trust had been built beforehand between research project staff and construction project staff.

CONCLUSIONS

The literature review and the analysis of primary data show that time-waste is not as easily measured as one might imagine. The detailing of the data used as a basis for the analysis is clearly important for the measured results, in the sense that greater detailing of the collected data results in higher figures for waste. For example, "personal time" is not captured by the boss method developed for this study.

Another central finding is that it is important, especially for the more detailed studies, to distinguish between the types of construction work being measured. For example, Diekmann et al. (2004) found that the time constituted by waiting on three steel erection jobs varied between 24 and 46% and that the value-adding time amounted to between 10 and 32%. Josephson and Saukkoriipi (2005) found that waiting constituted 23% of the working time for the group of construction workers they studied in connection with the construction of housing, and that directly value-adding work constituted 17.5% of the working hours.

The primary data show that waiting constitutes a negligible factor when the boss method is used, whereas it constitutes 4% according to the microanalysis, which includes additional categories such as waiting for others. Furthermore, the microanalysis at Havlimyra indicates at least 17% waste, 49% directly value-adding work, and up to 34% supportive work. However, the main findings based on the coarser boss method, which does not include personal time and waiting time on a microlevel, indicate that the time lost in primary building production amounts to the considerably lower figure of some 5% for the studied case. The largest contribution to this figure comes from inadequate fragmentation of the work and is thus related to "making-do". The applied categories for lost time are particularly aimed at factors that can be related to work flow. Excluding personal time from the microanalysis would have given a figure of 7% for measured waste.

The proportion of directly value-adding work is a result that is comparable to the Finnish studies referred to, with a value-adding time of 57-68%, where waiting times were minimal, and roughly of the same size as those measured by Thune-Holm and Johansen (2006), even though they used a much coarser measuring method.

In terms of the Swedish study (Josephson and Saukkoriipi), some of the significant differences might be ascribed to differing methods of measurement. However, the Swedish study does not document what kind of construction work was studied or whether entire crews were made the object of study. Differences in relation to the American study (Diekerman et al.) can probably to a large extent be ascribed to differences in the types of work involved, as steel erection jobs depend heavily on cranes. Cranes are often a "bottleneck" resource, and are therefore likely to be a frequent cause of waiting. It is found a similar difference between the concrete trade and carpentry at Havlimyra, as concrete work depends more heavily on cranes than what is the case for carpentry work[4]. The registered figures for waiting among concrete workers are low compared to the Swedish and American studies, however, but here it must be added that the work measured at Havlimyra consisted of concrete cast in situ. Measuring of concrete erection jobs involving prefabricated elements would probably result in higher figures for waiting time. According to a senior carpenter at Havlimyra, "*we have no waiting around. It is not accepted that we put down waiting on our time tickets, as concrete workers do. We always find something to do*." This indicates that "making-do" is widespread among the carpenters. The differences found between the different studies may therefore also be related to trade-internal cultural differences between different countries, regions and firms. There is no evidence to suggest that the relatively low figure of waste in the Havlimyra project is related to the fact that the object of study is a pilot project for implementing Last Planner.

The main focus of this report is on analysing waste in the actual production. The root cause of much of the waste in the actual production is found elsewhere, among the project engineers and architect, the owner, and other participants. In addition, other types of time-waste not included here can be ascribed to management, coordination, failure by other parties to meet their obligations, unnecessarily drawn-out production periods and so on, and a series of waste components exist that are perhaps best measured in terms of costs; cf. Josephson and Saukkoriipi (2006) and Mossman (2009).

It is difficult to verify on the basis of our results the proposition that estimates of lost time and low productivity in the construction industry tend to be exaggerated, but some of the data discrepancies are rather noticeable. However, these may also be caused by different conceptualisations, which are not always easily uncovered in published material.

With regard to theory, further work is needed on how to conceptualise waste in construction as well as how to operationalise the concept for measurement purposes.

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[4] Based on as yet unpublished material.

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