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Labor Productivity on Construction Sites: A Case Study of Biological Wastewater Treatment Plant Construction

Dr. **Burcu Balaban Ökten** [1], Dr. **Yaprak Arıcı Üstüner** [2], B.A. **Anıl Aksoy** [3]
Fatih Sultan Mehmet Vakıf University, Faculty of Architecture and Design, Istanbul, Turkey [1,2 & 3]
E-mail [1]: burcuokten@fsm.edu.tr , E-mail [2]: yarici@fsm.edu.tr , E-mail [3]: anil.aksoy@stu.fsm.edu.tr

Abstract
The production efficiency of labor on construction sites is an important factor for the success of projects. Skills, experience, and training are among the critical factors affecting labor productivity on construction sites. Especially in construction sites where a new construction technique is used, the teams' efficiency is affected by the learning processes. Laborers' unfamiliarity with the new technique can cause time delays and, accordingly, cost overruns. This research examines laborers' challenges in building an unfamiliar structure at construction sites through a case study. With a comprehensive literature review, interactions between laborers' learning process for new structures and construction time estimation were examined, and the case has been evaluated accordingly. It was observed that the time estimation could not be predicted during an unfamiliar construction form such as examined in the field study. This study is aimed to set an example for the construction sites where new productions take place.
Keywords: Labor Productivity; Construction Sites; New Construction Technique; Learning Processes; Success Factors.

1. Introduction

One of the major problems of big cities is the treatment of wastewater. Treatment of large-scale wastewater requires well-planned strategies (Marzouk and Othman, 2020). Wastewater treatment plant projects are therefore essential investments. Wastewater treatment is a process used to remove contaminants from wastewater and turn it into wastewater that can be returned to the water cycle or reused for various purposes with an acceptable impact on the environment. Biological wastewater treatment is designed to decompose pollutants dissolved in wastewater under the influence of microorganisms (Jung and Pauly, 2011). Water treatment involves a complex series of processes. This situation requires expert teams to work in the planning of water treatment facilities. Consequently, wastewater treatment plant construction projects are complex projects and need experienced construction project teams in this regard (Abi Shdid et al., 2019; Andary et al., 2019).

Success is always vital in construction projects as it is the goal in every field. There are various success criteria in the implementation of construction projects. The correct and complete determination of these criteria is crucial for the project to be successful. The accuracy of these criteria becomes more important in large-scale projects. Project success has been described as "achieving much better results than anticipated or normally observing in terms of cost, schedule, quality, safety, customer and contractor satisfaction". Lam et al. (2008) allow the success of construction projects to be evaluated according to critical success factors, compare construction projects, and facilitate the management process in the later stages of the project. There is no stereotypical definition of project success by the construction sector. However, it can be defined as completing the project within the defined sources, in the foreseen time and cost. Construction project development involves many parties, various processes, different stages of the work, and a large amount of input from both the public and private sectors. Its primary purpose is to bring the project to a successful outcome (Takim and Akintoye, 2002). Chan et al. (2001) defined project success as the extent to which the goals and predictions determined in the preliminary preparation phase of the project were achieved at the end of the implementation. Ashley et al. (1987) explained the project success as "achieving much better results than predicted in terms of cost, schedule, quality, safety, customer and contractor satisfaction or observing normally". While some researchers and managers evaluated the project's success as achieving the time, cost, and quality targets, other researchers and managers stated that the project should be evaluated together with other success factors to be considered successful (Mir & Pinnington, 2014). Project success is also the success of the resulting product.

The production efficiency of labor is a critical success factor for construction projects (Jang et al., 2011). Most construction projects suffer from cost overruns and extended construction time due to low productivity rates (Sun and Meng, 2009). Construction projects are products created by workers and managers with intense labor. Therefore, the project's success is directly proportional to the correct and effective management of the workforce. The workforce is described as all the physical and intellectual abilities that a person has to mobilize to produce

valuable things (Turkish Language Association [TDK]). Productivity is the value obtained by dividing the total output obtained from the project process by the total inputs used in the project process.
This research examines laborers' challenges in building an unfamiliar structure at construction sites through a case study. Researchers conducted fieldwork at a wastewater treatment plant construction site in Istanbul, Turkey. In this research, the relationship between the workers' productivity in the construction of the egg-shaped digestion tower structures produced on the construction site and the learning processes was determined by field observations.

2. Learning Processes on Construction Sites

Considering the development of the construction sector in the last 60 years, the complexity of the design and construction stages of the projects can prevent significant improvements and developments in the construction project processes. With the technological improvements in recent years, construction projects have become more unique and complex. The nature of the projects in the construction sector made it difficult to transfer the experiences gained in different projects to the field. "Learning from mistakes" and "learning from past experiences" issues are essential in improving the process in the construction sector. With those learning methods, it is thought that customer satisfaction will increase (Ofori, 2008; Dainty, et al., 2003; Siriwardena, 2015).
Although construction projects frame difficult, complex processes that involve various problems, it is possible to express that these difficulties are beneficial in terms of learning. The individual learning process includes learning and solving a difficulty encountered in an organization on behalf of the organization/company/firm. The studies indicate that there is a gap between the information people need in the field and the information obtained through pieces of training. According to that information, it can be thought that work-based learning is an important learning method for the construction sector (Lensjø, 2021; Musonda and Okoro, 2021). The construction projects are fully implemented in the field, and that work-based learning is continuous for the construction projects (Argyris and Schon, 1998; Siregar, 2018).
The efficiency of construction projects is directly proportional to experience and skill (Kazaz and Ulubeyli, 2007; Khanh et al., 2021; McDermot et al., 2020). Workers must have experience and knowledge of the field in which they will work. Workers who lack experience on the construction site should be teamed up with experienced workers to have the expertise (Schwartz, 2019). In addition, after a worker learns a production and repeats it constantly, the learning curve will increase over time, the time to finish the job will be shortened, and the number of manufacturing will increase (Ugulu and Allen, 2018). Therefore, if workers do the same work with the same team, it will positively affect the workforce productivity.
The construction sector is a sector where productivity increases with the laborers in the field, and the success of projects changes with the labors' performances. The complexity of the design and uniqueness of the projects, the construction technologies, regulations, laws, the construction site's situation, etc., can affect the production of labors. Considering the labors' impact on the projects, increasing labor productivity is important in terms of project success in the construction projects.

3. Labor Productivity on Construction Sites

Labor productivity is an important concept in every sector in developed and developing countries. Increasing labor productivity is a critical factor for the development of the country's economy. According to the values announced by the European Construction Industry Federation in 2020, the construction sector constitutes 9.5% of the gross domestic product (GDP) in the European Union (EU) in 2020 and 6.1% of the total employment in Europe (European Construction Industry Federation, 2021). According to Kazaz and Ulubeyli (2004), with the increase in labor productivity, employees will be able to produce higher-quality jobs by spending less over time and getting overpaid. The employer will be able to do more work with less cost and thus gain more income. According to these factors, the customer will be able to receive cheaper and higher quality services; the country's economy will be able to develop. As a result, the welfare, quality of life, and happiness level of the society will increase. According to Siriwardana and Ruwanpura (2012), increased efficiency in construction projects not only brings profits and gains to companies but can also result in significant cost savings for the construction sector (Mainga, 2017). Therefore, there is a strong need to find innovative methods to increase construction efficiency, both labor and management issues in construction projects.
Labor productivity in construction projects can be defined as the amount of work done per person-hour. In other words, it refers to the working time of the worker in hours for one unit of production (Ugulu and Allen, 2018). Labor productivity should not be confused with the concept of worker performance. Worker performance is the ratio of predicted workforce productivity to the resulting workforce productivity (Kazaz and Ulubeyli, 2004). Delivering a successful product is the goal of everyone working on the construction site. Golchin Rad and Kim (2018), defines workforce productivity as one of the key management factors for completing a project. Labor productivity is a success factor that directly affects the project's cost, time, and quality. It is important for project success that project managers identify the factors that affect workforce productivity and develop these factors and maximize workforce

productivity. If managers increase labor productivity in construction projects, the project's cost will decrease, the construction time will reduce, and the quality will improve. Since labor productivity is a variable measure, it should always be measured and followed up by project managers. According to Kazaz et al. (2016), to increase labor productivity, factors affecting labor productivity should be determined, and the extent to which these factors can be applied in the construction site environment should be determined. Therefore, the determining factors should be followed and measured throughout the production processes. These measurements can also be made by mathematical modeling or various indexing methods. All input and output relationships should be measured and analyzed. With labor productivity measurement, correct and consistent answers to such questions about the level of the project and how to reach better levels can be obtained. With the given answers to such questions, the strategy can be determined accordingly. Kazaz et al. (2008) found that physical factors as working at similar activities, design complexity, and error tolerance were the three most influential motivators in their research. Alinaitwe et al. (2007) examined the effects of 36 factors they identified on productivity in terms of time, cost and quality.
The most critical failure criteria affecting labor productivity in the Uganda construction industry are workers' lack of experience and knowledge, lack of materials and equipment, incomplete or defective construction methods, lack of communication, lack of control, design errors, repetition of works that are not accepted by the control, political insecurity and inadequate weather conditions. Jarkas and Bita (2012) examined the factors affecting labor productivity in the Kuwait construction industry. The most important ten factors affecting labor productivity in the survey they conducted on 45 productivity factors; They identified clarity of technical features, changes during implementation, coordination level between design disciplines, lack of worker control, proportion of subcontracted work, complexity level of design, lack of incentive program, lack of executive leadership, pressure by the engineer, and deficiency and delay in responding to information requests. In the study of El-Gohary and Aziz (2014), the five most important factors affecting construction workforce productivity in Egypt are workforce experience and skills, incentive programs, availability of materials and ease of use, leadership and competence of construction management, and adequacy of work control. Hasan et al. (2018), examined the studies about labor productivity in the last 30 years (1986-2016). As a result of the reviewed studies, the most important factors that reduce labor productivity are lack of control, lack of worker skills and experience, lack of material and equipment, incomplete drawings and specifications, failure to establish a proper communication, re-production, poor site planning, adverse weather conditions, and material orders. When the studies conducted in the field are examined, it is seen that the skill deficiencies of the workers and the complexity of the projects are among the factors that affect the efficiency of the projects.

4. Case Study

4.1. İSKİ Baltalimanı Biological Wastewater Treatment Plant Construction

Kuzu Group started the construction of the İSKİ Baltalimanı Biological Wastewater Treatment Plant on October 02, 2017, to transform the existing pre-treatment plant into a biological wastewater treatment plant with a capacity of 1,296,000 m³ / day (Kuzu Group, n.d.). Kuzu Group distributes the implementation of the construction project by sub-contractors and only employs technical personnel in the construction site. İSKİ is the employer, Kuzu Group is the main contractor, and NFB construction company is the sub-contractor. The existing pre-wastewater pre-treatment plant will be converted into a biological wastewater treatment plant, and the resulting sludge will be burned in sludge digesters to obtain biogas, and the biogas obtained will be used to meet some of the electricity of the facility (Figure 1).

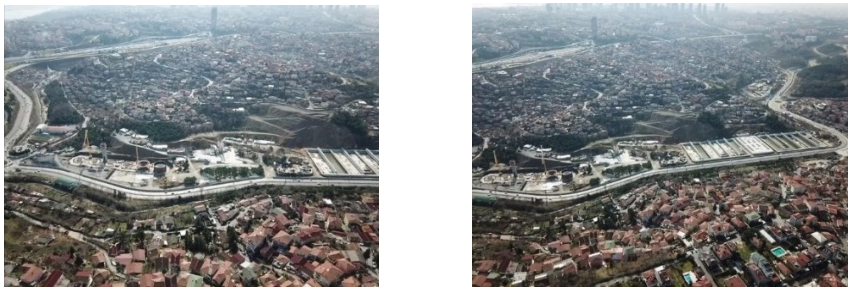

Figure 1. Baltalimanı İSKİ Biological Wastewater Treatment Plant construction site air photos. (Kuzu Group, 2020)

The wastewater coming from the coastal interception tunnel (-11.94 m) and the Cendere tunnels (-7.70 m) will pass through the pre-treatment units. The highly loaded activated sludge system will be treated. The units in its facility; Stone Separator, Coarse Screen, Inlet Pump Unit, Fine Screen Unit, Sand and Oil Holding Unit, Perforated Screen Unit, A Process Pools, Final Settling Tanks, Sludge Disposal Units, Biogas Production and Processing Units. After the facility's construction is completed, the treated water will be transferred from the facility to the existing deep-sea

discharge line via the landline built within the scope of this work. The sludge in the plant will be digested in sludge digesters and biogas will be obtained. One-third of the plant electricity will be met with the biogas generated. Built on an area of 270,000 square meters, the facility will treat wastewater from a population of 3 million.

4.2. Research Methodology

This research examines laborers' challenges in building an unfamiliar structure at construction sites through a case study. Researchers conducted fieldwork at a wastewater treatment plant construction site in Istanbul, Turkey. One of the researchers worked as a controller on behalf of the main contractor in this construction project. The research data were obtained from the daily reports of the construction site and the observations of the researcher working in the field as a controller. In this research, the relationship between the workers' productivity in the construction of the egg-shaped digestion tower structures produced on the construction site and the learning processes was determined by field observations.

4.3. Findings

The treatment plant construction project started on October 02, 2017. The project is aimed to be completed in the summer of 2021. During the application, the buildings are constructed using industrial and wooden formwork systems. As it is a large-scale, complex, and long-term project, it has been determined that labor productivity varies during the construction process. In this section, factors affecting labor productivity during facility construction will be examined.

4.3.1. Working at Similar Activities

In the construction of the treatment plant, there are six egg-shaped reinforced concrete digestion tanks that would construct for the first time in Turkey. Reinforced concrete digestion tanks with a height of 42 m and a diameter of 25.30 m and a thickness of 45 cm are cast in different 15 stages.
For each concrete casting, especially cut wood fill reinforcement is made by the project formwork plan.

Figure 2. Installation of the formwork.

Concrete casting is made with 26 inner and outer formwork models. For each casting, a separate project is made and explained to the workers, and the workers progressed by revising the formworks for each casting according to the formwork project (Figure 2). Labor productivity declines were occurring for workers who did not have such experience before. Since each casting was made using a different formwork model at different angles, the learning curve of the workers did not increase as desired. During the process, workers gained practice in constructing this different form, which they are not used to, and production processes accelerated. However, when it comes to the middle of the egg-shaped structure, the production rate has decreased again due to the change in the form made so far and the increase in the structure's height. For this reason, the time estimations for the construction period did not match with the application.
In this project, complex structure formwork caused slow learning processes. Such projects need skilled workers. These types of projects need experienced teams. However, the learning time of even experienced teams will take longer in the construction of such structures, which are not produced continuously, compared to the structures that are continually manufactured.

4.3.2. Complexity of the Design

The establishment of a scaffolding system along the circumference of the egg-section digester tanks and tanks, which were made for the first time in Turkey, and unique platforms on it, included a separate detail and complexity. Climbing platforms and formwork systems were used in the inner and outer parts of the scaffold system built around the tanks (Figure 3). Separate productions were carried out for each casting separately. The project design and application details of all units were different. Workers had a lot of detailed craftsmanship to learn. Every detail was explained to the workers by the technical staff. Industrial formwork systems used in this structure are a particular

type of material. It was a production that required skill and experience due to the building's construction for the first time. Formwork materials for this building were supplied from the PERI firm. Peri assigned its supervisor to the construction site to explain the formwork system to the workers. However, it was not possible to fully benefit from worker productivity in complex structures with such details.

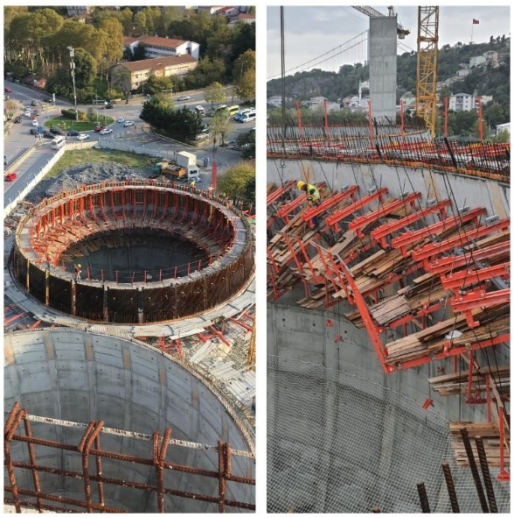

Figure 3. Egg-Shaped digester formwork process detail.

As a solution to this, great care should be taken to ensure that the design and composition of the products facilitate the production and accelerate the production flow during the project phase (Kazaz & Ulubeyli, 2007). In addition, the communication of the technical personnel with the workers must be efficient and healthy. Workers should be given adequate training and information. The same workers should be assigned the same task so that they gain experience and skills. New inexperienced workers should be employed together with experienced workers to gain experience.

5. Conclusions

In literature, the construction projects completed at the targeted time, resource, and cost are defined as successful projects. Due to the unique nature of construction projects, many factors affect these success criteria. Even the economic situation of the countries or inadequate weather conditions at the project time can affect the success of the projects. Labor productivity is also one of the important and critical project factors that can affect the success of the projects.

There are so many researches about labor productivity in the literature. Still, the precautions or preventions that are examined in those researches will not always be useful to increase labor productivity. In construction projects, the experiences are vital that gained together with the applications in the field. Still, due to the unique nature of each project, it is challenging to apply these experiences in the same detail and pattern in every project. Every construction site, every project is a new experience. For this reason, there will be situations where the researches and previous experiences on labor productivity will be insufficient.

In this research, a case study is examined. The case is about a design form applied for the first time in Turkey. The form of the design is egg-shaped, which causes changes of the form at every level of the design. This complex design of the form caused the time and cost estimates in the project to be inaccurate. With the changing of the form at every level, the speed of the construction has decreased rather than increased. Because the workforce working in this form in the field is not familiar with such a complex design form and decreases in labor performance, have been observed in the construction site. Due to such unforeseen problems, construction projects can lead to failures. To cope with such problems, it is important to take precautions such as assigning experienced workers, employing inexperienced teams with experienced teams, having healthy communication between technical personnel and workers, and giving workers detailed training and information about the project in complex design projects. Thus, projects can be completed successfully in determining time, resources, and time with those precautions.

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Conflict of Interests

The authors declare no conflict of interest.

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