Evaluation of Housing Product Quality Using Six Sigma Approach

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***Abstract*— The property industry in Indonesia is one of the areas that has been developing, such as housing. Quality management is very important to be applied in any housing development process. This study aimed to design an evaluation model of housing product quality and assess the quality of housing product in Malang City. By using purposive sampling, this research focused on 9 unit samples. Quality assessment used was standard quality measures, CONQUAS 21 and CIS: 7. The analytical method applied was Six-Sigma approach with DMAIC tools. Moreover, Pareto and Fishbone diagram had also been used as analytical tools. The result revealed that there was a low sigma level in housing product, the average was 2,18 sigma. The critical causes of this problems were unskilled labours, poor materials, and climate changes. The action plans for the improvement that could be implemented were a selection of qualified contractors, job skill training for labours, and a regular inspection according to standard.**

***Keywords*— housing product, quality, variation, Six Sigma, CIS, Conquas.**

I. Introduction

The property industry is one of the areas that has been developing, such as housing. However, housing developments are not always accompanied by positive opportunities. That might be because of any problems and challenges to developers, as in [1]. The developers have great challenges, such as policy alterations and firm competitions. The number of housing offers will provide consumers an option to choose the best housing product. An enterprise may have certain characteristics and distinctive qualities that will give the occupants feel comfortable [2]. The comfortable buildings are affected by some aspects, such as poor quality with any damages. Moreover, the damage always appeared since the construction phase has been completed [3].

Quality management is one of the organisation's strategies to ensure the conformity of products with the requirements of specification [4]. In a housing product, the quality expectation of a person is the consideration in choosing house units. Achievement of quality does not only affect customers' satisfaction but also becomes an important identity for the developers to provide and serve residential products and facilities. The purpose of quality management is to improve the quality and the productivity by eliminating the root cause of product failures. The approaches that could be applied in quality improvement among others are TQM (Total Quality Management), ISO 9000, just in time, gold plating, and Six Sigma. One of the methods that can be applied is Six Sigma. Six Sigma focuses on defect reduction and process management [5]. Six Sigma aims to reduce defects and process variations in performance enhancement. Six Sigma method has been widely used in manufacturing industries. While in a construction industry, the application of Six Sigma was rarely used. Six Sigma could be used as an analytical tool to repair defects that occurred in any processes or objects. No exception, it happened to the construction industry such as real estate development projects.

In Malang city, a housing which was developed by some developers has been increasing significantly. One of the developers which is currently developing is a new one which still has few experiences compared with other developers in Malang City. Based on the interview, the governance of the developer revealed that when the housing product had switched into consumers, there were a lot of complaints was lodged. Whereas, the life of a building was still new. The type of complaints that has been proposed was ceiling damages, wall cracks, seepage on the walls, peeling paint, floor cracks, payment system, inconsistent wide areas, and others. In order to improve the quality of housing product, a quality management on the construction process was required to be conducted.

One of the Six Sigma research that was successfully applied in housing product provided a quality assessment using CONQUAS standard [6]. However, this study still had the qualitative measurement criteria and did not reveal how the evaluation model used to assess the quality of house buildings. So, qualitative and quantitative evaluation models in this assessment were needed. The quality level could be used as a reference to determine the quality level based on physical aspects. Quality improvement was needed to achieve an optimum purpose. Thus this study aimed to establish quantitative and qualitative evaluation models using Six Sigma approach.

II. Method

The type of exploratory research was used in this study [6]. Exploratory research was conducted to find the causes or matters that affected the occurrence of the case. Sampling technique used in this research was purposive sampling with 22 populations of housing units. Total 9 sample units were used in this study. Determination of the sample was used to avoid the possibility of defects beyond developers' or contractors' faults during construction. Quality assessment was done by using a quality assessment system of the building, CONQUAS and CIS. CONQUAS and CIS had been selected as quality assessment tools because they were systems that could achieve the purpose, had standards, had measurement methods, and could classify the defect location.

The analytical method used descriptive analysis by using DMAIC phase. For the stage subsequent analysis,

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Fishbone and Pareto diagrams were also used in this analysis to get an improvement of defect causes. The stage of DMAIC phase can be found in Fig. 1. The quality assessment used in this research was a building quality assessment system, CONQUAS, and CIS. Determination of variation measurement criteria was obtained between research variables which tailored in the internal finishes (architectural view).

Not only based on the standards, the quality assessment criteria were also compiled by expert judgment arguments. The result of compilation can be seen in Table I. So that, it could be assumed as quality measurement criteria. After all stages for getting the measurement criteria were completed, the conclusion model could be used for other research needed. The concept of quality evaluation model is presented in Fig. 2.

III. Model Implementation

The quality evaluation model of housing product was implemented in one of the housings in Malang City. The housing used as a case study was located in residential district, Kedungkandang. The analysis of model implementation used Six Sigma method to get sigma level. DMAIC was used in this analysis to obtain any information related to the causes and the quality variation of the solution.

A. Study Object Profile

A developer used as a case study was a property company, housing specifically. The developer experience was still relatively new, but on the other hand, its employees had quite long experiences in the construction sector. The developer had built at least three housings located entirely in Malang City. Based on the results of preliminary surveys and interviews with the developers, one of the housing had any customer complaints. In fact, the old building was still relatively new, as it was built in the beginning of 2013. The house type at the housing started from type 36 to type 105. The housing type was categorized in a medium house. The number of house lots was 22 units with total 13 units had been built. 9 items available were used as research samples. According to the site plan, house units used as samples in this study were number 3, 6, 10 (type 40), 16, 18, 22, 24, (type 45), and 21 and 20 (type 50).

Based on the existing conditions, customers' complaints such as floor cracks, wall cracks, payment systems, the broken doors, leaks, and more were addressed to the developers. The result of the analysis in this study was using DMAIC phases. Whereas for the improvement and control phases have been described as a descriptive study for developers.

B. Respondent

Respondent in this research was divided into two categories, namely developer and contractor. The developer consisted of a director, supervisors, head of administration, head of marketing, marketing, head of finance. While the contractor comprising a coordination, staff, surveyor, foreman, and head of administration office.

C. Analysis of Model Implementation

1) Definition

The problems occurred in housing products by the developer was the quality variations of the housing. The problem was the damages of house components like floors, walls, ceilings, doors, and windows. The component damages constituted physical damages. The physical damages could be seen by naked eyes clearly. By CONQUAS, the grouping of damage types was based on architectural viewpoint in internal finishes. The type of damages were floor damages (cracks, uneven plaster, not precise plaster, and sounds hollow), ceiling damages (rift ceiling, poor finishing), wall damages (bad finishing, cracks), door and window damages (do not work, damaged accessories, joint or gap damages). The illustration of the quality variation in the housing is attached in Table 2.

The cause of the quality variations that occurred was due to various factors, such as natural phenomena, less of external environment, poor workmanship, lack of motivation, error work procedures, and others. The causes of the quality variation based on the results of the questionnaires can be seen in Pareto chart and Fishbone diagram.

2) Measurement

The result of the survey indicated that there was low sigma levels in housing products by the developer, which had an average sigma 2,18. The lowest sigma level was 1.90 and the highest sigma was 2.54.

3) Analysis

Based on the Pareto and Fishbone diagram, the significant causes of quality variations in the house were lack of skilled labors, poor material quality, climate changes, lack of work inspection, lack of quality management implementation, incompletion job, error procedures, misuse of building materials, claim against contractor, and lack of coordination.

Results of causal diagram were obtained by interviews with internal developers and contractors. Results of brainstorming problems were grouped into main reason by using fishbone diagram.

4) Improvement

To solve the problem of the quality variation in housing product, some action plans were required to be carried out for better improvement. The action plans that were used to overcome limited skilled labors such as more selective for qualified contractors. Therefore, the selection of expert workers was needed, some trainings were required to create some experience workers, as well as updating the technology and construction equipment as they were very important. To improve the material quality, selection of trusted suppliers and always control the incoming materials could be executed. While the method of execution was always carried out according to the standard, to perform inspection and to control during construction could also create a risk analysis for unpredictable factors.

III. Conclusion

The measurement result of the quality variations of product revealed a low sigma level with average sigma 2.18. Furthermore, the sigma level for the quality variations of type showed an average sigma 2.68. The lowest sigma level was found in the type of wall cracks and bad finishing of walls, while the highest sigma level was obtained from the doors or windows which didn't work. The improvement solutions to overcome these

problems were established by any action plans, such as the selection of qualified contractors, implementation of method based on standards and procedures, inspection and control during construction, and creation of a risk analysis for unpredictable factors.

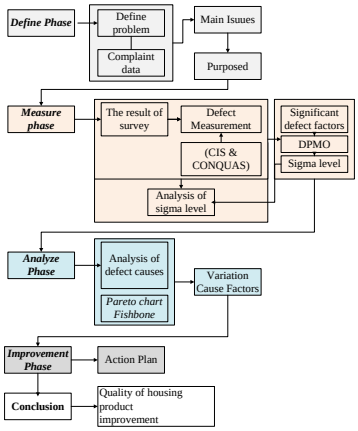


Figure. 1. DMAIC Phase.

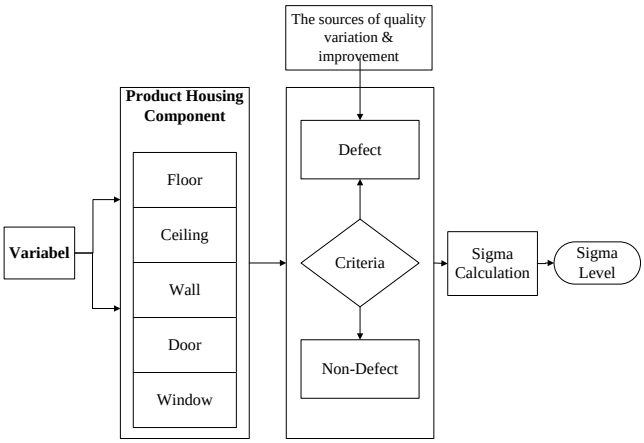


Figure. 2. The Chart of Evaluation Measurement.

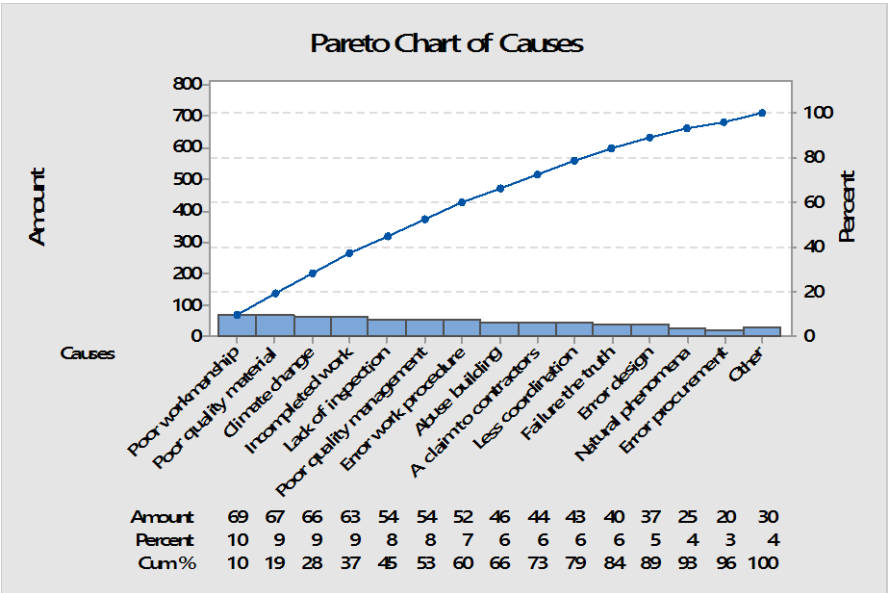


Figure. 3. Pareto Chart

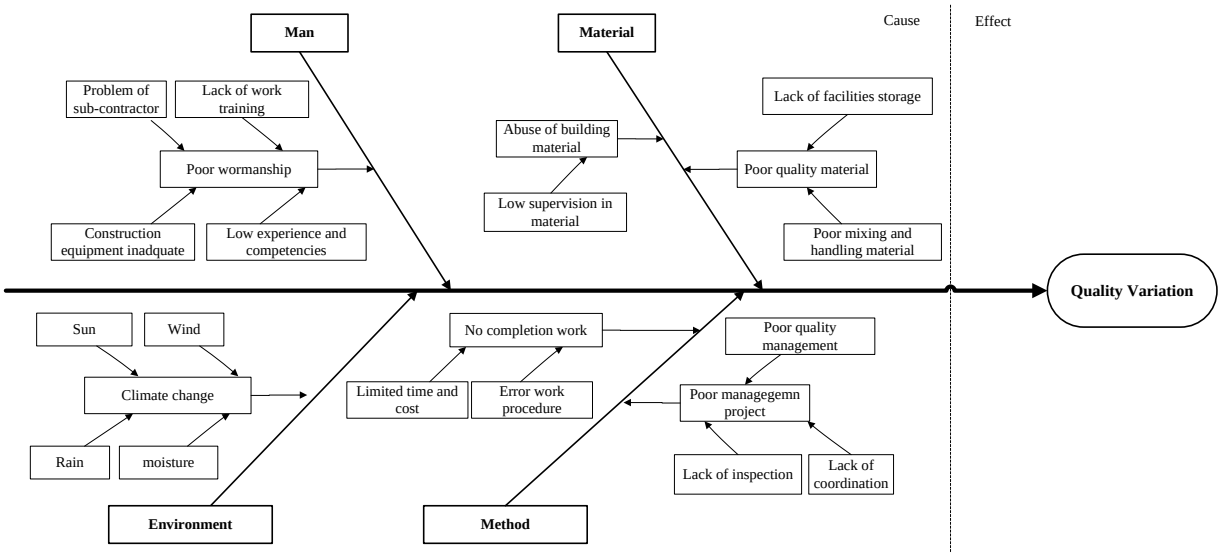


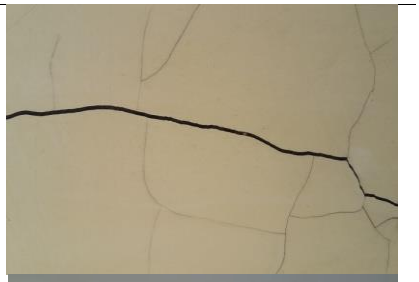
Figure. 4. Fishbone Diagram

TABLE 1.
VARIATION MEASUREMENT CRITERIA

Variable	Measurement Scale			
	1	2	3	4
Jointing on the floor	- Consistent skirting thickness and no visible gap between wall and skirting - Whole ceramic are precision	- One of the ceramics beside wall doesn't have skirting, but all grouts are precision	- One of the ceramic beside wall doesn't have skirting, - And there're many grouts aren't precision	- Side of the floor at wall has an uneven thickness with big gap - And there're many grouts aren't precision (more than 2 pairs of ceramic)
Hollowness floor	No hollow sound on all of the ceramics	Very petty hollow sound on one ceramic	Hollow sound on one ceramic	Big hollow sound on more than one ceramic
Cracking on the floor	No visible damage/defects on all of the ceramics	Scratch on one of the floor	Cracking on one of the floor	Cracking on more than one of the floor
Poor finishing ceiling	- No stain marks - Consistent color tone - No rough/patchy surface - No mosses	- A little dull color - No patchy surface - No mosses	- > 50 % of the surface are duty - Patchy surface - No mosses	- > 50 % of the surface are duty - Patchy surface - Mosses
Jointing on ceiling	Consistent, aligned, and neat	- No gap between ceiling material (asbestos) - No gap between ceiling and wall - But ceiling look no aligned	- There is gap between ceiling material (asbestos) - Or gap between ceiling and wall - Not aligned	- Big gap between ceiling material (asbestos) - And gap between ceiling and wall - Not aligned
Poor finishing wall	- No stain marks - Consistent color tone - No rough/patchy surface - No mosses	- A little dull color - No patchy surface - No mosses	- > 50 % of the surface are duty - Patchy surface - No mosses	- > 50 % of the surface are duty - Patchy surface - Mosses
Cracking on the wall	No visible damage/defects	Crack < 0,5 mm or there is hair line on the wall	Crack > 0,5 – 1 mm	Crack > 1 mm or many hair lines
No function window	- Easy in opening and closing - No sign of rainwater leakage - No squeaky sound during swinging the leaf	- Not easy in opening and closing - Or squeaky sound during swinging the leaf	- Not easy in opening and closing - Or squeaky sound during swinging the leaf - And sign of rainwater leakage	- Not easy in opening and closing - Squeaky sound during swinging the leaf - And sign of rainwater leakage
Accessories defect window	- Lock sets with good fit and aligned - No sign or defective accessories - Rivet at hinge in stainless steel	- Lock sets with good fit and aligned - Sign or defective accessories - Rivet at hinge in stainless steel	- Corrosion and broken window key - But no sign or defective accessories	- Corrosion and broken window key - And there is sign or defective accessories
Joint and gap window	- Consistent gap between window leaf and frame (not more than 5 mm)	- Consistent gap between window leaf and frame (not more than 5 mm)	- Window look not aligned - Gap between window leaf and frame < 5 mm	- Window look not aligned - gap between window leaf and frame > 5 mm

	- No visible gap between window frame and wall - Neat joint between window and wall internally and externally	- No visible gap between window frame and wall - But not aligned		
No function door	- Easy in opening and closing - No squeaky sound during swinging the leaf	- Not easy in opening and closing - Or squeaky sound during swinging the leaf	- Not easy in opening and closing - Or squeaky sound during swinging the leaf	- Really not easy in opening and closing - squeaky sound during swinging the leaf
Accessories defect door	- Lock sets with good fit and aligned - No sign of corrosion in iron - No missing accessories	- Lock sets with good fit and aligned - Sign or defective accessories - No sign of corrosion in iron	- Corrosion and broken window key - But no sign of corrosion in iron	- Corrosion and broken window key - And there is sign of corrosion in iron
Joint and gap door	- Consistent gap between door frame and wall - No visible gap between door frame and wall - Consistent gap between door leaf and frame and not more than 5 mm	- Consistent gap between window leaf and frame (not more than 5 mm) - No visible gap between window frame and wall - But not aligned	- Door look not aligned - gap between window leaf and frame < than 5 mm	- Door look not aligned - Gap between window leaf and frame > than 5 mm

TABLE 2.
QUALITY VARIATION ILLUSTRATION

Component	Defect Group	Illustration
Wall	Crack	
	Finishing	
Floor	Crack	
	Jointing	

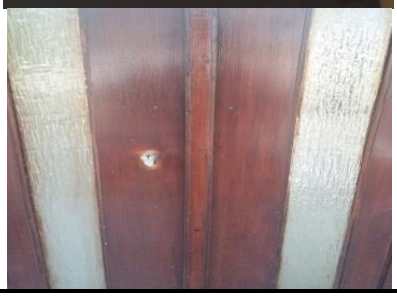
Ceiling	Finishing	
Door	Accessories defect	

TABLE 3.
SIGMA LEVEL OF HOUSING PRODUCT

No.	Type	Component	Defect Chance	DPMO	Sigma
3	40	86	24	279069	2.09
6	40	86	23	267441	2.12
10	40	86	24	279069	2.09
16	45	86	19	220930	2.27
18	45	86	13	151162	2.53
22	45	86	14	162790	2.48
24	45	86	28	325581	1.95
20	50	86	27	313953	1.98
21	50	86	20	232558	2.23
		Average			2.18

TABLE 4.
SIGMA LEVEL OF DEFECT

No.	Defect	Component	Defect Chance	DPMO	Sigma
1	Finishing	180	59	327777	1.95
	Crack	180	64	355555	1.87
2	Crack	45	5	111111	2.72
	Jointing	45	10	222222	2.26
	Hollowness	45	14	77777	1.99
3	Finishing	45	8	177777	2.42
	Jointing	45	10	222222	2.26
4	Functionality	36	5	138888	2.59

	Accessories	36	6	166666	2.47
	Joint & gap	36	2	55555	3.09
	Functionality	27	1	37037	3.29
5	Accessories	27	5	185185	2.40
	Joint & gap	27	3	111111	2.72
		Average			2.46

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