# International Journal of Productivity and Performance Management

Analyzing electrical installation labor productivity through work sampling

Sara Hajikazemi Bjørn Andersen Jan Alexander Langlo

# Analyzing electrical installation labor productivity through work sampling


## Abstract

Purpose

The construction industry is a labor-intensive industry, hence, the presence of labor with high productivity at each stage of the project plays a significant role in achieving project success. The main purpose for carrying out this study was to provide real-life empirical data about the current level of construction productivity, in this case electrical installation work, within construction projects in Norway. In addition, it was of interest to identify the areas which have the highest potential for improvement of labor productivity.

Design/methodology/approach

This study considers the construction labor productivity through an elaboration on productive vs. unproductive time within construction projects. It is based on a "frequency study" done on eight construction projects in Norway. The "work sampling" method has been used for collection of empirical data. For each project, four electricians were observed an entire working day and the amount of time they spent on performing each activity was recorded every 60th seconds. The activities observed were based on a predefined set of activities.

Findings

The results of the observations show that on average, 61.1 percent of the time was direct value-added work. This number is significantly better than what is normally discussed as being productive time. However, the findings also show that there is still potential for improvement. The activities that have the highest potential for improvement include "material transfer", "amendments to already executed installation", "personal needs" and "waiting times".

Practical implications

The study results will be of immense benefit to managers of construction projects as well as managers of construction organizations in enhancing their project performance and productivity.

Originality/value

This paper contributes both theoretically and empirically to the current discussion and findings on labor productivity and its relation to project success. The results presented in this paper have important implications of labor productivity in construction projects and future studies in the area of project performance.


*Keywords:* Labor productivity, Time loss, Project performance, Construction industry

## 1. Introduction

Construction industry productivity is a widely discussed topic, typically based on official statistics provided by various national statistical bodies. Unfortunately, such data often shows that construction sector productivity lags behind other sectors. This pertains especially to other types of production, as has been the case for many years in Norway, but the data offers little insight into how this situation can be improved. To allow such insights, gathering of more detailed productivity data is required, down to the project and project process levels. Unfortunately, data at this level are much scarcer - we will later review what little data we have been able to find - and they are more often anecdotal rather that empirically based. This paper reports the findings from a study undertaken to provide such data as a means of diagnosis and subsequent productivity improvement. The trigger for this study was a similar study funded by SBUF (the Development Fund of the Swedish Construction Industry) in the HVAC (Heating, Ventilating, and Air Conditioning) industry in Sweden. This study was completed in 2010 and found alarmingly low levels of craft productivity. At the request of a Norwegian industry association organizing electrical contractors, our study aimed to identify the portion of productive vs. unproductive time within construction projects, using a case study portfolio of eight ongoing construction projects in Norway for electrical installation work. Access to this kind of data, showing how craft worker time is spent on different activities, is important in understanding where time is wasted and which improvement efforts should be implemented. Even with the findings of our study, based only on a selection of projects and from one country, we still believe it is an important contribution in the quest for detailed insight into construction project productivity. Construction projects are quite similar across different regions and countries and to such an extent that data from our case portfolio should be valid in other contexts as well. We also hope that by providing such data and demonstrating that data collection at the project level is feasible, others might be inspired to undertake similar studies to broaden the data set available for analysis.

There are various definitions of the term "productivity" based on how one defines and considers the issue. This is mainly due to the fact that the development of this concept has gone through different processes in different industries. Horner and Duff (2001) defined productivity within the construction industry as follows:

*"Output measures how much we produce. Productivity measures how much we produce per unit input. From a client's perspective, higher productivity leads to lower costs, shorter construction programs, better value for money and a higher return on investment. From a contractor's point of view, higher productivity leads to more competitive edge, more satisfied customers, higher turnover and increased profits. From the country's point of view, higher productivity leads to more efficient use of scarce capital, greater incentives to invest, more jobs and economic prosperity."*

High-productivity labor is a crucial factor for success in construction projects due to the fact that a major part of the construction budget is allocated to labor expenses (Hanna et al., 2005; Sonmez, 2007). Increased value for money in construction, and improved competitiveness of the industry, can be achieved by a combination of means: better quality, better time and cost performance, improved labor productivity, and the continuous introduction of improved design and technology of products, equipment and processes. The need for increased productivity is an important element of the long-term strategy to improve the sector's competitiveness and quality and raise the level of construction output (WS Atkins International Ltd., 1994). Horner and Duff (2001) presented the importance of increased productivity within the construction industry by a simple example:

*"It takes but a simple calculation to demonstrate that a 10 percent increase in UK construction labor productivity would represent a saving of some £ 1.5 billion to the industries' clients; sufficient to produce perhaps an additional 30 hospitals or 30,000 house a year."*

However, the construction industry suffers from productivity loss as one of its greatest and most severe problems (Gundecha, 2012). Nevertheless, except for a few studies (Yi and Chan, 2014; Dolage and Chan, 2013; Panas and Pantouvakis, 2011) it is difficult to find actual data on the level of productivity within the construction sector. At the national level, many studies look at aggregate productivity levels using indices, but such studies do not present data at the level of productive time on site.

Based on the empirical findings, this study provides insight into the productivity level in a selection of case projects and potential areas for improvement of labor productivity. The paper comprises five sections. First, a literature review presents the definition of productivity within the construction industry, the elements which affect the productivity level, the state of the art within the construction industry regarding labor productivity and possible approaches for improving productivity level. Next, the research purpose, scope and methodology are described. The case study work is presented in the subsequent two sections; the first of these includes information about the case projects and the second section covers the results and findings. This is followed by a discussion about the empirical findings. The research conclusions are presented in the final section.

## 2. Background

The term "productivity" indicates the relationship between outputs and inputs. Productivity is defined in many different ways within different contexts (Gundecha, 2012). The outputs and inputs are different in various industries. In the construction industry, productivity is mainly referred to as "labor productivity". This is defined as units of work placed or produced per man-hour (Halligan et al., 1994). Labor productivity usually relates manpower in terms of labor cost to the quantity of outputs produced (Borcherding and Liou, 1986). According to Shehata and El-Gohary (2011), "productivity" can also be defined as the ratio of earned to actual hours. However, the problem with this concept lies in establishing reliable ‘‘norms’’, for setting standards. It also depends on the method used to measure productivity, and on the extent to which account is taken of all the factors affecting it.

Another way of looking at productivity in the construction industry is to look at the composition of the work day. The productive time is defined as "time during which useful work is performed in an operation or process" (McGraw-Hill Dictionary of Scientific & Technical Terms, 2003). One can consider non-productive time to include time associated with workers waiting for instructions, doing rework, taking advantage of a lack of proper supervision, etc. In addition, non-productive time includes a certain amount of what can be referred to as unnecessary support time, such as a worker carrying boards from one location to another merely because the material was not effectively stored in the proper location in the job site layout process. One specific approach to measuring labor productivity, which is the main research approach in this study, is called work sampling. Work sampling is a series of instantaneous observations, or “snap shots,” of work in progress taken randomly over a period of time (Jenkins and Orth, 2003). There are a number of studies that apply this method for measuring labor productivity. Some recent examples are as follows: the study performed by Chang et al. (2015) on steel framing work efficiency within construction projects applies this approach to gain insight into the different activities, hence allowing for process improvements. Pradeepkumar and Loganathan (2015) also applied the work sampling approach with the aim to minimize the construction waste through lean construction principles and improve the site productivity.

Many studies have been done on the elements that affect labor productivity within the construction industry. Mawdesley and Al-Jibouri (2009), in their study based on data collected from the construction industry in the UK, introduced 34 elements which affect productivity in the construction industry. Thomas and Sudhakumar (2014) also introduced and ranked a number of elements affecting labor productivity based on their severity index (SI). Ghoddousi et al. (2015) highlighted the main factors and items affecting labor productivity in construction projects in Iran, which are mainly of human resources management nature and could be attributed to motivation and managerial policy aspects.

The labor productivity level within the construction industry is generally accepted to be relatively low. The often-repeated message in media and literature concerning low labor productivity in the construction industry usually reports about 30-40 percent productive time. According to Jenkins and Orth (2003), the time used by workers on productive work on a daily basis averaged about 30 percent of the total time available for construction work. Few studies exist that actually document true productivity levels. The studies we have found that provide some data are presented in the following. Going back to 1980, in a study of nuclear plant projects, Borcherding and Sebastian (1980) found direct work to constitute 32 percent, 28 percent supportive work, and non-productive activities amounting to 40 percent of working time. Several Canadian studies have been undertaken; some dating back to the 1990s and early 2000s found actual working time (often called tool time) to be around 55-60 percent (Dozzi and AbouRizk (1993, Canadian data); Olomolaige, Jayawardane, and Harris (1998, UK data); McTague and Jergeas (2003, Canadian data). For concrete-placement operations in Canada, Christian and Hachey (1995) found similar levels of time distribution, with direct work and supporting activities amounting to 61 percent. Hewage and Ruwanpua (2006) studied carpentry work in Canada and found productive work time to be 50.7 percent, while the other half of the time was split across various categories (looking for materials, looking for tools, socializing, moving, etc.). Da Silva (2006) also looked at carpentry work in Canada and found working time of 61 percent for falsework and 56 percent for formwork. In Europe, the Swedish study in the HVAC area (Björkman, Josephson and Kling, 2010) mentioned previously found an average of only 13.2 percent productive time, considerably lower than the expected amount of productive time in construction projects and much lower than findings from the earlier studies. Some of the reasons for this could be that HVAC work is inherently much more dependent on the progress of other trades, but the number was still surprisingly low.

According to Thomas and Sudhakumar (2014) and Attar et al. (2013), low labor productivity has been identified as a major reason for delays and cost overruns within the construction industry. Site workers account for up to 40 percent of the direct capital cost of large construction projects and thus there is a need to maximize the productivity of labor resources (Ng et al., 2004). Sveikauskas et al. (2014), through a study on productivity growth within the construction sector from 1987 to 2011, concluded that the level of productivity within the construction industry is declining.

There is an abundance of literature on improvement of labor productivity and project performance (see for example Oglesby et al.,1989; Dozzi and AbouRizk, 1993; WS Atkins International Ltd., 1994; Weng-Tat, 2007; Shehata and El-Gohary, 2011; Gundecha, 2012; Nasirzadeh and Nojedehi, 2012; Attar et al., 2013; Thomas and Sudhakumar, 2014). These are only examples of the many studies performed in this area. This emphasizes the existence of low labor productivity within the construction industry and thus the need for improvement of labor productivity within this industry. Nevertheless, there are few sources which provide concrete empirical data on the productivity level within construction projects, with the exception of a number of Canadian studies from the 1990s and first half of the 2000s. This calls for more empirical research on real-life cases in order to build a solid foundation for further research within this field. For electrical installation work, we have not been able to identify any previous research on productivity levels, accordingly our work starts to fill that gap. It should be remarked that the level of labor productivity varies across different countries and different types of projects. Consequently, it is important to take this into account when measuring and comparing the productivity levels.

## 3. Research objectives, scope and methodology

The main purpose for carrying out this study was to provide real-life empirical data about the current level of construction productivity, in this case electrical installation work within eight construction projects in Norway. As already mentioned in section 2.1, this has been done through the application of a version of time study technique to assess labor productivity through measurement of productive time vs. unproductive time within the case projects. It was also of interest to identify the areas which have the highest potential for improvement of labor productivity. The work sampling approach lends itself naturally to this type of research. As mentioned previously, work sampling is a series of instantaneous observations, or "snap shots," of work in progress taken randomly over a period of time (Jenkins and Orth, 2003). This method provides information on the amount of time workers spend performing productive, supportive, and non-productive work (Jenkins and Orth, 2003). Work sampling is a technique that provides valuable information to a construction manager regarding areas of low productivity in need of corrective action (Thomas and Napolitan, 1999). Work sampling can be conducted by anyone with a basic knowledge of both construction and work sampling methods. However, is it desirable that the person(s) conducting the work sampling study be a neutral party and not employed by the company being evaluated, as this will help to reduce bias of the study and reflect the actual conditions of jobsite labor productivity. This is done through applying an observational research approach, which is a systematic data collection approach where researchers use all of their senses to examine people in natural settings or naturally occurring situations (Atkinson and Hammersley, 1994). There are a variety of reasons for collecting observational data. Some of the most relevant reasons include:

- When the nature of the research question to be answered is focused on answering a how- or what-type question
- When the topic is relatively unexplored and little is known to explain the behavior of people in a particular setting
- When self-reported data (asking people what they do) is likely to be different from actual behavior (what people actually do). One example of this is seen in the difference between self-reported vs. observed preventive service delivery in healthcare settings.

The main research questions to be answered within this paper are:

*RQ1.* What is the percentage of productive time and unproductive time within construction projects in Norway?

*RQ2.* What are the potential areas of improvement toward higher labor productivity in Norwegian construction projects?

In the frequency study, an observer followed the installers working on the construction site and recorded the specific task the installer performed every 60th second. The method was used to provide an overview of the tasks installers conducted during a full working day, and to see if there were clear indications of lost time.

The observations were made of installers in eight different projects from different construction companies selected among NELFO[1] members. The projects to be used as case projects were volunteered by the companies. It was required that the progress of the projects should be somewhere between 20 and 80 percent by the time that the observations took place (to avoid productivity deviations due to startup or closeout processes). Furthermore, it was said that the selection of case projects should be spread geographically across the country and represent different types of buildings and different types of labor craft payment schemes. In addition, it was specifically decided that one project should be in the shipbuilding sector. The basis for the choice of a ship-installation project was to examine whether there are significant differences between construction and shipbuilding projects.

It is important to emphasize that a frequency study is not about how effectively each person works, but rather how well the work is planned and the extent to which production is controlled by external factors. The activities were recorded based on a predefined list of possible activities that the observers brought along to the construction site. This list was based on the original Swedish SBUF study in the HVAC area, but was updated in collaboration with NELFO in order to adapt the activities to the Norwegian working conditions and electrical installation work. The following method was used for observation of the installers:

- Registration of work was done every 60 seconds, during the entire duration of the installers' work day
- Registration was done according to the predefined list of activities
- There was no registration during breaks, for example coffee and lunch breaks
- For each project, four days were allocated for registration. The exception was project A, which was conducted as a pilot study to test the method, where five registration days were undertaken.
- Only one installer was observed each day

All the projects within the case project portfolio were new building projects. They included different types of buildings, and the projects were geographically spread out across the country. The purpose was to compile a varied case project portfolio. The different project types and the number of observations that were carried out for each project are presented below:

- Project A: School, new building + rehabilitation (observations done on the new building project) – 2377 observations

- Project B: School, new building – 1657 observations

[1] NELFO is a trade association for the electrical and IT contractors and companies in Norway.

- Project C: Apartments, new building, 1601 observations
- Project D: Apartments, new building, 1839 observations
- Project E: Apartments/commercial, new building, 1597 observations
- Project F: Ship installation, new ship, 1472 observations
- Project G: Students' dormitory, new building, 1726 observations
- Project H: Shopping center, new building, 1484 observations

One of the challenges pertaining to the research approach is that the installers might work more effectively when they are aware that they are being observed. However, the feedback we received from the installers was that they did not feel they were working any differently while being observed, since they quickly got used to having observers around. We were also informed that some of the installers were not willing to be observed by us. In addition, a possible source of error could be observer errors while registering the activities.

The empirical results are based on the eight observed projects. The observations took place during the four registration days and therefore the results reflect the situation during these specific four days. Although the number of observed projects is too low to create a general view of actual productivity levels, it can provide an indication on the current situation. In addition, there were too few projects to conduct statistical analyses about differences between the projects.

Another source of error in this study was the fact that the projects were volunteered to be observed. Under this condition, it is possible that the companies have selected projects which are more likely to perform well rather than projects which are likely to underperform. This can influence the final results in a positive direction. In the following section, a description of the case projects and the results of the observations will be presented.

## 4. Empirical results and analysis

The results of the observations show that the productive time registered among the observed case projects is relatively higher compared to the general productivity level within the construction industry addressed by other relevant studies. The overall results from the observations of the case projects are illustrated in Figure 1. It presents the dominant activities that an installer performs during a normal working day.

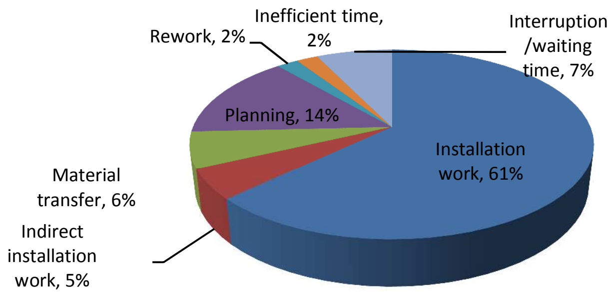


Figure 1. Illustrated overview of the working days' activity distribution

Table 1 presents the percentage of the time allocated to each activity category within a full working day. In addition, it includes the highest and lowest registered percentages of time allocated to each activity. Evidently, not only is there a large variation among the highest and lowest amounts, but there is also a large difference between those amounts and the average percentage. This will be further explained in section 5.

Among these activities, the most important is the "installation work", which constitutes 61 percent. Subsequently follow various activities in the "indirect installation work", "material transfer" and "planning" categories. These three categories fall under the "preparation" category and include all the activities necessary for the installation work to be carried out in the best possible way. "Amendments to already executed installation" is considered rework and is also regarded as loss of time.

Table 1. Percentage of time allocated to each activity

| Activity | Average | Highest | Lowest |
|---|---|---|---|
| **Installation work** | **61.1** | **77.9** | **27.6** |
| Installation work | 61.1 | 77.9 | 27.6 |
| **Preparation** | **28.1** | **45.5** | **16.5** |
| Indirect installation work | 5.4 | 10.2 | 1.0 |
| Material transfer | 9.3 | 14.2 | 3.4 |
| Planning | 13.4 | 29.5 | 6.4 |
| **Time loss** | **10.6** | **26.9** | **3.4** |
| Rework | 2.2 | 6.1 | 0.0 |
| Inefficient time | 1.9 | 5.7 | 0.0 |
| Interruption/waiting time | 6.5 | 19.6 | 1.0 |
| **SUM** | **100 %** | | |

The work activities' distribution during the working day is illustrated in Figure 2. Installation work is lower at the start and end of the workday, which is naturally related to startup preparations and ending the workday, and also during lunch. Preparation time is higher at the start and end of the working day.

The time loss is relatively the same throughout the working day at 10-15 percent, with some variations. The time loss is highest at the start of the day. The activities fall under three main categories: installation work, preparations, and time loss.

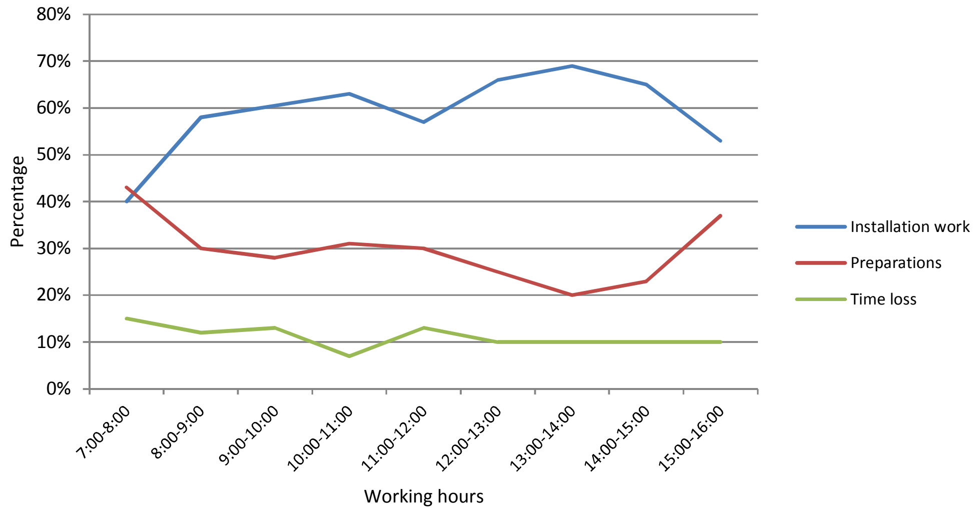


Figure 2. Activity distribution during the working day

*Installation work*

The "installation work" category includes the activities which are regarded as direct value-added work. Installation work amounted to 61.1 percent of the observed time within the case projects. This shows that more than half of the working day is spent on direct value-added work such as work with conduits, placing cables, assembly of equipment, and connecting cables and setting installations for operation. The main activity in this category is "direct installation work", which constitutes 55.3 percent of the working day. This applies evenly to all the projects, with the exception of Project C which had a relatively lower degree of direct installation work in the observed period. In addition, "functional testing, measurement and adjustment of installed equipment" has been an important activity for many of the observed projects, and included 4.0 percent of the working day.

*Preparations*

The "preparation" category includes all the activities which are required to be done in order for the installation work to be performed in the best possible way. These comprise activities such as collection/transfer of material/tools/equipment, cleaning and different types of planning for the work to be carried out. In total, the preparations took 28.1 percent of the working day where indirect installation work, material transfer and planning constituted respectively 5.4 percent, 9 percent and 13.6 percent of the working day.

The designated activities within this category are: "tidying and cleaning after the work is done" (2.6 percent), "collection/transfer of material" (5.9 percent), collection/transfer of tools and equipment (2.5 percent), "discussion with colleagues or managers for clarification of tasks (7.1 percent), "reading drawings and other work and installation-related documentation" (2.7 percent) and "planning own tasks" (1.9 percent).

There are differences between the amounts of time used for preparation work among the observed projects. In Project C, 45 percent of the time was consumed by preparations while Project E and Project F used much less time for preparation, respectively 17.3 percent and 16.5 percent of the working day.

*Time loss*

Time loss is the time during the working day which is not consumed by direct or indirect value-added work and is thus considered as activities which are desirable to be eliminated/reduced. Time loss constituted a total of 10.6 percent of the time throughout a working day. It included "rework" (2.2 percent), "inefficient time" (1.9 percent) and "interruption/waiting time", which was the most frequently registered activities within the time loss category, consuming 6.5 percent of the working day. This category displays a variety of elements which contribute to time loss. Some of these can imply unfortunate organization or logistics of the construction site, while others can point to potential for improvement in the organization of the projects, including planning and management. In addition, some of the time loss is directly related to the workers. Examples are personal needs, late arrival at work or too long lunch breaks. There were considerable differences among the projects pertaining to time loss. Project C stood out with a time loss of 26.9 percent. This consisted mainly of interruption/waiting time, which amounted to 19.6 percent of the time loss. "Waiting for others" and "transferring" amounted to respectively 3.4 percent and 9.1 percent of the lost time. Project D had the second highest amount of time loss among the projects, 19.1 percent. In this project "personal needs" has been registered as one of the main reasons for time loss, 3.6 percent, being the highest among all the projects. Table 2 presents the total amount of time used on each main category for each of the case projects.

Table 2. Total time consumed in each category within the case projects

| **Activity / project** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **A-H** |
|---|---|---|---|---|---|---|---|---|---|
| | School | School | Apartments | Apartments | Apartments/ commercial | Shipbuilding | dormitory | center | |
| Installation work | 66.0 | 58.8 | 27.6 | 51.9 | 77.9 | 75.2 | 67.3 | 64.2 | **61.1** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Preparations | 30.6 | 30.0 | 45.5 | 29.0 | 17.3 | 16.5 | 26.0 | 29.6 | **28.1** |
| Time loss | 3.4 | 11.2 | 26.9 | 19.1 | 4.8 | 8.3 | 6.7 | 6.3 | **10.6** |

## 5. Discussion

**The elements affecting labor productivity**

First of all, the data from this study show that the portion of productive time for electrical installation craft workers in a selection of case projects is at about the same level as a number of previous studies have found for carpentry work, i.e., about 50-60 percent. The Swedish study of HVAC work found an astonishingly low amount of productive time using the same research method, approximately 13 percent, so our study indicates that there is nothing inherent in the method used that would produce lower levels of productive time. Our study is also the first we have seen to document electrical installation work productivity, confirming that this craft matches or even surpasses carpentry and concrete work, based on data available for the latter two.

The results drawn from the observations show that there are significant differences among the times used in each activity category within different projects. This gives rise to the question whether we can observe any systematic differences among the results, originating from the projects' characteristics. The following factors relating to the projects were initially mapped:

- The level of completion at the time of the observation, based on the idea that productivity is higher in normal production phases compared with startup or closeout phases.
- Salary system applied, based on curiosity whether performance-related pay (PRP) contributes to higher productivity than fixed salaries.

Data regarding these elements were collected from the case projects, presented in Table 3.

Table 3. Information on salary system and completion level of the projects

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| **Project** | School | School | Apartments | Apartments | Apartments/ commercial | Shipbuilding | dormitory | center |
| Appr. completion level | 80% | 75% | >90% | 20-25% | 50-60% | 50% | 90% | 40% |
| Salary system | PRP | Fixed | PRP | Fixed | PRP | PRP | PRP | PRP |

The completion levels of the projects show large variations. However, all the projects can be regarded as being in the normal production phase, being at between 40 percent and 90 percent of completion level. It is almost impossible to identify any specific pattern due to the great variation among the time used in each category within different projects. The only projects that stood out are Project D, which was in its early phase, regarded more as being in the startup stage, and project C, being more than 90 percent completed and therefore considered as being in its final phase.

Project D seemed, however, to have gotten started with actual installation work, with 51.9 percent of the time spent on installation work. Project C, however, had a significantly lower proportion of assembly work and the highest percentage of both preparation and time loss among all the eight projects. One might say that this is fully expected since in the final phase most of the installation work has been done and the remaining work constitutes mostly control, rework, cleaning and tidying, etc. However, data gathered from one project is too limited for allowing a conclusion based on it.

Regarding the salary system, there are six projects with PRP and two with fixed salary systems. The average amount of the time spent on each of the categories is shown in Table 4, displaying considerable differences.

Table 4. Average time spent on projects with different salary systems

| Salary system | PRP | Fixed salary |
|---|---|---|
| Installation work | 63.0 | 55.4 |
| Preparations | 27.6 | 30.0 |
| Time loss | 9.4 | 15.2 |

Projects with PRP have better values for all the three categories, with a higher proportion of installation work (7.6 percent more), lower proportion of preparation work (albeit only 2.4 percent more) and lower time loss (5.8 percent less). This is probably as one might expect, regarding the extent to which each of the individual installers can influence their own productivity. This result is also aligned with the literature findings indicating that jobs with PRP attract workers of higher ability and motivate the workers to provide greater effort, leading to higher productivity rates (Booth and Frank, 1999). Gielen et al. (2010) claimed that PRP increases productivity at the firm level with 9 percent and employment growth with 5 percent. However, it should be mentioned that although PRP has potentially positive productivity effects, PRP may not always increase the productivity rate. In case of teamwork, individual performance is difficult to measure; therefore, there is an incentive to free-ride. Additionally, perverse incentives may arise in case of multitasking. When employees are required to perform several tasks, they will focus only on those activities being rewarded and neglect other activities. It is thus not always clear that the introduction of a PRP scheme will indeed increase productivity (Gielen et al., 2010). In order to accurately measure the effect of PRP on labor productivity, it is crucial to take into account all the mentioned aspects which might directly or indirectly influence the process.

In addition, in our case, although the results from the observations are interesting, the selection of projects is too small to generalize the findings and thus there is a need for further investigation in a more extensive study to obtain more valid and generalizable results.

**Potential for improvement**

61 percent of installation work is considerably higher than one might expect given the often-repeated message in media and literature about low labor productivity in the construction industry, frequently referring to about 30-40 percent productive time. Our study provides a factual basis demonstrating that this portfolio of projects performs much better. As mentioned earlier, the trigger for this study was a similar study performed by SBUF in the HVAC industry in Sweden. Although this study and our study focus on different branches within the construction industry, it is interesting to compare the overall results (see Table 5). As the table shows, there are large differences among the percentage of time spent on each category.

Table 5. A comparison of the Swedish and Norwegian overall results

| Activity | Percentage (electrical installations - Norway) | Percentage (HVAC – Sweden) |
|---|---|---|
| Installation work | 61.1 | 13.2 |
| Preparations | 28.3 | 51.9 |
| Time loss | 10.6 | 34.9 |

The two studies of HVAC in Sweden and electrical installations in Norway demonstrate totally different results, especially regarding the time spent on "direct installation work". This large divergence can be attributed to the difference between the two branches where the measurements have taken place and also to the fact that the studies have been conducted in two different countries. HVAC installers are traditionally to a greater extent dependent on completion of other tasks within the project compared with electrical installers, who can work more independently with their own tasks. In addition, the SBUF study included a greater variety of projects, particularly with regard to new construction/rehabilitation, which can contribute to a lower proportion of assembly work.

Nevertheless, the data from our study shows a significant potential for further improvement. The results of this study show a total time loss of 10.6 percent. Based on this, we should look for potential areas for improvement. The activity "transfer", consuming 3.2 percent of the time, makes the largest contribution to time loss. Thus, it is important to evaluate the project's need for transfer of material and equipment and examine whether the construction site's logistics and organization meet this need in the best possible way. Attar et al. (2013) and Nepal et al. (2006) also referred to advancement of site layout and properly and in advance material procurement and management as contributing factors to improvement of labor productivity. Thomas and Sudhakumar (2014) stated that timely availability of materials at the worksite is the most critical factor impacting productivity. Therefore, attempts at improving logistics in a manner that will contribute to better availability of materials can contribute much to improvement of labor productivity.

In addition, the "changes in already completed installation" also contributed significantly to time loss, consuming a total of 1.5 percent of the registered working hours. In a trade-off between spending some more time on an installation to ensure that the work is done right the first time or doing it faster and with higher risk of errors, it will often be more profitable to ensure quality from the beginning. The activity "other (interruption/waiting time)" (1.5 percent) is a combination and will include interruptions of a different nature. Installers should to the highest extent possible be encouraged to use their agreed breaks for fulfilling their personal needs, so that the activity "personal needs" (1.2 percent) can be reduced. The activity "waiting for other people" (0.7 percent) includes waiting for other departments/disciplines, and can be reduced by the project being well planned, and by updating and following up plans throughout the project in order to ensure that different departments/disciplines do not need to work in the same place at the same time.

In general, according to Dozzi and AbuRizk (1993), good planning practices including both overall job organization and work distribution at the site level motivates workers to build up and maintain momentum towards completing their tasks, thus increasing productivity. This is also in line with the findings from the work done by Thomas and Sudhakumar (2014) which articulated that improper project coordination and poor project planning and scheduling are among the top five factors adversely influencing labor productivity within construction projects.

Preparation time is basically less "unproductive" in nature, in comparison to pure "time loss". However, it will be beneficial if part of the preparation time can be used for direct installation work. A ranking of the five most important activities included in the preparation category shows that "preparatory discussion with colleagues/manager for clarification" constituted 7.1 percent of the time. These types of clarifications are always needed; however, this could possibly be reduced by a higher degree of standardized solutions or by conducting these activities in parallel with direct installation work. An example can be maximizing the use of machinery and automation systems within construction projects (Attar et al., 2013). "Collection/transfer of material" (5.9 percent), like any other type of transfer, can be reduced by optimizing the design of the construction site and logistics on site. In larger projects, it is also possible to use other resources, like logistics couriers, to undertake such activities. The third activity, which consumed 2.7 percent of the time, includes performing clarifications on impending operations. This can also be reduced by more experience, both general and specifically on products/operations. “Tidying and cleaning after the work is done” (2.6 percent) is an essential activity, but can possibly be reduced by employing internal resources (where the project size allows for this) or through choice of solutions which create less waste. “Collection/transfer of tools and equipment” (2.5 percent) also constituted an inevitable part of the work. However, this may also be reduced by decreasing the degree of sharing of common tools and equipment among the installers. This is likely to be achieved through proper and in advance material procurement and management (Attar et al., 2013).

## 6. Conclusions

This research has examined the amount of time spent on different activities within a working day among assemblers of electrical installations through a frequency study. A total of eight different projects, with different geographical locations, have been observed. The results of the observations show that 61.1 percent of the working day was spent on installation work and direct value-added work. The time loss during a working day in this study was found to be 10.6 percent. The rest of the registered working hours were allocated to preparations. The percentage of the time spent on direct installation work is quite high within the case projects compared to what is often anecdotally claimed in the literature, but at about the same or a little higher than what has been reported from the few other studies found that have measured actual productive tool time. As such, our findings, from projects carried out in 2015, show that there has been no significant increase in construction labor productivity and that there is still a potential for improvement, both by reducing the 10 percent pure time loss and the nearly 30 percent preparation time. The activities that have the most potential for improvement are the activities "transfer", "changes in the already completed installation," "personal needs" and "waiting for other people". Based on the results of the observations, several approaches for improvement of the labor productivity were suggested.

A logical continuation of the work in this study would be to identify and test how to further reduce the time loss within construction projects. It would also be interesting to see whether activities within the preparation category can be converted into direct installation work. More specific suggestions for further research include studying a larger number of projects in order to obtain an expanded data set, and studying differences among rehabilitation projects vs. new-building projects. It will also be relevant to collect data in order to examine the correlation between the time spent on different categories within the project and the following elements:

- The project's financial results, preferably profit/deficit and actual hours worked vs. calculated hours
- The size of the project management team, as this reflects how much of the management functions must be handled by the craft team itself
- The responsible for the engineering work (electrical contractor itself or external advisor) and preferably also an assessment of the quality of the drawings and other production documents

Moreover, it is of interest to further explore what constitutes good planning and good work management, how to ensure good construction site logistics and how to communicate well - both within the team and interdisciplinary - in order to increase labor productivity.

## Acknowledgements

This research was made possible by NELFO, which financed the frequency study project. The authors would like to thank Siri Bøe Halvorsen, the project manager of the frequency study project and also the main author of the original project report.


## References


Atkinson, P. and Hammersley, M., 1994. Ethnography and participant observation." In NK Denzin and YS Lincoln (Eds.) Handbook of Qualitative Research (pp. 248-261). Thousand Oaks: Sage Publications.

Attar A. A., Gupta A. K., Desai D. B., 2013. A Study of Various Factors Affecting Labour Productivity and Methods to Improve it, Second International Conference on Emerging Trends in Engineering (SICETE) - Journal of Mechanical and Civil Engineering Special Issue, e-ISSN 2278-1684 / p-ISSN 2320–334X, 1(3), February 2013, 11-14.

Björkman, L., et al., 2010. Arbetstidens användning vid VVS-montage – en fråga om struktur och ledarskap. Stockholm, Svenska Byggbranschens Utvecklingsfond/VVS-företagen.Booth, A.L. and Frank, J. 1999. Earnings, productivity and performance-related pay, Journal of labor economics, 17 (3), 447-463.

Borcherding, J. D. and Sebastian, S. J., 1980. "Major factors influencing craft productivity in nuclear power plant construction." Transactions of the American Association of Cost Engineers: I11-I15.

Borcherding, J. D, and Liou, F. S., 1986. Work sampling can predict unit rate productivity. Journal of Construction Engineering and Management, 112(1), 90-103.

Chang, S., Yi, J. and Son, J., 2015. The Productivity Improvement for Steel Framing Work

Efficiency by Work Sampling and 5-minute Rating Technique, KICEM Journal of Construction Engineering and Project Management, 5(1), 40-46.

Christian, J. and Hachey, D., 1995. "Effects of Delay Times on Production Rates in Construction." Journal of Construction Engineering and Management 121(1): 20-26.

Da Silva, S. P. (2006). Developing planning best practices to improve contruction productivity. Department of Civil Engineering. Calgary, University of Calgary.

Dolage, D.A.R. and Chan, P., 2013. Engineer: Journal of the Institution of Engineers, Sri Lanka, 46(4), 31-42.

Dozzi, S.P. and AbouRizk, S.M., 1993. Productivity in construction, Institute for Research in Construction, National Research Council, Ottawa, Ontario, Canada

Ghoddousi, P., Poorafshar, O., Chileshe, N. and Hosseini, M.R., 2015, Labour productivity

in Iranian construction projects, International Journal of Productivity and Performance Management, 64(6), 811 – 830.

Gielen, A.C., Kerhofs, M.J.A. and Ours, J.C., 2010. How performance related pay affects productivity and employment, Journal of population economics, 23, 291-301.

Gundecha, M.M., 2012, Study of factors affecting labor productivity at a building construction project in the USA: web survey, MSc. Thesis, Construction Management and Engineering Faculty, North Dakota State University of Agriculture and Applied Science, USA.

Halligan, D. W., Demsetz, L. A., Brown, J. D., and Pace, C. B., 1994. Action-response model and loss of productivity in construction. Journal of Construction Engineering and Management, ASCE, 120 (1), 47-64.

Hanna, A. S., Taylor, C. S., and Sullivan, K. T., 2005. Impact of extended overtime on construction labor productivity, ASCE Journal of Construction Engineering Management, 131(6), 734-740.

Hewage, K. N. and Ruwanpura, J. Y., 2006. Carpentry workers issues and efficiencies related to construction productivity in commercial construction projects in Alberta. Canadian Journal of Civil Engineering 33(8), 1075-1089.

Horner, M. and Duff, R., 2001. More for Less: A Contractors' Guide to Improving Productivity, CIRIA, London.

Jenkins, J. and Orth, D., 2003. Productivity Improvement through Work Sampling. AACE International, Transactions of the Annual Meeting. CSC.5.1-CSC.05.7.

Mawdesley, M.J. and Al-Jibouri, S., 2009. Modelling construction project productivity using systems dynamics approach, International Journal of Productivity and Performance Management, 59(1), 18 – 36.

McTague, B. and Jergeas, G., 2003. Productivity improvement on Alberta major construction projects. Calgary, Canada, Alberta Economic Development Board.

Nasirzadeh, F. and Nojedehi, P., 2013. Dynamic modeling of labor productivity in construction projects, International Journal of Project Management, 31, 903–911.

Nepal, M.P., Park, M. and Son, B., 2006. Effects of schedule pressure on construction performance. Journal of Construction Engineering and Management, 132(2), 182-188.

Ng, S.T., Skitmore, R.M., Lam, K.C., Poon, A.W.C., 2004. Demotivating factors influencing the productivity of civil engineering projects. International Journal of Project Management, 22, 139–146.

Olomolaiye, P., et al., 1998. Construction productivity management. Harlow, UK, Chartered Institute of Building.

Panas, A. and Pantouvakis, J.P., 2011. Multi-attribute regression analysis for concrete pavement productivity estimation, Organization, Technology and Management in Construction: An International Journal, 3(2), 347-353.

Pradeepkumar, C. and Loganathan, S., 2015. A study on minimization of construction waste through work sampling, International Journal of Science and Engineering Research, 3(4), 5687-5691.

Shehata, M.E. and El-Gohary, K.M., 2011. Towards improving construction labor productivity and projects' performance, Alexandria Engineering Journal, 50, 321–330.

Sonmez, R, 2007. Impact of Occasional Overtime on Construction Labor Productivity: Quantitative Analysis. Canadian Journal of Civil Engineering, 34, 803-808.

Sveikauskas, L., Rowe, S., Mildenberger, J., Price, J. and Young, A., 2014. Productivity Growth in Construction, BLS WORKING PAPERS, U.S. Department of Labor, U.S. Bureau of Labor Statistics, Office of Productivity and Technology

Thomas, A.V. and Sudhakumar, J., 2014. Factors Influencing Construction Labour Productivity: An Indian Case Study, Journal of Construction in Developing Countries, 19(1), 7753–68.

Thomas, H.R., and Napolitan, C., 1999. Quantitative Effects of Construction Changes on Labor Productivity. Journal of Construction Engineering and Management, 124, (2), 290-296.

WS Atkins International Ltd., 1994. Strategies for the European Construction Sector - A Programme for Change, A report compiled for the European Commission, Construction Europe, KHL Publishing Limited, Southfields: UK

Yi, W. and Chan, A.P.C., 2014. Critical Review of Labor Productivity Research in Construction Journals. Journal of Management in Engineering, ASCE, 30(2), 214-225.

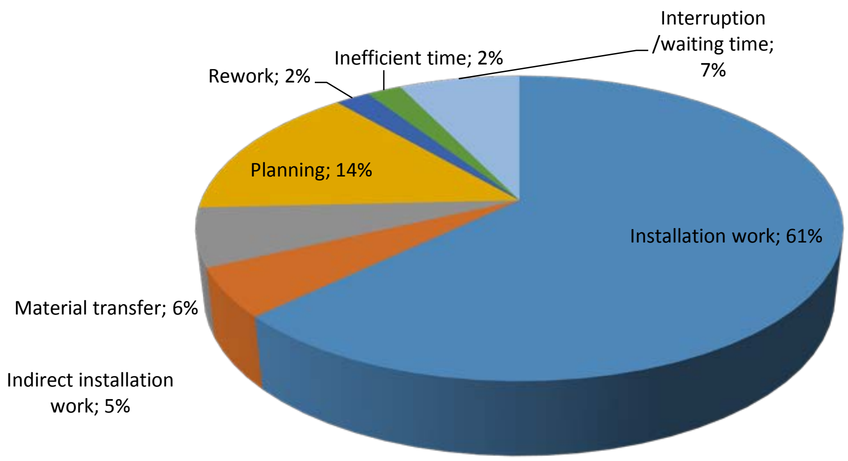


Figure 1. Illustrated overview of the working days' activity distribution

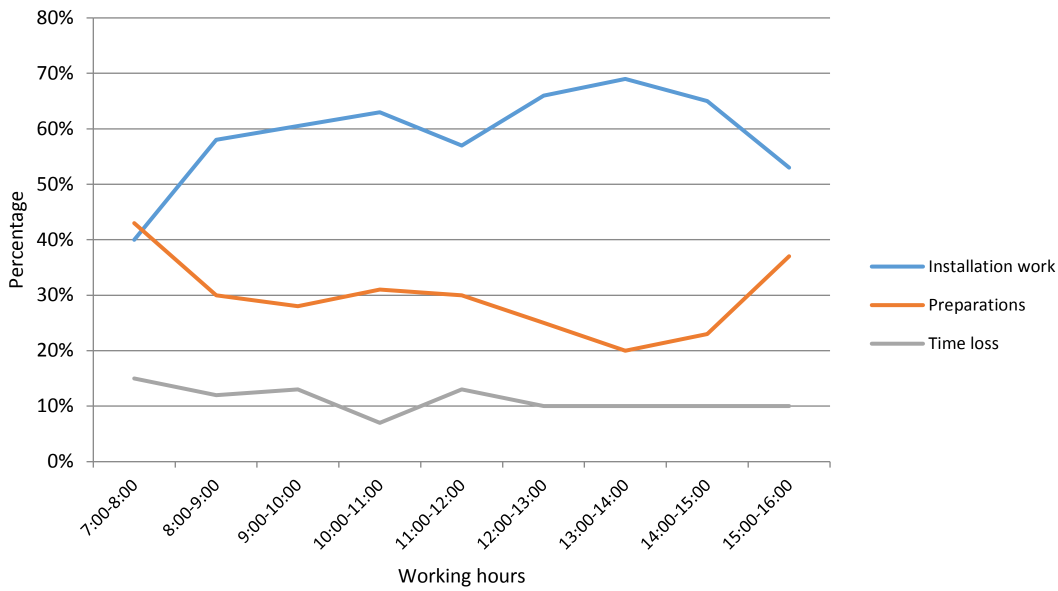


Figure 1. Activity distribution during the working day

## Authors' Biography

**Sara Hajikazemi**, has obtained her doctoral degree in project management from the Norwegian University of Science and Technology. She has authored/co-authored numerous papers for international journals and conferences and has been involved in several national and international research projects. She is a currently a research scientist at SINTEF Technology and Society, a multidisciplinary research institute active in the fields of industry, technology and social sciences.

**Bjørn Andersen**, is a professor of quality and project management at the Norwegian University of Technology and Science. He has authored/co-authored around 20 books and numerous papers for international journals and conferences, in total more than 250 publications. He has managed and been involved in several national and international research and implementation projects. He serves as Director of the Norwegian Center of Project Management, is an Academic in the International Academy of Quality, is co-editor of the International Journal of Production Planning & Control and reviewer for several other journals and conferences, and directs the NTNU master program in mechanical engineering.

**Jan Alexander Langlo,** PhD, holds a position as Research Manager at SINTEF, as well as a position as Associate Professor at Norwegian University of Science and Technology (NTNU). Langlo has more than 18 years' experience as researcher, project manager, lecturer and supervisor within Project Management and Operations Management, as well as being consultant to a broad range of companies in Norwegian industry and public sector.