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TOTAL QUALITY MANAGEMENT USING PARETO DIAGRAMS AND STATISTICAL PROCESS CONTROL CHARTS (SPC) APPLIED TO PRECAST BEAMS

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This paper presents the application of Total Quality Management Method using Pareto diagrams and Statistical Process Control charts (SPC). These tools can be applied to both the manufacturing and construction sectors. A Pareto diagram can figure out some of the dominant problems of the projects, and SPC can determine whether the data variation is within control limits. SPC can measure the quality of performance in learning curve using the upper-range limit and lower-range limit of the control analysis. A case study was conducted on a precast beams installation at a rental multi-story residential project in Jakarta, Indonesia. Based on the measurement, some data are outside of the control limit due to the problems identified in the Pareto diagram. Further analysis by measuring the Process Capability Ratio (C_p) produces a value <1, indicating that project management needs to be careful about process variation.

Keywords: Quality performance, Learning curve, Variation.

1 INTRODUCTION

The concept of Total Quality Management (TQM) was started with Quality Assurance in the 1920's, then developed into a managerial philosophy (Harsanto 2013). One of the principles related to the implementation of TQM is minimizing variation. It will result in a shortfall in expected targets in terms of economy, product, and cycle time, so variation is the enemy of quality (Escalante 1999). The principles of TQM can also be applied in the construction sector, including the use of statistical controls to measure the variation of productivity (Baweja 1997). Related to this, a learning curve is part of the productivity performance (Hijazi et al. 1992). Research on the application of the learning curve for precast work has been done, since the character of the work is repetitive (Santanu 1999). Furthermore, Pareto diagrams also have been widely applied in the construction sector, among others, mapping the problem of failure (Ortega and Bisgaard 2000).

Based on Pareto diagrams, we can determine the contribution map of issues, while with Statistical Process Control charts (SPC) we could get a picture of the variation of the process, whether or not it was still within control limits. Furthermore, the Process Capability Ratio (C_p) was calculated to assess whether or not the overall process is still able to respond to the variations that exist. The greater the C_p, the less process that produces the damage caused by variations (Finch 2008). This study can answer the following questions:

- What is the application of Pareto diagrams and SPC in the learning curve?
- What is the stability of process of the precast beam installation?
- What is the quality performance of installation of precast beams for this case study?

2 METHODS

A selection of studies was done on precast concrete work because using SPC reduced work time by 11% to 20% (Agustian 2007). In principle, the method of laying work of precast beams consists of phases such as preparation, swing (i.e., moving material within the site by crane), installation, and returning the crane hook to its original position. These case studies were chosen for the installation phase because labor productivity is a crucial problem in that phase compared to other phases.

Data were taken from IAPPI (Ikatan Ahli Pracetak Pratekan Indonesia) in collaboration with a team from Indonesia Research Institute for Human Settlements. The first time step for the model is to make the learning curve start from 2^{nd} to the 7^{th} floor, and look during a stable period (see Figure 1). Estimates of stable periods on the graph below will be tested through SPC, after problems have been previously mapped through a Pareto diagram. SPC is made with an individual graph (Stagliano 2004). Furthermore, process capability is calculated on the 7^{th} floor after repairing of the graph (after deleting points ouside the upper- and lower-range control limits). Calculations were performed with SPSS software.

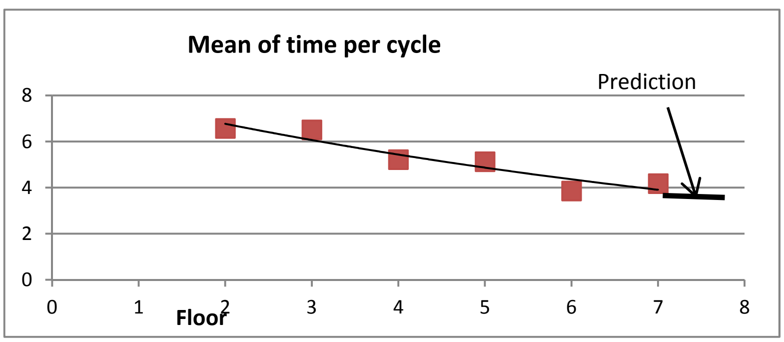

Figure 1. The learning curve of 2-7 floors, predicted stable period in the 7th floor onwards.

Mapping problems through a Pareto diagram has several steps. The first step is mapping the various problems that take more time than average for the whole phase (e.g., utilizing a crane hook: preparation, swing, installation of materials, and returning the crane to its original position) starting from the 2^{nd} floor up to the 7^{th} floor. Some problems are very time-consuming, so that work time per cycle time exceeds the average value (see Figure 2) for the following reasons:

- Linking the steel reinforcement at the ends of beam connection to the junction points, as stated in the A notation in Figures 2 and 3.

- A lack of oil for opening mold or formwork (at preparation phase), as stated in the B notation in Figures 2 and 3.
- Inaccuracy in the dimensions of the beam itself, requiring additional work in cutting parts of the beam, as stated in the C notation in Figures 2 and 3.
- Pipe support is less available, as stated in the D notation in Figures 2 and 3.

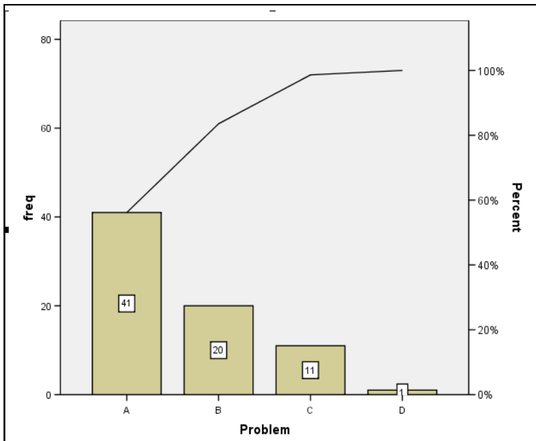

Figure 2. Pareto diagram from 2nd floor to 7th floor for overall phases.

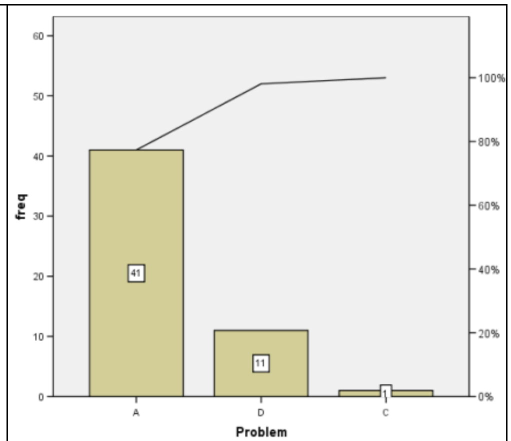

Figure 3. Pareto diagram from 2nd floor to 7th floor for beams installation phase.

Based on Figure 2, 25% of the problems can contribute 60% to the impact of time per cycle that is above average. In Figure 3, 33% of problems contribute 80%. The problem of oil in the mold is removed in Figure 3 because it was done in the preparation phase.

The second step is to map the Pareto diagram mapping problem when the learning curve is predicted to be stable (on the 7th floor).

3 FINDINGS

3.1 Pareto Diagram

Based on Figures 2 and 3, the contribution of the main problem approaches 60%-80%, in the case of Problem A. The result is not much different on the 7th floor. It turns out that Problem A has a major impact on the stability of performance. Table 1 describes this condition. Standard deviation is 2.85 minutes/cycle.

3.2 Statistical Process Control Chart

According to Figure 4 below, two major problems that must be considered are called assignable cause. The first case is an absence of data above the upper control limit (triangles), while in the other case there are 7 consecutive points below the average value (ovals). Based on this graph, we know that Problem A in the Pareto diagram is one of the major causes in the SPC. How does the overall process influence variations in the precast beams installation in the 7th floor? To verify this, we calculated the C_p, after we fixed all above charts so that all data in the upper control limit and lower control limit are included (see Figure 5). Based on that figure, the standard deviation is 0.69 minutes/cycle.

Table 1: Cycle time for installing precast beams on 7th floor.

seq of cycle	time (minute)	seq of cycle	time(minute)	seq of cycle	time(minute)	seq of cycle	time(minute)	seq of cycle	time(minute)
1	4,9	11	3,38	21	1,78	31	4,38	41	2
2	2,63	12	4,02	22	5,03	32	6,03	42	1,45
3	3,13	13	3,93	23	9,98	33	8,35	43	1,53
4	2,3	14	3,38	24	3,55	34	2,82	44	1,17
5	2,78	15	3,57	25	3,75	35	3,93		
6	2,65	16	17,6	26	2,93	36	9,05		
7	1,83	17	7,6	27	3,72	37	6,05		
8	2,5	18	3,28	28	3,75	38	3,08		
9	4,2	19	3,2	29	3,9	39	1,18		
10	4,72	20	3,45	30	4,03	40	5,48		

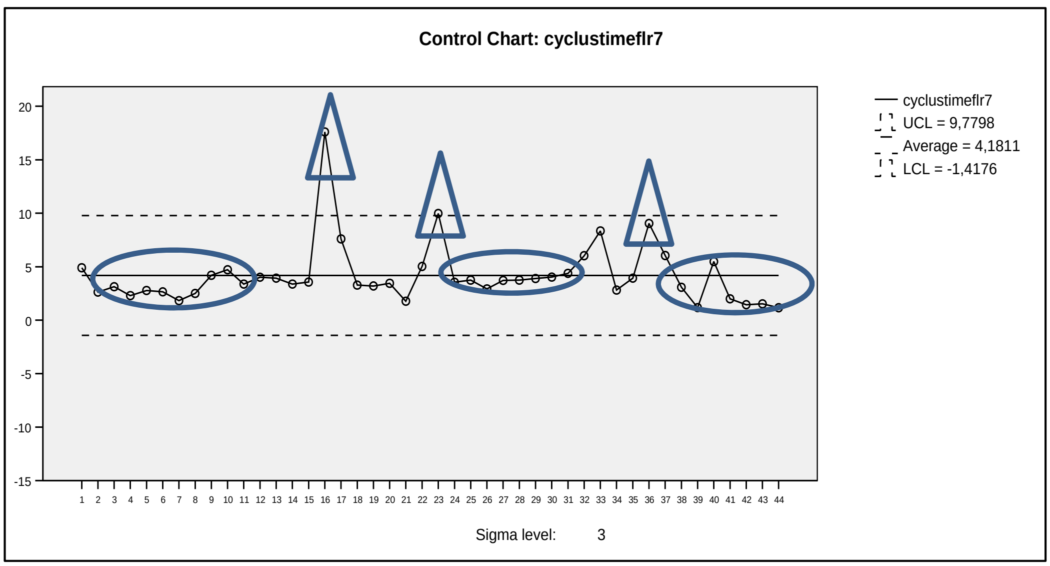

Figure 4: Individual Control Chart for installation of precast beam on 7th floor.

The result of C_p is 0.752, so it can be called a low-process capability criteria. Management is needed to control the performance improvement process as much as possible.

4 CONCLUSION

(1) The source of major problems in the Pareto diagrams is the same as the source of major problems in the data variation in the control chart (for the 7th-floor case).

(2) The capability process is low, indicating that there are problems with variation. Management has to make innovations related to human-resource performance,

especially for problems that cause great impact. This can be done through the selection of workers that are more skilled and professional, more specialists, improved inspection methods, and improved incentive and motivation systems.

(3) Analysis indicates that learning curves have not reached a stable stage yet, and quality performance at the installation of precast beam is insufficient.

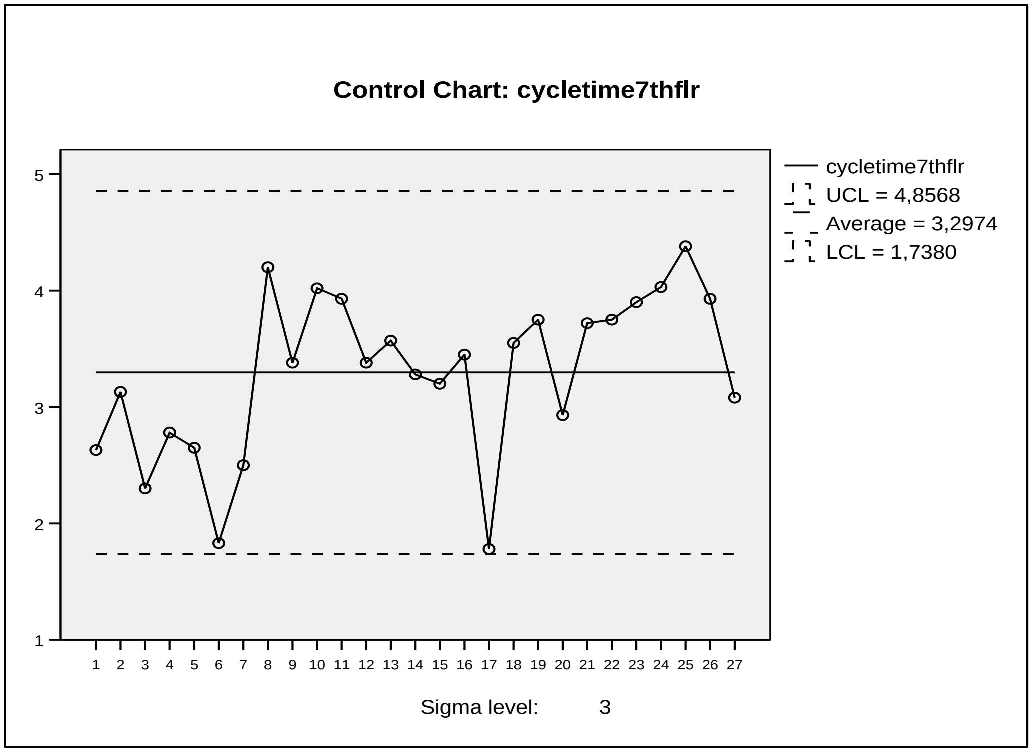

Figure 5: Revision of the Individual Control Chart on 7^{th} floor (Figure 4).

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