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The implementation of lean construction and six sigma concepts in light brick installation: A case study in Cordova apartment project

The implementation of lean construction and six sigma concepts in light brick installation: A case study in Cordova apartment project

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Abstract. PT Adhi Perkasa Gedung is a construction company engaged in building construction that is a subsidiary of PT Adhi Karya (Persero). Sustainability has become a significant issue this decade, as well as construction projects. Construction companies are required to be able to manage their resources effectively and efficiently through the completion of environmentally friendly projects. PT Adhi Perkasa Gedung as the construction contractor for the Cordova Apartment, strives to minimize waste in light brick installation. The light brick is used as a bulkhead between rooms in the apartment. The problems that occur are the waiting time of light brick procurement, product defects, material handling, and installation process errors. The purpose of this study is to minimize waste in light brick installation using lean construction and six sigma methods. The results of this study indicate the existence of rework due to installation process errors, material quality.

1. Introduction

The Industrial Revolution 4.0 has required that many companies or industries perform their activities effectively and efficiently including companies engaged in construction. One of the industries that has a important impact toward the country is construction industry [1]. Based on Global Construction, the construction industry is intended to put up around 15 % of GDP by 2020 and is estimated in the next few years giving annual growth rate of 4 % [2]. Meantime, compared to other industries, many criticisms are directed toward the construction sector such as wasteful, being inefficient, and a high-risk industry [3]. Those problems on construction sector can be traced to the industry characteristics such as supply chain fragmentation, and also in project management issues like time overruns, cost overruns, safety issue and quality problems in construction project [3]. Whereas, construction companies are required to provide the best service to consumers. Construction services can be measured by delivering a product on time with agreed specifications and good quality. Also, a

successfull projects is when the project completion is efficient in terms of time and cost as well as achieving work efficiency.

PT. Adhi Persada Gedung is demanded in giving products based on customer expectations. To provide quality products at competitive prices and to manage their resources effectively and efficiently through the completion of environmentally friendly projects become one of their strategies. Cordova Apartment is one of PT. Adhi Persada Gedung Projects. In the development process, there are still various identified waste activities in terms of time and cost. The problems that occurred in the Cordova Apartment Projects is the light brick installation. Waiting time for light brick procurement, products defects, excessive inventory, inappropriate processing, and excessive transportation are several waste which often happens.

There are various methods that can be applied to reduce waste on every activity. One well-known method used is the Lean Construction and Six Sigma method. This method has a function to identify and minimize waste in an activity through a process of continuous improvement. Based on previous research, lean construction and six sigma have advantages in terms of financial improvement, quality improvement, and benefits for companies and consumers. Therefore, this study was conducted to minimize waste in light brick installation in Cordova Apartment using lean construction and six sigma methods.

2. Research Methods

2.1. Lean construction

The lean construction is first introduced by the International Group for Lean Construction in Finland in 1993 [4]. Koskela (2002) state that lean construction is approach to reduce materials waste, time, and effort to bring up the maximum value of material, time and effort. Other researchers defined that lean construction has objective to minimize waste, developing productivity, safety and health, and raising value in order to fulfill the costumer's needs [4]–[6]. Lean construction can be said as a production management strategy that has function to assure continuous improvement through dispose of waste of resources that are not meet the customer's need or do not add value [7], [8]. Previous research found that lean construction can set productive flows in motion to develop control systems with the aim of reducing cycle time, raising productivity and revenue and also maximize workforce encouragement during the project life cycle [9]. Nahmens et al. (2011) prove that lean construction has the positive impact on the sustainability such as well-performance of economic, social, and environment[10]. Also, another research show that the lean construction tools such as 5S methods and Last Planner System can significant improve the safety management [16]. In Egypt, lean construction can cut down 15.57 percent the completion time of a project [7]. Lean construction also has a significant impact on reduce construction period, develop project performance rising from lean construction principles, effective coordination and communication, increase the workforce productivity, and reduce reworks and zero value-adding activities [5], [12]. While, The big serious barriers toward lean construction are related with factors of leadership, the company culture, lack of knowledge in adapting the new system, and employee resistance [9].

2.2. Six sigma

Six sigma is a profit-maximizing technique achieved by meeting consumer satisfaction. It was first successfully implemented by the cellular company, 'Motorola' in 1986 and since then, other companies have also adopted it [13]. This technique follows a statistical approach and it is attained by minimizing variations and providing quality services or defect-free products. By reducing deficiencies, fewer materials are wasted and hence an optimal amount of raw materials is completely utilized. As six Sigma seeks to enhance the organization's capacities and satisfy the ever-changing consumer demands, it uses data in order to provide better solutions and statistically speaking, reaching the sixth sigma means that the achieved products or outputs have almost no defects. These are the kind of results that any organization would like to achieve [14].

Improving process performance and achieving high-levels of quality with identifying and disposing of the root causes of waste is becoming an objective of Six Sigma [15]. The Six Sigma has five phases that is Define, Measure, Analyze, Improve, and Control (DMAIC). DMAIC is particularly used to lead Six Sigma Implementation in order to reach company goal [16].

By imitating Six Sigma in construction, company can recognize and reduce waste that leads to customer satisfaction. Previous research also stated that by implementing six sigma in construction projects can increase customer satisfaction at the expected cost and can become business excellence [17], [18]. In addition, the term of continuous improvement and the DMAIC phase may enable company to develop customer values by delivering world-class projects [19], [20].

2.3. Lean six sigma

Manufacturing and other sector industry has known prevalent tool in order to develop operational excellence, namely Lean Six Sigma (LSS). The LSS method adopts the DMAIC phase of the Six Sigma and combined with Lean tools for improving the existing processes [21]. The LSS method is first introduced in the manufacturing sector [22]. After reaching a high achievement, many other sectors tried imitating this method to get better quality of their services and products [23].

There is several definition LSS based on previous researchers. According to Chen and Liu (2009), LSS method is a great strategy for employing a well-structured continuous improvement to effectively and efficient eliminate process variance and raise quality using statistical tools [24]. Laureani et all (2010) "LSS is a business improvement methodology that aims to maximize shareholders' value by improving quality, speed, customer satisfaction and costs: it achieves this through merging tools and principles from both Lean and Six Sigma"[25]. While, based on Burch et all (2016), LSS is a way that concern on improving and developing the finished products quality and continuous improvement by eliminating variation and reducing non-value-add activities [26][27].

The usage of the LSS method in the construction industry is started in 2000 [23]. Many researches has performed using the LSS method but the several did not perform the practical part in construction processes [28]. By eliminating waste, the LSS method can give process stabilization. In contruction project, the LSS could be used to eliminate variability between the customer expectations and his actual experience. Those variabilities are caused by many processes happened in construction such as project planning, material handling, materials supply chain, supplier, contractors and so on. Thus, the objective of Lean is to eliminate wastes and cycle times. In the other side, the aim of Six Sigma is to eliminate process variability. To sum up, based on those objective, the LSS method can provide a way to bring continuous improvement environment by eliminating process variability and cycle times and increasing quality [23].

2.4. Failure mode effect analysis (FMEA)

Failure mode and effects analysis (FMEA) is a technique used concerning on safety and reliability analysis. FMEA has an objective to define, recognize and reduce potential failures, error and problems in design, system, process, and service before sent to the customer [32,33]. Unlike other risk assessment standard, FMEA can evaluate the important potential risk. In addition, this method has significant effect in managing innovation on construction sectors.

Because the construction project is very expensive, the usage of FMEA will play a significant part in perform better. FMEA method recognize activities which can eliminate the chance of potential error and execute the implementation of activities in construction [31]. FMEA can be defined as a set of organized activities that are used to following goals [31]: recognizing and estimation of potential errors in a process or product or material or outcomes results from these errors; determination of activities which can eliminate probability of potential errors occurrences.

3. Results and Analysis

The research was conducted in collaboration with the Cordova Apartment. The research project has adopted the Lean Construction and Six Sigma method to identify or recognize the sources of waste to

give the recommendations or suggestion for improvements. The Lean Six Sigma methodology is based on the five steps called the define, measure, analyze, improve and control (DMAIC) approach that are as follows:

3.1. The "define" phase

The "Define" phase concerns the identification of the problem. There are several waste that occurs in Cordova Apartment Develompment as shown on Table 1.

Table 1. The define phase

No	Waste	Description
1	Overproduction	PT. Adhi Persada Gedung does not produce light bricks but does build light bricks. In the construction process design has been set as a reference in the process of building light bricks, so there is no overproduction process.
2	Defect	The process of building the Cordova Apartment, damage that often occurs is a light brick broken or not according to size. The light brick broken is caused by the process of sending light bricks from suppliers to the project work site. *Critical to quality for defects* is the light brick has appropriate and do not break.
3	Unnecessary Inventory	The need for light bricks will be predicted by the procurement department every month using forecasting method. This method has a low accuracy so that the results is in excess inventory. Another result from excess inventory is the leadtime of light brick are longer so the impact is the light bricks damaged before installation, and increase in storage costs. *Critical to quality for unnecessary inventory* is product leadtime is not more than one month.
4	Inapropriate Processing	Workforces often engage in inefficient activities due to limited equipment and poorly trained workforces. Workforces often disobey work procedures (SOP) so the impact that result in the installation of light bricks is not passing the final quality test or must do rework. *Critical to quality for inappropirate processing* is not rework.
5	Excessive Transportation	The moving of materials and equipment from a storage area is still carried out quite a long distance. This results in an inefficient transportation system. *Critical to quality for excessive transportation* is a short distance in material moving.
6	Waiting	Waiting material often occurs in the work process of the Cordova Apartment project. *Critical to quality in waiting* is no more than 2500 minutes
7	Unnecesary Motion	Workforces at PT. Adhi Persada Gedung often rotates which causes understanding in light brick installation is not appropriate with SOP. In addition workforces often do work by smoking. *Critical to quality for unnecessary motion* is the workforce doing the installation appropriate with SOP.

3.2. The "measure" phase

The "measure" phase is about collecting the right data to visualize the current state of the process to help understand the causes behind the identified problem.

1. Overproduction

   In the installation of light brick is in accordance with SOP. Cordova Apartment has an area of 258.72 m^3 and requires 21473 units of light brick.

2. Defect
   Data on the number of defects that occur in light bricks at the Cordova Apartments in March to July 2019 is shown below:

Table 2. Defects number on March-July 2019

Defect Types	One lot	Defects	%Defects	DPMO	Level Sigma
Broken	3100	500	16,19	322580,65	2,00
Raw Material size is not appropriate	3100	300	9,67	193548,39	2,40

From Table 2 can be seen that the defects with the lowest sigma level are in inappropriate size. It can be said that the defects are more frequent. Therefore, at the analysis phase will be identified why the light brick defects causes of the size is not appropriate.

3. Unnecessary Inventory
   There is an unnecessary inventory on the light bricks installation in the Cordova Apartment shown in the Table 3:

Table 3. Unnecessary inventory data March– July 2019

Month	Unnecessary Inventory	%Overproduction
March	150	4,84
April	100	3,23
May	170	5,48
June	130	4,19
Jule	140	4,52
Total	8400	13,5

4. Inappropriate Processing
   There is one type of inappropriate processing that is the rework process due to the light brick installation is not according to specifications. The rework that occurred due to defect products during March-July 2019 was 4 times dismantling with the number of light bricks which were dismantled 400 light bricks with one times the removal of light bricks equal to 75 minutes.
5. Excessive Transportation
   The excessive transportation in the project is as follows:

Table 4. Excessive transportation data

Start Position	Final Position	Distance (meter)
Material Storage	QC Department	15,09
QC Department	Light brick installation location	5,17

6. Waiting
   This measurement of this waste is when waiting the light bricks from the raw material warehouse to the Quality Control department to be inspected. One lot of the light brick which is 3000 light bricks and the waiting time for one light brick lot is one hour.
7. Unnecessary Motion
   There is several unnecessary movements of workforces such as smoking at work time, resting too long. It caused by workforces changes frequently.

3.3. The "analyze" phase

The analyze phase is carried out using the FMEA method. The use of the FMEA method is done to identify how the light brick, processes, or systems that exist in PT. Adhi Persada Gedung. The FMEA Table as shown below:

Table 5. The FMEA of light brick installation

Process Function Requirement	Potential Failure Mode	Potential Failure Effects	Sev	Potential Causes	Occ	Current Control	Det	RPN
Company policy	Excessive lead time	Holding cost is high	6	Forecasting error	5	Evaluation	6	180
Material procurement	Broken and an appropriate size material	Purchase of new material	6	Supplier selection error	2	Monitoring supplier	5	60
Installation process	Broke during installation	The product cannot be installed	9	Equipment and workforces	2	Light brick installation monitoring	5	90
Weathering	Uneven light brick wall	Rework	9	Oxygen levels are not right	3	Baking Monitoring	5	135
Material Handling	Material handling is too far	Increasing the production process time	6	Layout is not appropriate	10	Evaluation	6	360
Entire Production Process	Rework	Increasing failure cost	9	Defect	9	Increasing preventive cost	9	729
	Waiting is greater than the target	Increasing processing time and production costs	5	Machine breakdown	9	Uncontrollable	7	315

Based on FMEA identification, the biggest potential failure mode is rework, so analysis is needed using a fishbone diagram together with analysis to defect for broken bricks.

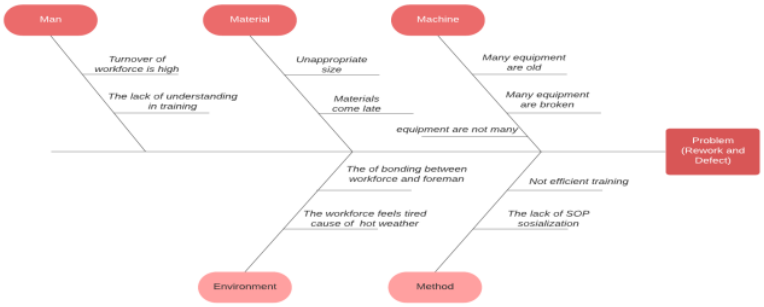

Figure 1. Fishbone diagram of rework and defect

Based on the analysis of fishbone diagrams, it is found that the rework caused by several factors. First, the equipment factor, the equipment is old, many are damaged and the numbers are small. Second, the human factor, many new workforces lack understanding in light brick installation training, the QC department should provide more treatment for workforces. Third is the material factor of the supplier, the material arrival from the supplier is sometimes late and the light brick size is not

appropriate. Fourth, the method factor, lack of SOP socialization to workforces and less efficient training, the foremen and the QC department should be more agile to provide SOP light brick and improve training method so the rework is not happen. Last, the environmental factors, the lack of bonding the foreman and the workforce, foremen should create a comfortable situation toward the workforces.

3.4. The "improve" phase

The "improve" phase will try to find solutions and modifications in the process to eradicate the root. In this phase, we use PDCA (*Plan-Do-Check*-Action) to improve.

1. Plan
   PT Adhi Persada Gedung must arrange the installation of light brick planning carefully. The QC department have to inspect directly the light brick that comes from supplier. The inspection is based on the standard size of light brick which is 10x20x60 cm. Also, the QC department provides regular training for new workforces cause the turnover of the workforce is high.
2. Do
   PT Adhi Persada Gedung must prepare the light brick installation tools such as meter, rubber hammer, meter, thread, and water pass. The foreman conducts supervision for light brick installation workforces such as measuring using the meter and thread and stirring cement.
3. Check
   The foreman and the QC department do the controlling toward the light brick installation such as the straightness of the thread, the installation is according to the standard operation procedure (SOP) of the Cordova Apartment, and the density between glue in the marking line.
4. Action
   The foreman and the QC department write the report to the head of the Cordova Apartment concerning in occurrence happened in installing the light bricks including defects or reworking. Based on the report, it can be a future improvement. In addition, about the workforce, The Cordova Apartment must be strict on SOP, the workforce will be fired when do mistake 3 times in the light brick installation.

4. Conclusion

The conclusions of the research on the application of the lean six sigma method to the Cordova Apartment construction project are as follows:

1. DMAIC is conducted to identified the waste in light brick installation on Cordova Apartment. In the define phase, the VSM method is used to identify actions that are non-value added.
2. There is several waste in this case which is waiting, excess transportation, unnecessary inventory, unnecessary motion, and defects.
3. FMEA method is conducted to identify the biggest waste. Based on the FMEA, RPN value for a potential failure mode overproduction greater than safety stock is 168; leadtime exceeding the limit is 180; broken raw material or not in accordance with the size is 60; break during inspection is 90; uneven light brick is 135; the product moving disctance which far away is 360; rework is 729; waiting is greater than the target is 315. Based on the calculation of the RPN, the highest RPN is the rework. Fishbone diagram is used to identify the cause of the rework.
4. For the improvement, PDCA concept is suggested toward PT. Adhi Persada Gedung. In plan stage, PT Adhi Persada Gedung must arrange the installation of light brick planning carefully. In do stage, PT Adhi Persada Gedung must prepare the light brick installation tools. In check stage, the foreman and the QC department do the controlling toward the light brick installation. In action stage, the foreman and the QC department write the report to the head of the Cordova Apartment concerning in occurrence happened in installing the light bricks

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