Analysis Lean Construction Application to Reduce Material Waste at Bridge Construction Project

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Abstract. This abstract discusses the amount of concrete and steel waste that are produced at the manufacturing stage in Precast Plant as well as examines the processes that cause the generation of waste. This abstract also discusses the implementation of Lean Construction concept in bridge construction projects and the influence of this concept on waste minimization in the construction processes. The study was qualitative research using study case method and also through unstructured interviews to seek information according to the approach used in this research that is Last Planner System. This result of this research proves lean construction contribution to reduce waste.

Keywords: Material waste, bridge, precast, lean construction, last planner system

1. Introduction

The construction project involves many participants (multiparty) to carry out planned activities. Each participant interacts with each other until all scheduled work is finished. All act for their own interests, trying to optimize the use of labor, equipment, and materials they provide. For this reason, an approach is needed to bring the interests of each stakeholder in harmony with the promises to the customer.

Each project is unique in terms of design specifications, methods, administration, and people involved [1]. The method chosen to use during the construction project implementation process will provide a clear picture of the resources that must be available. In the competitive construction world, reducing costs in an effort to increase market competitiveness and profits is a common goal among all construction companies [2]. The three most common metrics for describing productivity are productivity or unit level factors (ratio of labor costs, material, and equipment to output units); labor productivity (working hour ratio to output unit), and productivity factor (schedule ratio for actual working hours).

Productivity in the construction sector experienced a negative development compared to the manufacturing industry. The level of innovation in this sector is too low, considered by many people, so that efforts are needed to improve it. Productivity is closely related to achieving a number of production units at a certain time. Productivity has implications for the duration needed. The right method means more production and or cheaper costs while still making quality as a constraint that must be fulfilled [3]. In the book Total Construction Management Project [4], it explains that planning is well-prepared before the project is implemented. In the project planning phase several main areas to be controlled are:

1. The money plan
2. The time plan
3. Quality standards  
4. Material resources and delivery  
5. Labor supply and productivity  
6. Cashflow projections  

During the process of implementing a project there are three limits that must be controlled, namely costs, quality and time of implementation. To control these constraints, implementation of planning is needed, namely: the method of implementation work, implementation budget, implementation schedule and cash budget. How much effort is used to increase efficiency, as long as the construction process takes place it will still produce waste. There is no accurate method that has been developed to measure the incidence of waste in Indonesia.

The amount of material that is wasted or the waste is the concern of construction implementers because almost all raw materials as inputs for construction are materials produced from non-renewable sources [5]. The responsibility to eliminate waste does not only depend on the Project Manager, but also clients, consultants, suppliers, foremen and workers [6].

2. Methods
This research will be that the implementation of the project must be in accordance with the plan stipulated based on the last planner system consideration. Productivity measured based on the flow of work, for this purpose, is needed in this chapter and will explain the appropriate research method to answer research questions and achieve the research objectives, namely identifying processes that produce waste (waste sources) in precast companies and evaluating the types of waste produced in bridge construction projects in precast companies by using lean construction techniques.

2.1 Research Methods
To obtain these data, the research strategy that will previously be used must be determined. Three factors that influence the type of research strategy are the types of questions that will be used, the control of the events under study and the focus on current or newly completed events (Yin, 1996). In this case the research questions related to what processes produce waste and how lean construction can reduce waste, implementation of field observations and interview interviews must be done because researchers do not have control of events but must focus on what happened during the study. The methodology used in this study covers all the issues concerned with the application of Lean Construction in reducing material waste during the construction process of the bridge project in the production phase in the precast company. In achieving the objectives of previous research, relevant data must be obtained by using a research method that refers to the research strategy suggested by Yin (1996) as shown in the table below.

| Strategy          | Type of Question Used          | Control of Events Researched | Factors Against Current / New Events Completed |
|-------------------|--------------------------------|------------------------------|-----------------------------------------------|
| Experiment        | How, Why                       | Yes                          | Yes                                           |
| Survey            | Who, What, Dimana, How many    | No                           | Yes                                           |
| Archival Analysis | Who, What, Where, How many     | No                           | Yes/No                                        |
| History           | How, Why                       | No                           | No                                            |
| Case Study        | How, Why                       | No                           | No                                            |

Source: Yin, 1996

2.2 Data Analysis

2.2.1. Qualitative Data Analysis
That is a naturalistic research process that is cyclical, not linear because of its cyclical nature and, the research is done repeatedly. The number of repetition periods will depend on the level of depth and
accuracy desired, and the research will focus more on the actual problems that occur in the project. Qualitative research can be done in several codes. The process of each research period consists of:

- Research question.
- Data collection.
- Record data.
- Analyzing data.
- Making research reports

The data used in qualitative research is qualitative data, that is, data can simply be called numbers. Qualitative data has characteristics that cannot be done using mathematical operations such as addition, subtraction and multiplication.

3. Results and Discussions

3.1 Analysis of Production Flow

The design process is a refinement of the exact stage for specifications where the needs and desires that are not clearly changed into requirements, then through various number of steps, for detailed design. Simultaneously, this is the process of detecting problems and solving. The results of the design will be a benchmark for what activities should be carried out.

The Last Planner System discovered by Ballard when implementing Lean Production for the construction industry is a system that focuses on flow (Flow View). During the development of this system the aim was to shift from increasing productivity to increasing reliability/reliability of the work flow. The work flow starts with a complete design result. Furthermore, the work will be determined from the objectives of the design. Pull system is an important part of the Last Planner System.

The results of observations by researchers in the two companies of this case study, although the company indirectly knew about Lean Construction but in practice did it. Basically the concept is to streamline the work so that the process is not too much and spend a large amount of time, costs and energy. In this study, work or activities will be carried out in the production of the same girder for each order. Differences are specifications, number and time of order were made by the client. General description of the production process for PCI GIRDER in the Plant.

Precast is depicted in the Production Flow Chart as Figure 1. Each part of the production process has the same sequence of methods as follows:

1. Ironing
2. Installation of ducting
3. Installation of formwork
4. Casting
5. Demolition of formwork
6. Care
The above diagram explains the work done by company as a precast producer. According to the head of the production division of Company B that the scope of work carried out includes manufacturing, storage in the factory before the product is sent to the project location, product delivery and storage at the project location if the installation is not directly carried out and subsequently the installation. With the completion of the installation work, the work is considered complete. To prove the product according to the client's request, it takes as long as 180 days the maintenance period for the product installed.

3.2 Production Analysis

The construction management process is a process in which detailed design changes into construction/fabrication and plans into days of coordination and process control at the site or at the factory. The flow of material and information in girder production is done in several teams where each team does work spatially. Each team is interrelated to produce products desired by customers. This requires good teamwork and clarity of information and communication to avoid conflict which results in unfinished work.

3.2.1 Planning

Planning is done as detailed as possible until it approaches the actual work. In making a plan we must work with people who will carry out these workshops. The obstacles in the project need to be discussed together and resolved together. Planning this work is not limited to the technical part, but also all aspects involved directly or indirectly in the project.

In planning the implementation of the project, the work is divided structurally into a Work Breakdown Structure. Milestones can be divided based on the distribution of activities within the WBS. From the determination of these milestones, project implementation strategies can be carried out. Based on experience and expertise in project implementation, schedule project (Schedule master) can be arranged.

All work in the factory can be carried out according to the specifications described in the project, especially the agreed time problem. There are no significant problems that cause both parties to sit down
to discuss due to differences in perception. The success of this work is due to the fact that the factory and the client have the same perception of the goods ordered by the client. The production process in the factory is very dependent on a production warrant that explains all information agreed to in the contract, namely costs, quality and time of execution regarding orders from clients. If the production department experiences difficulties due to lack of information from the client, the factory will immediately discuss the matter so that there is no difference in perception between the client and the adhimix.

3.2.2 PPC measurement
There is no significant problem so that the activities carried out are always completed on time. Thus, according to the Last Planner System, PPC for all activities carried out is 100%. This is not too surprising because basically precast manufacturing is a manufacturing industry not part of construction. All of them have been properly systemized so that if the productivity is small then it that should be questioned. But if the role of precast companies is different, for example, as a subcontractor who is the provider and installer of girder the possibility of planned activities that are not completed has a chance. Where in the project activities it was very crowded and filled with workers.

| Task Item | Week I | Week II | Week III | Week IV |
|-----------|--------|---------|----------|---------|
| Planned   | 3      | 3       | 6        | 6       |
| Completed | 3      | 3       | 6        | 6       |
| PPC       | 100%   | 100%    | 100%     | 100%    |

According to experience, usually the main cause of unemployment is not equipment (Equipment). The equipment is of great potential to be the cause of incomplete work, especially cranes during lifting and transporting girder at the project site. The next problem that causes the failure of the project is erratic weather problems at the project location. This is totally out of everyone’s control. Except for all the activities carried out at the factory, the weather problems, especially rain, will not stop work at the factory.

| No | Reason for Noncompletion | Description |
|----|--------------------------|-------------|
| 1  | Client                   | controlled  |
| 2  | Engineering              | controlled  |
| 3  | Material                 | controlled  |
| 4  | Equipment                | controlled  |
| 5  | Craft                    | controlled  |
| 6  | Pre-Requisite            | controlled  |
| 7  | Subcontractor            | controlled  |
| 8  | Plan                     | controlled  |
| 9  | Weather                  | controlled  |
| 10 | Other                    | controlled  |

It is difficult to determine the factors that support success in the product work done. Because the data obtained from this case study is employment data that has been completed. For this reason, the researcher conducted an interview related to the factors that influence the completion and not the completion of the planned work. Based on the experience of the head of production and the production supervisor of company A, the results are as shown in the table above.

3.2.3 Waste Analysis
Conceptualization of the design and construction process as a flow of information and appropriate materials to reduce waste by minimizing information time or material spent waiting to be used, time
spent checking information or material for conformity with requirements, time spent reworking information or material to achieve conformity and time spent on transfer. The fact that PPC achieves 100% value illustrates that to achieve the desired product, the work is done by the right person, the right time and doing the things planned.

3.2.4 Concrete
The production process produces almost no waste. In the calculation of mix design, the technical section provides volume tolerance of up to 2% or in other words for 1 m³, the more tolerable volume is 20 liters of wet concrete. But the production part requires a smaller plant tolerance of 1% so that for 1 m³ of concrete mixture it can be tolerated by 10 liters. Because the dimensions of the girder are large, the volume is directly large, so a small percentage also results in waste that needs attention. Waste in the production process is indeed small, except the remnants of mixer truck washing. This waste is very difficult to know how big it is. Based on experience the production of waste produced does not exceed 3% of the total volume of use of concrete mixtures. This calculation is based on the assumption that the tolerance of 2% is not used and the waste produced by mixer and cracks that occur and the possibilities of aggregates which contain mud are not in accordance with the provisions. But this waste is not just discarded because it can be used as a tool, for brick materials and heaps for homes and roads.

Technically, the quality of this waste is not the same, but the reuse of this waste, for example for bataco, provides economic value. In addition, this is the amount of waste reuse the waste discharged into landfill that will decrease so that pollution to the environment will also decrease.

To reduce the amount of waste produced from the precast production process, in addition to reuse, greater quality improvement is needed. Planning a good job, carrying out work in accordance with the plan must also be supported by better quality workforce and equipment. Increased production of labor can be done by conducting training in accordance with the focus of each work and for equipment that requires regular maintenance.

3.2.5 Iron
The use of this material in large quantities as reinforcement for each product is offered so that ironing work is not focused on one product only. Iron measurements are very important for this. The waste produced by the production process is only 1% in general. This waste is explained in Figure 1 that iron waste is produced in the iron manufacturing process. This process starts with "bestat", which is the process of determining the dimensions and shapes of iron which will be arranged as reinforcement.

Determining the dimensions and shape of this circuit is usually in manual enumeration or by using Microsoft Excel. The use of iron in a number of products causes the desired size to be varied so as to avoid cutting errors and optimize the use of iron more sophisticated. If possible by using a computer-based program that cannot cover data collection of iron stock and deductions in accordance with the provisions.

4. Conclusion
From the two implementation of case studies in precast factories it is known that by using the Lean Construction concept, the waste in the construction project can be reduced. The research was conducted at two different precast companies. The company is a company that provides precast concrete products. Customer service is done by providing precast products including:

1. Beam Column slab System
2. Facade
3. Diaphragm wall, PC Pile
4. PC Slab
5. Girder

Prestressed girder beams are precast beam structures that are used as structural elements over bridges to support gravity loads and live loads, made by monolite and segmental which consists of several small
parts during fabrication in a precast concrete plant and finishes stressed on site before erection work. From the data and discussion carried out in the previous chapter, it can be concluded:

1. During the production process of the girder, the work produces waste as discussed
   a. The process of iron fabrication in cutting iron
   b. Casting on truck mixer or concrete bucket washing
2. The lean construction system that is applied to bridge construction projects as described in the discussion gives the following results:
   a. The amount of waste material produced during the production process of Girder precast is 3% of the planned volume and 1% of the total weight of the plan.
   b. Improving production and decreasing the incidence of concrete and iron waste can be done by providing training to improve the quality of labor, maintenance of equipment and the use of computer-based programs

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