P-ISSN: 2087-1244
E-ISSN: 2476-907X

Quality Function Deployment for Quality Performance Analysis in Indonesian Automotive Company for Engine Manufacturing

Choesnul Jaqin[1], Ahmad Rozak[2]*, and Humiras Hardi Purba[3]

[1-3]Master of Industrial Engineering Program, Mercu Buana University
Jln. Meruya Selatan No.1, Jakarta Barat 11650, Indonesia
[1]sansurijaqin@gmail.com; [2]ahmadrozak66@yahoo.com; [3]hardipurba@yahoo.com

Received: 9th December 2019/ **Revised:** 6th February 2020/ **Accepted:** 7th February 2020

How to Cite: Jaqin, C., Rozak, A., & Purba, H. H. (2020). Quality Function Deployment for Quality Performance Analysis in Indonesian Automotive Company for Engine Manufacturing. *ComTech: Computer, Mathematics and Engineering Applications, 11*(1), 11-18. https://doi.org/10.21512/comtech.v11i1.6164

Abstract **-** The research aimed to improve the quality problem from the previous plant that contributed to the Rate of Quality (RQ) and Overall Equipment Effectiveness (OEE) value in Cylinder Block Machining (CBM). The research was done in one of an automotive company in Indonesia. It had been applying Total Productive Maintenance (TPM) with Kaizen spirit to make continuous improvement even though this company had reached a world-class level on the Japan Institute of Plant Maintenance (JIPM) standard. To express the needs and wants of the current machining plant and improve quality problems from the previous process in the casting plant, the researchers used Quality Function Deployment (QFD) method. From the result, it is known that shrinkage defect at a casting product becomes the priority of the kaizen team to achieve next process customer satisfaction in a machining plant to increase the RQ and OEE value. By implementing improvement based on the highest value of Technical Priorities (TP) from House of Quality (HOQ), it can increase RQ value in CBM from 96,4% in December 2018 to 97,9% in February 2019. Then, OEE value increases from 92% to 93% within two months.

Keywords: Quality Function Deployment (QFD), quality performance analysis, automotive company, engine manufacturing, House of Quality (HOQ)

I. INTRODUCTION

Pawestri, Setiawan, and Linawati (2019) informed that the amount of car sales from 2016 until 2018 had increased very significantly in Indonesia. Similarly, Kusuma and Sharif (2019) stated that from time to time, the demand for cars in Indonesia had also increased well. Thus, to win the competition among car manufacturers, each of them should create various types and models of cars. The tight competition in the automotive industries forces some companies to increase their quality and productivity as well as to reduce the cost. Recently, new automotive brands are joining the competition to win the automotive market in Indonesia. They are from China, India, and Korea.

There are many researchers in the automotive company all over the world. Punnakitikashem, Laosirihongthong, Adebanjo, and McLean (2010) suggested an increasing realization that customers and suppliers were equally important to all organizations in the ASEAN automotive supply chain. Meanwhile, Yadav and Goel (2008) said that automotive companies faced challenges by improving vehicle quality and reducing the lead time of product development for new model product introduction. These conditions put tremendous pressure to achieve customer satisfaction and improve business effectiveness and high-quality products development with fewer resources in a shorter time.

Stylidis, Wickman, and Söderberg (2015) proposed a common terminology and perceived quality definition in the field of the automotive industry. Then, Fragassa, Pavlovic, and Massimo (2014) stated that methods of quick response and clear problem-solving strategies were needed to overcome these barriers in small observations of design specifications or the process of manufacturing suppliers in automotive plants.

In Indonesia, there are also researchers in an automotive company, such as Nurcahyo and Wibowo (2015). They showed that manufacturing strategy was influenced by manufacturing capability. Then,

*Corresponding Author

manufacturing strategy significantly affected the performance of automotive component manufacturers in Indonesia. Next, Romli, Pusnawati, and Siswandi (2019) studied the car sales level in Indonesia.

There is a difference between previous research and this research. The researchers uses the Quality Function Deployment (QFD) method to find out the expectations at the next machining process as the customer. The researchers also coordinate with the previous casting process as the producer that contributes to the defect for the following machining process. By involving all related parties from the casting and machining process, the researchers can develop House of Quality (HOQ) using QFD. Finally, the Kaizen team will improve the problem in the casting plant to increase machining quality performance. Customers are the main focus of all types of industries, both products and services. It is because customers are the most important element in measuring satisfaction with the products and services provided by the company. Customer satisfaction can be measured by how many expectations can be met according to the customers' needs and wants. To measure the level of Voice of Customer (VOC) and choose the right solution in overcoming quality problems, the researchers uses QFD method.

The research is the extension of the previous research which was done at one of the big automotive companies in Indonesia, especially at the engine plant. In this engine plant, it consisted of Crankshaft Machining (CSM), Cylinder Head Machining (CHM), CAM Machining (CAMM), Cylinder Block Machining (CBM), and Engine Assembly (EA). Based on The Japan Institute of Plant Maintenance (JIPM) standard, this company, especially at the engine plant, had achieved a world-class company level through the achievement of Overall Equipment Effectiveness (OEE) score from September till November 2018 as mentioned in Figure 1.

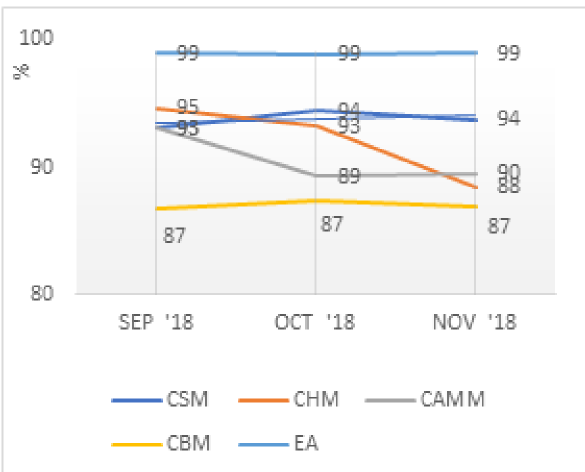


Figure 1 Overall Equipment Effectiveness (OEE) Score at Engine Plant

From Figure 1, it could be seen that the lowest OEE score CBM (87%). Meanwhile, the score of the others was 94% (CSM), 88% (CHM), 90% (CAMM), and 99% (EA). Even though CBM had achieved the world-class target at 85% based on JIPM standard, this company continued to apply the kaizen spirit to improve OEE. The researchers chosed CBM as the research area because it had the lowest OEE than the others. Based on September till November 2018 data for CBM, the researchers calculated the OEE and three factors for Availability (AV), Performance Efficiency (PE), and Rate of Quality (RQ). The calculation result was in Figure 2.

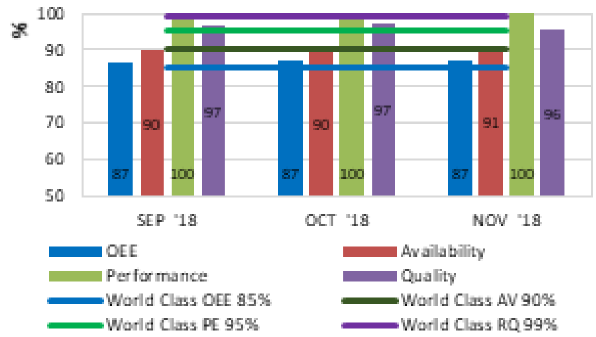


Figure 2 Overall Equipment Effectiveness (OEE) Achievement Versus World-Class Target

Based on Figure 2, the OEE of CBM achieved a world-class target at 85%. Similarly, its AV and PE were at 90% and 95% of the world-class target. However, RQ value was still below the target (99%).

The researchers improve AV score by conducting several activities, according to Rozak, Shadrina, and Rimawan (2019). First, additional Planned Maintenance (PM) in Total Productive Maintenance (TPM) was not just for running components but also for static components that impacted for a long time and frequent machine breakdown. Second, it was additional Autonomous Maintenance (AM) in TPM for production operators that impacted for a long time and frequent machine breakdown. Third, there was a feedback system to other components in the same machine and other similar machines. After implementing these, AV increased from 91% in November 2018 to 96% in December 2018. Then, OEE achievement became 92% of the previous value of 87%, as mentioned in Figure 3.

In Figure 3, OEE of CBM had achieved a world-class target at 85%. Then, AV and PE also achieved world-class target 90% and 95%. However, RQ was still below the target of 99%. Thus, the researchers focused on RQ improvement. The RQ score still had a gap of 3% to the world-class target. According to the RQ problem in September until December 2018, the researchers showed the problem classification found at CBM in Figure 4. The biggest problem of quality at CBM was from casting plant with composition

96,5%. Meanwhile, the quality problem happening at the machining plant was just 3,5%.

To improve RQ in CBM, the researchers focus on the big contribution to the machining quality problem from the casting plant. The researchers chose quality problems happening at the casting plant to increase RQ and OEE in the machining plant, especially for CBM.

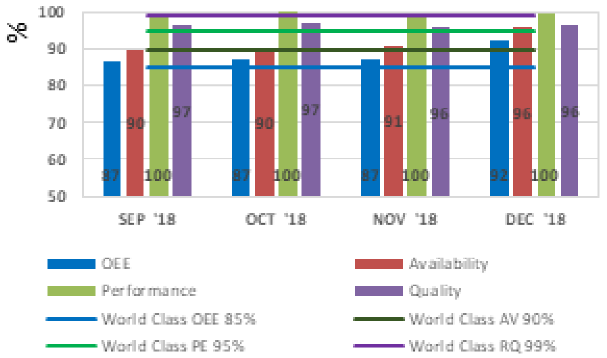


Figure 3 Overall Equipment Effectiveness (OEE) after the First Improvement

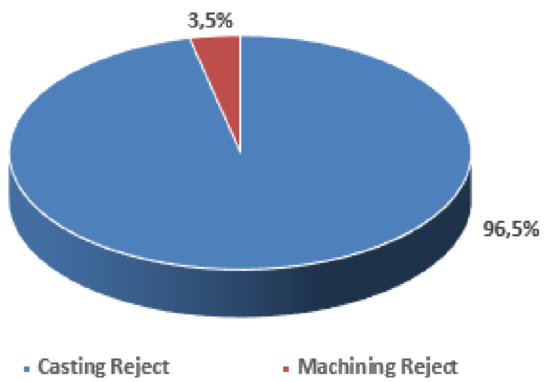


Figure 4 RQ Problem Classification

Al-Najjar (2001) studied the crankshafts manufacturing in Volvo Motor in Sweden. The researcher found that integrated Vibration-Based Maintenance (VBM) deviations in product quality could be detected at an earlier stage compared to usual quality control diagrams. Then, Kermanpur, Mahmoudi, and Hajipour (2008) aimed to help the design process with short lead time and optimize casting parameters to reduce scrap, use less energy, and make better castings. They analyzed the fluid flow across the ceramic filter designed in the gating system. This model was used to investigate the suitability of various cavity moulding and operating systems for each automotive component.

Rosso and Grande (2007) suggested that the casting process exerted a high influence on the fatigue strength properties, in particular the presence of defects like shrinkage cavities. It decreased the fatigue strength because they aided the fracture initiation and propagation.

Cristiano, Liker, and White (2000) stated that QFD as a tool to bring VOC into the process of product development from conceptual design until the manufacturing stage. It started with a matrix that connected customers' desires to product engineering needs, along with competitive benchmarking information, and further matrices. It was used to connect to the design of the manufacturing system ultimately. Similarly, Goetsch and Davis (2014) explained that QFD was a special way of making customer's needs and wants as an integral part of the design and production of a product or service. It was used by the company to translate its customer requirements into technical languages. It was not only used in the manufacturing industry, such as the research of Azizah, Lestari, and Purba (2018) to reduce customer claims related to quality and delivery in automotive component manufacture.

Ionica and Leba (2015), Ko (2015), and Darmawan *et al.* (2017) also implemented QFD as the method for product quality development. Then, Hadi *et al.* (2017) integrated the QFD in new product development. Next, Purba, Prayogo, Wibowo, Pradipta, and Aisyah (2017) conducted research at helmet manufacture by increasing thermal comfort, ergonomics, and safety using QFD in Indonesia.

Schillo, Isabelle, and Shakiba (2017) used QFD for advanced biofuels policies with stakeholder interests. Meanwhile, Rizlan, Purba, and Sudiyono (2018) integrated TPM and QFD. Furthermore, Jin, Ji, Liu, and Johnson Lim (2015) used QFD to translate VOC into engineering characteristics. Then, Moghimi, Jusan, Izadpanahi, and Mahdinejad (2017) utilized MEC-QFD model that incorporated user values into housing design through indirect user participation. Last, Chowdhury and Quaddus (2016) stated that based on the optimization approach to sustainable service design, they used a multi-phased QFD.

The objective of the research is to find a solution to the quality problem from the previous process that impacts the performance in the next process. Specifically, the research aims to improve the quality problem from the previous plant that contributes to the RQ and OEE value in CBM.

II. METHODS

The researchers use the descriptive method. It is because the research is done by analyzing the real situation problems. The research uses QFD method by brainstorming and involving all related parties to collect data, information, suggestion, and new idea from all team members. The research is done at the same company as the previous company. It is one of the big automotive companies in Indonesia, especially at the engine plant. Then, the researchers involve all related parties in CBM team, such as production, inspection, engineering, maintenance, and management team as the customer of casting plant that produces the cylinder block casting product. Total participants from engine and casting plant teams are 20 employees. It consists of the quality department, engineering department, production department, and maintenance department.

The framework of the research is illustrated in Figure 5. It starts from the gap between OEE achievement and OEE company target at CBM. The gap is R*Q*. Based on QFD literature review, there are eight steps from the VOC identification until the priority action plan stage. All steps utilize the focus group discussion from engine and casting plant members. Finally, the Kaizen team proposes and does the countermeasure based on HOQ recommendation.

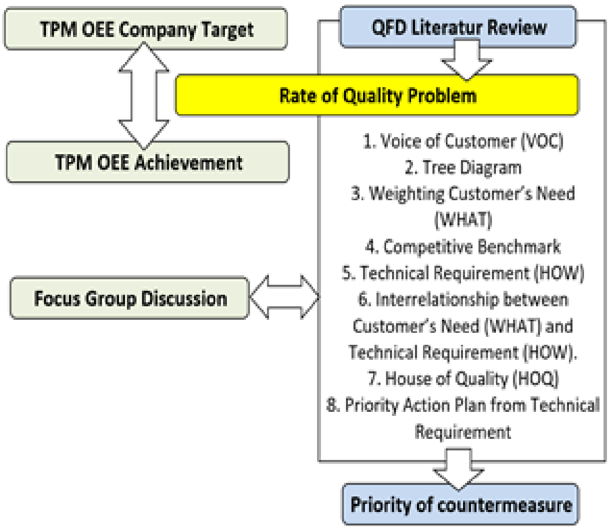


Figure 5 Research Framework

In short, the eight steps in QFD application following the previous researchers are (1) VOC; (2) tree diagram; (3) weighting customer's need (WHAT); (4) competitive benchmark; (5) technical requirement (HOW); (6) interrelationship between customer's need (WHAT) and technical requirement (HOW); (7) HOQ; (8) priority action plan from technical requirement.

The researchers invite the related parties to do brainstorming in the focus group discussion. The researchers use a post-it to gather all quality requirements from the engine plant and all relevant technical requirements from the casting plant team. Those are to increase RQ and OEE at CBM.

The researchers use five steps in collecting VOC following previous researchers. First, participants are gathered in one area. Second, the researchers explain to the participants to get their expectations of maintenance performance, especially RQ problem. Third, the researchers also explain the rules for collecting VOC. For example, the engine plant team writes their needs and wants in a post-it sheet. One post-it is only for one requirement. Participants are allowed to write all the requirements related to RQ. Fourth, the engine plant as participants is not permitted to fill the name or personal identification on the post-it. Fifth, The researchers divide the content of post-it into two categories, namely, process quality and transport quality.

Engine plant participants as customers are involved from the first to the eighth step. Meanwhile, the casting plant as a producer involved is from the fifth to the eighth step. Those are for identifying and weighting the customers' needs, technical requirements, the interrelationship between customers' needs and technical requirements, competitors' selection, target for each technical requirement, and priority of action plan. All participants have the same spirit of improving TPM performance through QFD method for this continuous improvement in the project.

III. RESULTS AND DISCUSSIONS

QFD, as a tool to translate VOC to be technical language, requires eight steps. The first step is grouping VOC. To obtain this information, the researchers collects data from all related parties that correlate to CBM. The purpose is to know what customer needs and wants related to the quality of this product. This primary information is gained based on the report from September to December 2018. It consists of casting process quality and transportation quality problems at CBM. There are two groups of quality problems. First, it is casting process quality improvement with five quality requirement items. Those are no intake manifold bosh shrinkage, no air condition bosh shrinkage, no engine number surface pinhole, no shiftner bosh shrinkage, no cylinder head surface shrinkage. Second, it is transport quality improvement with three quality requirement items. There are no chipped part, no crack, and no broken part. VOC gathered from the machining plant team can be seen in Table 1.

Table 1 Two Categories of Voice of Customer (VOC)

Casting Process Defect	Transportation Defect
No Intake Manifold Bosh Shrinkage	No Chipped Part
No Air Condition Bosh Shrinkage	No Crack
No Engine Number Surface Pinhole	No Broken Part
No Shiftner Bosh Shrinkage	
No Cylinder Head Surface Shrinkage	

The second step is the tree diagram for mapping the issues from the VOC from the first step. This tree diagram shows customer's needs and wants from the casting process and transport quality improvement. These requirements are for quality improvement in customer satisfaction. It can be seen in Figure 6.

The third step is weighting VOC that had been decided in the first step. This step is to know the importance level of each customer's needs and wants from VOC. The weighting of the VOC is done by the machining plant team using the brainstorming method. The weighing scale is from 1 to 5, which 1 is the lowest priority, and 5 are the highest. This weighting score is decided based on the number of reject ratio and cost. The result of each customer's needs (WHAT) and weighting of customer's needs are shown in Table 2. The highest score is customer's needs for intake manifold bosh shrinkage. Meanwhile, the second position is air condition bosh shrinkage, and the third position is pinhole at engine number surface. Moreover, the transport quality gets the lowest scale.

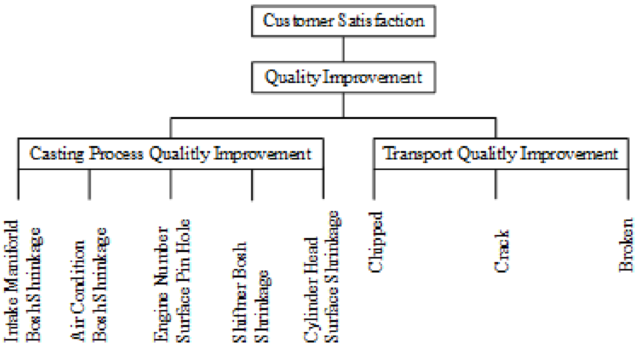


Figure 6 Two Categories of Voice of Customer (VOC)

The second step is the tree diagram for mapping the issues from the VOC from the first step. This tree diagram shows customer's needs and wants from the casting process and transport quality improvement. These requirements are for quality improvement in customer satisfaction. It can be seen in Figure 6.

Table 2 Customer's Needs and Weighting Customer's Needs

Customer's Needs (WHAT)	Weight of Needs
No Intake Manifold Bosh Shrinkage	5
No Air Condition Bosh Shrinkage	4
No Pin Hole at Engine Number Surface	3
No Shiftner Bosh Shrinkage	2
No Cylinder Head Surface Shrinkage	2
No Chipped Part	1
No Crack	1
No Broken Part	1

The third step is weighting VOC that had been decided in the first step. This step is to know the importance level of each customer's need and wants from VOC. The weighting of the VOC is done by the machining plant team using the brainstorming method. The weighing scale is from 1 to 5, which 1 is the lowest priority, and 5 are the highest. This weighting score is decided based on the number of rejected ratio and cost. The result regarding each customer's need (WHAT) and weighting of needs are in Table 2. The highest score is customer's needs for intake manifold bosh shrinkage. Meanwhile, the second position is air condition bosh shrinkage, and the third position is pinhole at engine number surface. Moreover, the transport quality gets the lowest scale.

The fourth step is product analysis from competitors. This step aims to find out the advantages and disadvantages of their product. The competitors chosen are the suppliers of casting components to the machining plant. The researchers and the brainstorming team identify the score for each item that mentions in the planning matrix by using the same scale of needs and wants of the customer. The result of brainstorming is to see the position in the performance of casting plant quality. In the planning matrix, it needs to calculate the Improvement Factor (IF) by using the following data of the Planned Customer Service Rating (TPCSR) and CS Rating Researcher Company (CSRRC). It uses Equation (1) as follows:

$$IF = ((TPCSR - CSRRC) \times 0{,}2) + 1 \quad (1)$$

To calculate the value of Overall Weighting (OW), the researchers use the data of Weight of Customer Importance (WCI), IF, and Sales Point (SP). It is done by Equation (2).

$$OW = WCI \times IF \times SP \quad (2)$$

To calculate the value of Percent of Total Weight (PTW), the researchers use the data of OW and Total Overall Weighting (TOW) utilizing Equation (3).

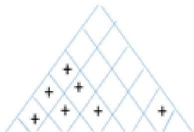
$$PTW = (OW / TOW) \times 100 \quad (3)$$

The comparison from the product and two competitors has the same score for each VOC. The machining plant team decides that planning customer service rating for casting process quality improvement is 4. Then, planning customer service rating for transport quality improvement is 5. Based on PTW calculation using Equation (1), the researchers can decide the priority of VOC. It is based on the highest PTW value. For example, no intake manifold bosh shrinkage is 28%. Then, no air condition bosh shrinkage has 22,4% score of PTW. Next, no pinhole at the engine number surface is 16,8%. The result is shown in Figure 7.

The fifth step is technical requirements (HOW) for determining the technical aspect of the casting plant team to meet customer's needs in CBM. The researchers, casting plant, and machining plant teams identify what technical requirement is needed to improve customer's needs. Brainstorming results in casting recycle sand arrangement, casting

Customer Needs (WHATs)	Weighing of Customer Needs	Interelationship Matrix	CS Rating Reasearcher Company	CS Rating Competitor (A)	CS Rating Competitor (B)	Our Planned CS Rating	Improvement Factor	Sales Point	Overall Weight	% of Total Weight
			Planning Matrix							
No Intake Manifold Bosh Shrinkage	5		3	3	3	4	1.2	1.5	9.0	28.0
No Air Condition Bosh Shrinkage	4		3	3	3	4	1.2	1.5	7.2	22.4
No Engine Number Surface Pin Hole	3		3	3	3	4	1.2	1.5	5.4	16.8
No Shiftner Bosh Shrinkage	2		4	4	4	4	1.0	1.5	3.0	9.3
No Cylinder Head Surface Shrinkage	2		4	4	4	4	1.0	1.5	3.0	9.3
No Chipped	1		5	5	5	5	1.0	1.5	1.5	4.7
No Crack	1		5	5	5	5	1.0	1.5	1.5	4.7
No Broken	1		5	5	5	5	1.0	1.5	1.5	4.7
Note, CS : Customer Satisfaction			Total						32.1	100

Figure 7 Competitive Benchmark



	Weighing of Customer Needs	Casting recycle sand arrangement	Casting material parameter standard control	Die casting sprue improvement	Casting mould construction modification	Casting product box improvement	Casting product handling improvement	CS Rating Reasearcher Company	CS Rating Competitor (A)	CS Rating Competitor (B)	Our Planned CS Rating	Improvement Factor	Sales Point	Overall Weight	% of Total Weight
No Intake Manifold Bosh Shrinkage 1	5	●	●	●	●			3	3	3	4	1.2	1.5	9.0	28.0
No Air Condition Bosh Shrinkage 2	4	●	●	●	●			3	3	3	4	1.2	1.5	7.2	22.4
No Engine Number Surface Pin Hole 3	3	●	●	●	●			3	3	3	4	1.2	1.5	5.4	16.8
No Shiftner Bosh Shrinkage 4	2	●	●	●	●			4	4	4	4	1.0	1.5	3.0	9.3
No Cylinder Head Surface Shrinkage 5	2	○	●	●	○			4	4	4	4	1.0	1.5	3.0	9.3
No Chipped 6	1	△	△	△	△	●	●	5	5	5	5	1.0	1.5	1.5	4.7
No Crack 7	1	△	△	△	△	●	●	5	5	5	5	1.0	1.5	1.5	4.7
No Broken 8	1					●	●	5	5	5	5	1.0	1.5	1.5	4.7
Technical Priorities		233	251	251	233	41	41								
% Total Priorities		22	24	24	22	3.9	3.9								
Rate of Quality at Reasearcher Company		6	6	6	6	9	9								
Rate of Quality at Competitor (A)		7	7	7	6	9	9								
Rate of Quality at Competitor (B)		7	7	7	6	9	9								
Design Target		7	8	8	7	9	9								

Note: ● 9 = Strong Relationship
○ 3 = Medium Relationship
△ 1 = Weak Relationship
CS = Customer Satisfaction

Figure 8 Complete HOQ

material parameter standard control, die casting sprue improvement, casting mould construction modification, casting product box improvement, and casting product handling improvement.

The sixth step connects between WHAT (VOC) and HOW (technical requirement) using symbols. This symbol identifies how strong the relationship between customer's needs as WHAT and technical requirements as HOW. The researchers use scales of significance from 1 to 9. The lower number indicates a weak relationship. Meanwhile, a higher number means a stronger one. The interrelationship rating of the technical requirement is divided become three categories, namely weak (1), medium (3), and high (9).

The seventh step is HOQ. In this step, the researchers select the values of the design target of the technical requirements. The brainstorming team compares the technical requirement implementation between casting plant with two external casting competitors. Casting competitors get higher score compared to the casting plant for following technical requirements. For example, there are casting recycle sand arrangement, casting material parameter standard, and die casting sprue improvement. In HOQ, the researchers need to calculate Technical Priorities (TP) with Equation 4. Then, to complete the HOQ, the researchers also need to calculate the Percentage of Total Priorities (PTP) with Equation (5).

$$\begin{aligned} TP = {} & \textit{(Interrelationship between HOW and WHAT}_1 \times \textit{Overall Weighting of WHAT}_1\textit{)} \\ & + \textit{(Interrelationship between HOW and WHAT}_2 \times \textit{Overall Weighting of WHAT}_2 \\ & + \textit{(Interrelationship between HOW and WHAT}_8 \times \textit{Overall Weighting of WHAT}_8 \end{aligned} \tag{4}$$

$$PTP = \textit{(Technical Priorities}_1 \textit{ /Sum Score of Technical Priorities)} \times 100 \tag{5}$$

The example to calculate TP of casting recycle sand arrangement is (9 × 9,0) + (9 × 7,2) + (9 × 5,4) + (9 × 3,0) + (3 × 3,0) + (1 × 1,5) + (1 × 1,5) + (0 × 1,5) = 233. Meanwhile, the example to calculate PTP of casting recycle sand arrangement is (233 / (233 + 251 + 251 + 233 + 41 + 41)) × 100 = 22%.

The complete HOQ is in Figure 8. Then, the brainstorming team put the mark to indicate the relationship between VOC and technical requirements. The colored circle suggests a strong relationship, circle for a medium relationship, and triangle for weak relationship. Meanwhile, no mark indicates no relationship. Furthermore, the brainstorming team put the mark to indicate the relationship between each technical requirement. The plus sign (+) shows that there is a relationship between technical requirements.

The eighth step is the priority action plan from technical requirements. To increase RQ of CBM, the researchers can choose the priority of technical requirements from HOQ. The first priority is the technical requirement that has the highest point to improve casting shrinkage problems. Based on HOQ, the researchers can find the top score of technical priorities for further improvement. There are casting material parameter standard control (251) and die casting sprue improvement (251). Other recommendations to improve the quality problem will be made in the next activity.

The improvement based on the high score of technical priorities in HOQ can be conducted in two steps. First, the casting material parameter standard control is done by additional measuring tools for confirmation sampling since the middle of January 2019. Second, die casting sprue improvement is by modification from the upper runner till the lower one. Then, it becomes directly to a lower runner from the sprue gate since the end of January 2019.

At the end of February 2019, the researchers can reduce casting reject because of the shrinkage problem. It is reduced by 42,6%. Then, the RQ of CBM increases from 96,4% in December 2018 to 97,9% in February 2019. Last, OEE value increases from 92% in December 2018 to 93,0% in February 2019. The comparison result between before and after improvement can be seen in Figure 9.

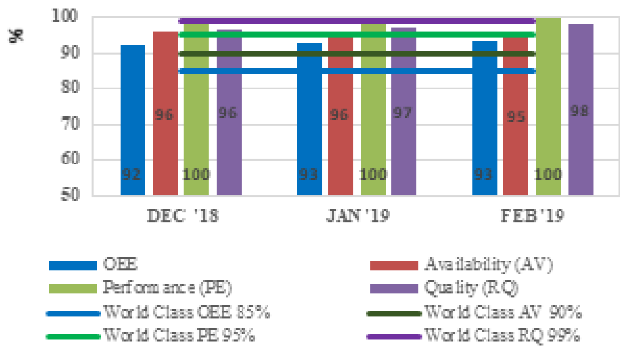


Figure 9 OEE Before and After the Second Improvement

IV. CONCLUSIONS

This research shows that through QFD method, it can contribute to TPM performance in this company. The impact of this research and improvement at the casting plant is the reduction of casting reject ratio at CBM. Then, it increases RQ from 96,4% in December 2018 to 97,9% in February 2019. Similarly, OEE value rises from 92% in December 2018 to 93% in February 2019 by improving several things. Those are additional measuring tools for confirmation sampling of casting material parameters and casting mould construction/modification from the upper runner system to be a lower runner from the sprue. The researchers can use QFD method combined with TPM to improve quality problems in the Indonesian automotive company. Moreover, future researchers can observe the remaining defects from casting and machining plant to increase the value of RQ and OEE higher.

REFERENCES

Al-Najjar, B. (2001). A concept for detecting quality deviation earlier than when using traditional diagram in automotive: A case study. *International Journal of Quality & Reliability Management*, *18*(9), 917-940. https://doi.org/10.1108/02656710110407118

Azizah, I. N., Lestari, R. N., & Purba, H. H. (2018). Penerapan metode Quality Function Deployment dalam memenuhi kepuasan konsumen pada industri komponen otomotif. *Jurnal Teknik Industri, 19*(2), 127-136. https://doi.org/10.22219/jtiumm.vol19.no2.127-136

Chowdhury, M. M. H., & Quaddus, M. A. (2016). A multi-phased QFD based optimization approach to sustainable service design. *International Journal of Production Economics*, *171*(January), 165-178. https://doi.org/10.1016/j.ijpe.2015.09.023

Cristiano, J. J., Liker, J. K., & White, C. C. (2000). Customer-driven product development through Quality Function Deployment in the U.S. and Japan. *Journal of Product Innovation Management*, *17*(4), 286-308. https://doi.org/10.1016/S0737-6782(00)00047-3

Darmawan, H., Purba, H. H., Rezeki, R., Hidayat, N., Siregar, A. R., Retna, F., & Aisyah, S. (2017). Product development strategy with Quality Function Deployment approach: A case study in automotive battery. *Management Science Letters*, *7*(12), 601-610. https://doi.org/10.5267/j.msl.2017.8.005

Fragassa, C., Pavlovic, A., & Massimo, S. (2014). Using a total quality strategy in a new practical approach for improving the product reliability in automotive industry. *International Journal for Quality Research*, *8*(3), 297-310.

Goetsch, D. L., & Davis, S. (2014). *Quality management for organizational excellence: Introduction to total quality.* Harlow: Pearson.

Hadi, H. A., Purba, H. H., Indarto, K. S., Simarmata, R. G. P., Putra, G. P., Ghazali, D., & Aisyah, S. (2017). The implementation of Quality Function Deployment (QFD) in tire industry. *ComTech: Computer, Mathematics and Engineering Applications*, *8*(4), 223-228. https://doi.org/10.21512/comtech.v8i4.3792

Ionica, A. C., & Leba, M. (2015). QFD integrated in new product development - Biometric identification system case study. *Procedia Economics and Finance*, *23*, 986-991. https://doi.org/10.1016/s2212-5671(15)00454-2

Jin, J., Ji, P., Liu, Y., & Johnson Lim, S. C. (2015). Translating online customer opinions into engineering characteristics in QFD: A probabilistic language analysis approach. *Engineering Applications of Artificial Intelligence*, *41*(May), 115-127. https://doi.org/10.1016/j.engappai.2015.02.006

Kermanpur, A., Mahmoudi, S., & Hajipour, A. (2008). Numerical simulation of metal flow and solidification in the multi-cavity casting moulds of automotive components. *Journal of Materials Processing Technology*, *206*(1-3), 62-68. https://doi.org/10.1016/j.jmatprotec.2007.12.004

Kusuma, F. A., & Sharif, O. O. (2019). Analisis customer value index dalam memilih mobil hatchback di Indonesia. *E-Proceeding of Management, 6*(3), 5498-5509.

Ko, W. C. (2015). Construction of house of quality for new product planning: A 2-tuple fuzzy linguistic approach. *Computers in Industry*, *73*(October), 117-127. https://doi.org/10.1016/j.compind.2015.07.008

Moghimi, V., Jusan, M. B. M., Izadpanahi, P., & Mahdinejad, J. (2017). Incorporating user values into housing design through indirect user participation using MEC-QFD model. *Journal of Building Engineering*, *9*(January), 76-83. https://doi.org/10.1016/j.jobe.2016.11.012

Nurcahyo, R., & Wibowo, A. D. (2015). Manufacturing capability, manufacturing strategy and performance of Indonesia automotive component manufacturer. *Procedia CIRP*, *26*, 653-657. https://doi.org/10.1016/j.procir.2014.07.046

Pawestri, V., Setiawan, A., & Linawati, L. (2019). Pemodelan data penjualan mobil menggunakan model autoregressive moving average berdasarkan metode bayesian. *Jurnal Sains dan Edukasi Sains*, *2*(1), 26-35. https://doi.org/10.24246/juses.v2i1p26-35

Punnakitikashem, P., Laosirihongthong, T., Adebanjo, D., & McLean, M. W. (2010). A study of quality management practices in TQM and non-TQM firms: Findings from the ASEAN automotive industry. *International Journal of Quality & Reliability Management*, *27*(9), 1021-1035. https://doi.org/10.1108/02656711011084819

Purba, H. H., Prayogo, H., Wibowo, R., Pradipta, Y., & Aisyah, S. (2017). Increasing the thermal comfort, ergonomics and safety of helmet by using of Quality Function Deployment method: A case study in Indonesia. *Journal of Scientific and Engineering Research*, *4*(7), 184-192.

Rizlan, W., Purba, H. H., & Sudiyono. (2018). Performance maintenance analysis using QFD method: A case study in fabrication company in Indonesia. *ComTech: Computer, Mathematics and Engineering Applications*, *9*(1), 25-35. https://doi.org/10.21512/comtech.v9i1.4456

Romli, I., Pusnawati, E., & Siswandi, A. (2019). Penentuan tingkat penjualan mobil di Indonesia dengan menggunakan Algoritma Naive Bayes. *E-Prosiding SNasTekS 2019*, *1*(1), 367-380.

Rosso, M., & Grande, M. A. (2007). Influence of the casting process on the properties of AI based automotive components. In *Advanced Materials Research* (Vol. 23, pp. 25-32). Trans Tech Publications Ltd. https://doi.org/10.4028/www.scientific.net/AMR.23.25

Rozak, A., Shadrina, A., & Rimawan, E. (2019). Kaizenin world class automotive company with reduction of six big lossesin cylinder block machining line in Indonesia. *International Journal of Innovative Science and Research Technology*, *4*(7), 339-344.

Schillo, R. S., Isabelle, D. A., & Shakiba, A. (2017). Linking advanced biofuels policies with stakeholder interests: A method building on Quality Function Deployment. *Energy Policy*, *100*(January), 126-137. https://doi.org/10.1016/j.enpol.2016.09.056

Stylidis, K., Wickman, C., & Söderberg, R. (2015). Defining perceived quality in the automotive industry: An engineering approach. *Procedia CIRP*, *36*, 165-170. https://doi.org/10.1016/j.procir.2015.01.076

Yadav, O. P., & Goel, P. S. (2008). Customer satisfaction driven quality improvement target planning for product development in automotive industry. *International Journal of Production Economics*, *113*(2), 997-1011. https://doi.org/10.1016/j.ijpe.2007.12.008