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Performance Maintenance Analysis Using QFD Method: A Case Study in Fabrication Company in Indonesia

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***Abstract* -** This research aimed to determine the needs and wants of production and management team to improve the machine and performance maintenance. Voice of the Customer (VOC) method was used to capture the needs and wants of production and management team. Meanwhile, the method of Quality Function Deployment (QFD) was used to translate the needs and wants of production and management to the technical requirement that should be done to improve machine and performance maintenance. Moreover, Total Productive Maintenance (TPM) was a part of technical requirement. From the result, it is known that long breakdown machine, huge inventory of spare part, and high cost of maintenance become the first of priority of maintenance team to achieve customer satisfaction. To develop the performance maintenance, the company should standardize the procedure, identify the critical spare part, reduce the time to purchase critical spare part, and increase lifetime of spare part.

Keywords: Performance maintenance, Quality Function Deployment (QFD), Voice of the Customer (VOC), total productive maintenance

I. INTRODUCTION

The competition in the industrial world forces some companies to increase their productivity. One of them is one fabrication company in Indonesia. This company is a professional company in fabrication industry with machine facility. It sets target of 82% in efficiency and 10% in productivity to increase their production. Figure 1 shows the data of this company in 2016. Mean Time Between Failure (MTBF) or the average distance between breakdown machine in Balikpapan plant was 1.073 minutes or 17,9 hours in 2016. It meant that the machine would not work or breakdown every 17,9 hours. Meanwhile, Mean Time to Repair (MTTR) machine in Balikpapan was 37 minutes. Thus, it meant that the machines would stop as much as 18 times per month with assumption 15 hours per day and 22 days per month and total time to repair would be 18 × 37 minutes = 11,1 hours. For Cikupa plant, MTBF was 6.004 minutes or 100 hours. It meant that the machine would not work or breakdown every 100 hours. With assumption of 15 hours per day and 22 working days per month, machine would stop thrice per month. MTTR for Cikupa plant in 2016 was 21 minutes. Then, total time to repair would be 3 × 21 minutes = 1 hours.

In addition to the repair time, maintenance also needed additional time to search for the tools, machine, administrative, cost of spare parts; wait for the maintenance to check the machine; and reject the product due to breakdown machine. In terms of maintenance cost, the total cost in 2016 for Balikpapan Plant was Rp1.628.173.766,00 and Cikupa Plant was Rp.1.749.620.159,00.

One way to increase efficiency and productivity is improving performance maintenance. The need to improve maintenance skills from only maintaining the equipment to becoming part of the company that makes improvements by increasing productivity in each equipment. However, there is a lack of synchronization between the wants and needs of the company with the performance maintenance team. The inconvenience of the performance maintenance team in determining the action plan can be an obstacle to achieve the efficiency and productivity targets. This research is conducted to identify the effective tools as a bridge between customer (production & management) and maintenance team. This tools can support maintenance to identify some action plan to improve their performance and satisfy their customer.

Goetsch and Davis (2014) explained that Quality function deployment (QFD) was a special method for making customers' needs/wants to become important components of the design and production of the product or service. QFD combined quality strategies with function deployment from the field of engineering value. It was with QFD in the customer or the potential user of product and became part of the team that designed the product.

Moreover, QFD helps the company to translate the vague language (want and need) into technical languages. It enables the percolation of customers' voice into the practical arena and to facilitate customers' voice to obtain exactly what they want (Pramod, Devadasan, Muthu, Jagathyraj, & Dhakshina Moorthy, 2006)

Goetsch and Davis (2014) identified three steps as a guide for designers and planners to focus on the attributes of the product. It was the most important for the customer. First, it was identifying customers' needs, or in QFD, it was Voice of the Customer (VOC). Second, it was identifying the product attributes that would satisfy the VOC. Third, it was establishing product development and testing targets and priorities. It would result in a product or service that satisfied VOC.

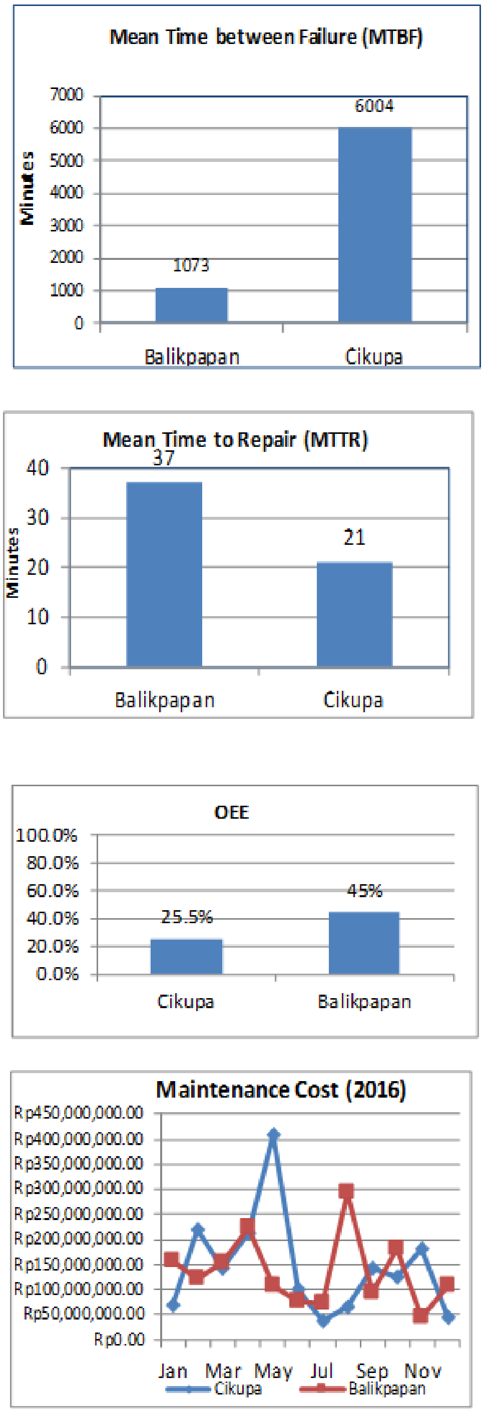

Figure 1 MTBF, MTTR, OEE, and Maintenance Cost in the Fabrication Company in Indonesia

Figure 2 is the set of QFD process or known as House of Quality (HOQ). It consists of several parts. First, it is customer needs. Before product or service is designed, designer should have good understanding of the customers' requirement. Second, planning matrix is the benchmarking between the existing product or services and the competitor. Third, technical requirement is how the company intends to respond to each of the customer's need. Fourth, there is interrelationship matrix. It is how technical requirements (HOW) relate to the customers' requirements (WHAT). Fifth, it is correlation matrix. It is the correlation type (supportive, impeding, or having no correlation) is determined for each of the technical requirement against all other technical requirements. Sixth, design target is how much the characteristics need to be provided.

QFD is not only implemented in the manufacturing industry. Some researchers suggest that QFD as tools to develop the quality of a product. Jaiswal (2012) analyzed a case study by using Quality Function Deployment (QCD). Moreover, Ionica and Leba (2015) integrated QFD in new product development. Similarly, Ko (2015) used HOQ for new product planning. A 2-tuple fuzzy linguistic approach was used.

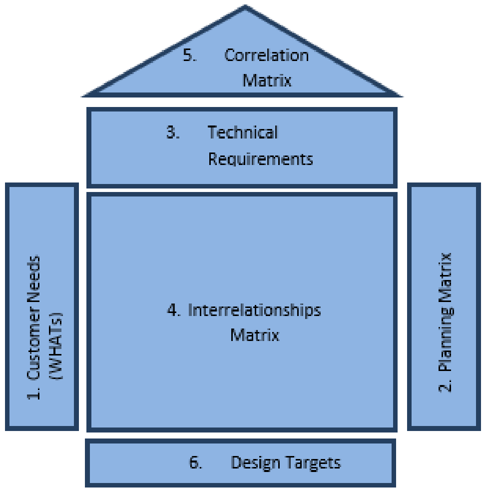

Figure 2 QFD's House of Quality (HOQ)

Futhermore, Purba, Prayogo, Wibowo, Pradipta, and Aisyah (2017) increased the thermal comfort, ergonomics, and safety of helmet by using QFD method in Indonesia. Popoff and Millet (2017) designed sustainable life cycle using constraint satisfaction problem and QFD. Meanwhile, Rajesh and Malliga (2013) adapted implementation of QFD to services in supplier selection based on AHP QFD methodology. Schillo, Isabelle, and Shakiba (2017) linked advanced biofuels policies with stakeholder interests by using QFD. Then, Pramod *et al*. (2006) integrated Total Productive Maintenance (TPM) and QFD to improve quality in maintenance engineering

Then, Jin, Ji, and Liu (2015) translated online customer opinions into engineering characteristics in QFD. Similarly, Moghimi, Jusan, Izadpanahi, and Mahdinejad (2017) incorporated user values into housing design through indirect user participation using MEC-QFD model. Chowdhury and Quaddus (2016) used a multi-phased QFD based on the optimization approach to sustainable service design. Meanwhile, Eldermann, Siirde, and Gusca (2017) used QFD framework for selection of industry development scenarios, and Akbaş and Bilgen (2017) utilized an integrated fuzzy QFD and TOPSIS methodology for choosing the ideal gas fuel at wastewater treatment plants (WWTPs).

In manufacturing industry, customers needs do not only come from external manufacturing, but it can also be from internal manufacturing. It will be easier to understand and process. Meanwhile, on the services, customers' involvement (external) will greatly affect the process of obtaining customers' needs data. Another difference is in the knowledge of what technical requirements should be used to meet all customers' needs (WHAT). The receptiveness of all participants regarding the tight competition will greatly affect the score on planning matrix. Furthermore, solid cooperation is needed to determine which technical requirement is the main priority. This will also affect the responsibility of process owner to run the required technical requirement to meet customers' needs.

Some obstacles that could hamper the process of application of QFD are the method of collecting VOC. This has an impact on the exact required technical requirement to meet the customers' needs. In addition, the knowledge of technical requirement will greatly affect the effectiveness of improvement.

Nakajima (1984) and Garg and Deshmukh (2006) explained that complete definition of TPM included five elements. First, TPM aimed to maximize the effectiveness of the equipment (over-all effectiveness). Second, TPM established a through system of preventive maintenance for the equipment's entire lifespan. Third, TPM was implemented by various departments (engineering, operations, maintenance, supply chain, and others). Fourth, TPM involved all employees. Fifth, TPM was based on the promotion of preventive maintenance through motivation management and autonomous small group activities.

Overall Equipment Effectiveness (OEE) can be said to be a measure of progress of TPM in an organization. OEE in TPM activity focuses on eliminating six major losses. Those are equipment failure, set-up and adjustment time, idling and minor stoppages, reduced speed, defect in process, and reduced yield. The formula of OEE can be seen as follows.

$$OEE = Availability \times Performance \times Quality \quad (1)$$

Availability is percentage of time that equipment can produce a product by excluding downtime in the production plan. It includes the downtimes for scheduled maintenance and management activity such as meeting at the beginning of shift. Some of the non-added value activities that reduce the availability are extended equipment breakdown, changeovers, unavailable material, unavailable operator, interruption or shutdown, significant equipment adjustment, equipment warm up, and cleaning.

Moreover, performance is comparison between the ideal speed based on equipment capacity as designed with actual operating speed. Some of the non-added value activities that can reduce performance are flow of product obstructions, stopped sensor, checking time, substandard material, unbalance capacity between process, underperformance due to equipment aging, lack of training, or inefficiency. Then, quality is the comparison between quantity of good product with total quantity produced (good and rejected product). Quality reduction often includes rework, scrap during test run, scrap during start-up, scrap during changeovers, damages, or reject product.

In addition to OEE, performance maintenance is also measured by two other key performance indicator s. Those are MTBF and MTTR. MTBF is a measure of failure frequency. It is the average time elapsed from one failure to the next or average time until it fails and needs to be repaired again. Meanwhile, MTTR is the average time that it takes to repair something after a failure. The equations can be formulated as follows.

$$MTBF = (Total\ up\ time)/(numbers\ of\ breakdowns) \quad (2)$$

$$MTTR = (Total\ downtimes)/(number\ of\ breakdowns) \quad (3)$$

For technical references related with maintenance performance, some literature and actual case help researchers to understand the successful factor of implementation of TPM. Mwanza and Mbohwa (2015) designed of a total productive maintenance model for effective implementation in a chemical manufacturing company. Then, Shen (2015) discussed the successful factors of TPM in enterprises. There is also product development and design, simultaneous consideration of TQM and TPM influence on multicolor offset machine using SD methodology (Kamath & Rodrigues, 2016). Meanwhile, Park, Won, Yoon, Kim, and Han (2016) analyzed a tiny hypervisor-based trusted geolocation framework with minimized TPM operations. For other researches, see Franciosi, Lambiase and Miranda (2017); Madureira, Flores-Colen, de Brito, and Pereira (2017); Lin, Luo, and Zhong (2017); Singh and Narwal (2017); Charaf and Ding (2015); and Chauhan and Pancholi (2013). A lot of the way in TPM, the researchers have to select which tools to help maintenance performance in the company. By using QFD method, the researchers can select the technical requirement.

II. METHODS

There are many methods to analyze maintenance performance. Researchers use QFD due to limitation of data from the database in maintenance team. In the first month, researchers & all maintenance team (5 employees) try to collect data from database and compare it with actual condition in Balikpapan Plant. There is a big gap between actual data and the database. It is difficult to identify and analyze the problem.

In QFD, researchers can use brainstorming method. It is to collect data, information, feedback, and new idea for all team members. In this research, researchers involve production and management team as the customer of maintenance team. The researchers also invite planner, quality, continuous improvement, finance team, production team, supply chain team as the partner of maintenance team. Total participants are 14 employees, including maintenance team. There are eight steps in QFD. First, it is VOC. Second, it is tree diagram for performance maintenance. Third, it is weighting the customer need. Fourth, there is competitive benchmark with competitor. Researchers invite employees who have experience working in that company. Fifth, it identifies technical requirement to meet customers' requirement. Sixth, it identifies interrelationship between customer need and technical requirement. Seventh, it identifies the current performance and sets new target to achieve customers' requirement. Eighth, it Identifies priority action or plan related to technical requirement.

Researchers use writing system through post-it to get need and wants of production and management team.

There are several steps used in the collecting VOC. First, participants are present in one area. In this case, researchers gather them in one room. Second, researchers explain the purpose of the meeting which is to get their expectations of performance maintenance. Third, explain the rules of the game. For example, the participants write their expectations into a post sheet. One post-it sheet is only for one expectation. Participants are given the freedom to write all the wants and needs related to maintenance. Fourth, participants are not required to fill in the name or other identification on the post-it sheet. Fifth, the content of post-it is grouped into four categories. There are inventory, maintenance, cost, and customer. Only partner team involves in the second to the eighth step. Those are for identifying and weighting the customers' need, technical requirement, interrelationship between customer needs and technical requirement, competitor selection, target for each technical requirement, and priority of action plan. All participants have the same feeling that they are process owner for this project.

III. RESULTS AND DISCUSSIONS

Tabel 1 Different objective between QFD and TPM

No	Objective of QFC	Objective TPM
1	To translate vague customer's language into technical languages	To achieve zero breakdowns
2	To enable the percolation of customer voice into practical arena	To achieve zero defects
3	To facilitate customer's voice to obtain exactly what he/she wants	To achieve improved throughputs
No	Benefit of QFD	Benefit of TPM
1	Development of teamwork and participation culture	The increase of sense of ownership of equipment among the operators
2	Systematic development of documentation connecting all functional requirements	Development of cross functional teams to improve individual employee and employer performance
3	Reducing field problems	The increase of the life of equipment and plant
4	Fewer design changes	Identification of reason for equipment failures
5	Identification of strengths and weakness of products with reference to competitors products	Increase of motivation level of employees
	Synergic Objectives of QFD & TPM	Synergic Benefit of QFD & TPM
	To gather both internal & external customer's perception in achieving zero defect, improve throughput, and translate them into practically implementable and viable proposition	Development teams consist of not only operators but also managers who are concerned with equipment effectiveness for providing tangible and intangible gains that will be received by both internal and external customer

Table 1 is the description of integrating TPM and QFD for improving quality in engineering maintenance by Pramod *et al*. (2006). The collaboration between TPM and QFD will create benefit. If people talk about maintenance performance, it means they talk about machine performance. There are three factors related to machine performance. Those are MTBF, MTTR, and OEE. In this case, customers request to put maintenance cost as one of the factors.

QFD as a tool to translate VOC to technical language has eight steps. There are affinity diagram, tree diagram, the weighting of customer need, competitive benchmark, technical requirement (HOW), interrelationship of WHAT and HOW, target design, and HOQ.

The first step is grouping VOC. It consists of maintenance, inventory, cost, and company and customer. It can be seen in Table 2.

Tabel 2 Four Categories of VOC

Maintenance	Inventory
Lack of maintenance skill especially maintenance at the site area.	A lot of various and similar spare parts and storage location in different location (Plant/ Site)
Standardizing the machine, spare part, performance maintenance activity, and others.	Huge inventory of spare part due to long lead time purchasing process and vendor
Low efficiency in manpower of maintenance.	Manual tracking to check historical consumption of spare part.
Cost	**Company and Customer**
Difficult tracking in the maintenance cost history for each machine (consumption of spare part, manpower services, and others)	Late delivery due to machine breakdown
High air shipping cost due to limited stock for some critical spare	Lack of trust in maintenance due to low efficiency of preventive maintenance
Low utilization of machine	Low performance in machine (defect and speed)

Second, tree diagram is used for plotting the issue from the first step. It is to determine customers' needs into two categories. Those are maintenance performance and cost maintenance improvement. The result can be seen in Figure 3.

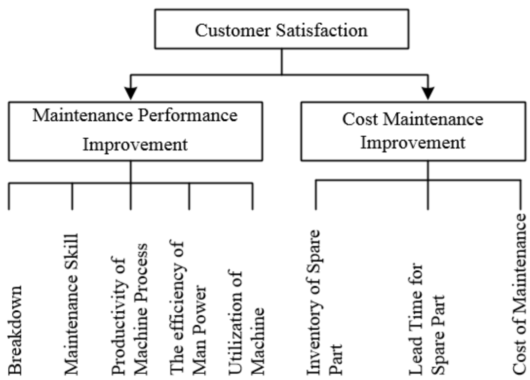

Figure 3 Tree diagram for Maintenance Performance

Third, it is weighting customers' needs. It is to know the level of importance in customers' needs. The weighting process is decided by team members. The scale of weighting is 1-5 with 5 as the highest priority. It is divided into long breakdown machine, efficiency of maintenance, and high cost of maintenance. The result is in Figure 4.

Customer Needs (WHATs)	Weighting of Customer Needs
Long Breakdown Machine	5
Lack of Maintenance Skill	3
Efficiency of man power	3
Huge Inventory of spare part	5
Long lead time spare part	3
High cost of maintenance	5
Increasing Utulization of Machine	4
Increasing Productivity of Machine Process	3

Figure 4 Customer Needs (WHAT) and Weighting Customers' Needs

Fourth, it is competitive benchmark with competitors who fully implement the twelve steps of TPM Development and partially implement. The result of brainstorming is to see the position in performance maintenance of company. By using scale of 1-5, the researchers and team brainstorm the identification score for each item in planning matrix. Based on percentage of total weight, it is decided that the first priority from VOC is long breakdown machine, huge inventory of spare part, high cost of maintenance with range of score of 13-17. Moreover, Long lead time for spare part and increasing machine productivity are the second priority with score of 12. Then, lack of skill in maintenance, number of manpower, and the utilization of machine are the third priority with score of 10. The result is in Figure 5.

For example, to calculate improvement factor for long breakdown machine (see the blue arrow with intermittent line) :

Improvement factor = ((The Planned CS Rating – Maintenance Performance in Fabrication Company)
$\times$ 0,2) + 1 (4)

CS is Customer Service. Moreover, 0,2 and 1 are constants from formula of improvement factor. To know the planned CS rating, the researchers have to follow the row of long breakdown machine and stop in column the planned CS rating. Then, score 5 will be obtained. To know maintenance performance for long breakdown machine, the researchers have to follow the same procedure previously in column maintenance performance in fabrication company. Then, score 3 will be obtained. Moreover, to calculate improvement factor for long breakdown machine, the result is as follows.

Customer Needs (WHATs)	Customer Importance	Interrelationships Matrix	Maintenance Performance in one of Fabrication Company in Indonesia	Maintenance Performance in company MNC	Maintenance Performance in local company	Our Planned CS Rating	Improvement Factor	Sales Point	Overall Weighting	% of total weight
Long Breakdown Machine	5		[illegible]	5	5	5	1,4	1,5	10,5	17
Lack of Maintenance Skill	3		3	5	5	5	1,4	1,5	6,3	10
Efficiency of man power	3		3	3	4	5	1,4	1,5	6,3	10
Huge Inventory of spare part	5		2	5	5	4	1,4	1,4	9,8	16
Long lead time spare part	3		2	5	3	5	1,6	1,5	7,2	12
High cost of maintenance	5		2	5	3	3	1,2	1,3	7,8	13
Increase Utilization of Machine	4		2	4	3	3	1,2	1,3	6,2	10
Increase Productivity of Machine Proce	3		2	5	3	5	1,6	1,5	7,2	12

Customer Importance — Interrelationships Matrix — Planning Matrix

Note : CS is Customer Service

Figure 5 Competitive Benchmark

Improvement factor = ((5 – 3) × 0,2) + 1 = 1,4

By using the same case, overall weighting for long breakdown machine can be calculated. The equation is as follows.

Overall Weighting = Weight of Customer Importance × Improvement Factor × Sales Point (5)

To know weighting of customer importance from long breakdown machine, the reseachers have to follow the row of breakdown machine and stop in column customer importance. Score 5 will be obtained. It is the same with improvement factor and sales point. The researchers need to follow the same procedure in column improvement factor and sales point. Then, score 1,4 and 1,5 will be found. In calculating overall weighting from long breakdown machine, the result will be as follows.

Overall Weighting = 5 × 1,4 × 1,5 = 10,5

For % of Total Weight = (Overall Weight/Total Overall Weighting) × 100 (6)

Total Overall Weighting is summary overall weighting for long breakdown machine, lack of maintenance skill, efficiency of man power, huge inventory of spare part, long lead time spare part, high cost of maintenance, increase utilization of machine, and increase in productivity of machine process. To know overall weighting for long breakdown machine, the researchers follow the row of long breakdown machine and stop in column overall weighting. Score 10,5 is obtained. The result can be seen as follows.

% of Total Weight of Long Breakdown Machine
= (10,5/ (10,5+6,3+6,3+9,8+7,2+7,8+6,2+7,2)) ×100 = 17
(see row of long breakdown machine and column % of total weight)

Fifth, technical requirements (HOW) is to determine the technical aspect for maintenance team to meet customers' needs. In this step, team and researchers start to involve some departments to implement TPM. The researchers identify some technical requirement to achieve customers' needs. Manpower arrangement, skill development in maintenance, standard procedure (maintenance activity and purchasing), wrench time (efficiency of maintenance activity), target inventory of spare part, lead time for each spare part, lifetime spare part, maintenance for continuous improvement, integrated system, and review of preventive maintenance schedule are technical requirements to improve machine and performance maintenance. The result of Technical Requirement (HOW) applied to the HOQ is in Figure 6.

Technical Requirement (HOWs)

Planning Matrix

Customer Needs (WHATs)

Customer Needs (WHATs)	Customer Important	Man Power Arrangement	Development Skill Maintenance	Standard Procedure (Maintenance & Purchasing)	Wrench Time (Efficiency Maintenance Activity)	Inventory of Spare Part	Lead Time for each spare part	Life Time Spare Part	Involve Maintenance for each continuous Improvement	Integrated System	PM Schedule	Maintenance Performance in one of Fabrication in Indonesia	Maintenance Performance in one of MNC	Maintenance Performance in One of Local Company	Our Planned CS Rating	Improvement Factor	Sales Point	Overall Weighting	% of Total Weight
Long Breakdown Machine	5											3	5	5	5	1.4	1.5	10.5	17
Lack of Maintenance Skill	3											3	5	5	5	1.4	1.5	6.3	10
Efficiency of Man Power	3											3	3	4	5	1.4	1.5	6.3	10
Huge Inventory of Spare Part	5											2	5	5	4	1.4	1.4	9.8	16
Long Lead Time Spare Part	3											2	5	3	5	1.6	1.5	7.2	12
High Cost of Maintenance	5											2	5	3	3	1.2	1.3	7.8	13
Increase Utilization of Machine	4											2	4	3	3	1.2	1.3	6.2	10
Increase Productivity of Machine Process	3											2	5	3	5	1.6	1.5	7.2	12

Figure 6 Technical Requirement (HOW) Applied to the HOQ

Sixth, it is interrelationship of WHAT and HOW. It identifies how strong the relationship between customers' needs and technical requirement is. This is usually done using scales of significance of 1 to 5 or 1 to 9. The higher number indicates a stronger relationship. Figure 7 shows that researchers use symbols for visual to descript relationship between customers' needs and technical requirement.

Seventh, it is design of HOQ by selecting the design target (values) of the technical requirements. In this step, the researchers will compare the implementation of technical requirement between Fabrication company with two competitors. It will decide the design target for each technical requirement. It is at the same level or more than their competitor.

Figure 8 shows how to determine priority technical requirement. In QFD, the researchers can multiply each interrelationship rating of the technical requirement. There are weak (1), medium (3), or high (9) from the interrelationship matrix with overall weighting and sum the column. For percentage of total priority, the researchers can divide individual technical priorities value by sum of all technical priorities value, and multiply it by 100. Example, to calculate Technical Priorities for Man Power Arrangement, the researchers just need to see column man power arrangement and column overall weighting. The researchers consider every symbol in column man power arrangement. There are 3 strong relationships (score 9), and 1 medium relationship (score 3), 4 pcs weak relationship (score 1). The researchers multiply for each score man power arrangement with overall weighting and sum all into the box between technical periorities and man power arrangement (see red box in Figure 8)

Technical Periorities of Man Power Arrangement = (Interrelationship between Man Power Arrangement and Long Breakdown Machine multiply with Overall Weighting of Long Breakdown Machine) + (Interrelationship between Man Power Arrangement and Lack of Maintenance Skill multiply with Overall Weighting Lack of Maintenance Skill) + ... + (Interrelationship between Man Power Arrangement and Increase Productivity of Machine Process multiply with Overall Weighting Increase Productivity of Machine Process) (7)

Technical Periorities of Man Power Arrangement = $(3\times10{,}5) + (9\times6{,}3) + (9\times6{,}3) + (1\times9{,}8) + (1\times7{,}2) + (9\times7{,}8) + (1\times6{,}2) + (1\times7{,}2) = 246$

The equation of percentage total periorities is as follow.

%Total Periorities Man Power Arrangement=(Technical Periorities Man Power Arrangement / Sum Score of Technical Periorities)×100 (8)

%Total Periorities Man Power Arrangement = $(246/(246+198+349+273+308+356+363+273+187+185))\times100=9\%$

From the result in QFD house, the increase in maintenance performance will be done by several ways. The first priority is to improve the three technical requirements. Those are identifying and reducing lead time for each spare part machine, increasing concerning spare part, and defining standard procedure (maintenance activity, and purchasing spare part, machine, and tools). The second priority is to improve four technical requirements. There are increasing the wrench time (efficiency of maintenance activity), improving the inventory of spare part, and involving maintenance for continuous improvement activity and man power arrangement. The third priority is to improve three technical requirements. It consists of skill development in maintenance, integrated system (preventive maintenance schedule, purchasing spare part, The productivity arrangement, and skill development), and preventive maintenance schedule.

If it is viewed from the overall technical requirement, TPM implementation will involve many parties ranging from management level to operators level who operate the machine. The cooperation at all levels is not just within a department, but it involves all departments. From the QFD in Figure 8, it shows that the involvement of the supply chain team is the top priority. The collaboration between maintenance and supply chain team in identifying critical spare part in critical machine, lead time spare part, and price determine the amount of inventory that must be stored in company.

If the researchers compare the result with some references in this journal, this reseach has different method to get feedback from the team. The researchers involve all related departemnt and ask them to give what kind of technical requirement to improve maintenance performance. Thus, the researchers obtain different technical requirement compared to technical requirement from the references.

Based on the recomendation from QFD, the researchers implement some technical requirement. It is started from priority 1, 2, and 3 (see Figure.8). In Figure 9, there is the impact of implementation in some technical requirement. If the researchers compare maintenance cost between 2016 and 2017, maintenance cost reduces around Rp121 million for Cikupa Plant and around Rp612 million for Balikpapan Plant. However, not all technical requirements can be implemented perfectly. Some technical requirements need to be reviewed in detail.

Moreover, Figure 10 shows maintenance capacity and compares it to the workload, this is part of man power arrangement. The reactive maintenance of 30% in the total capacity and preventive maintenance of 25% in the wrench time. For activity preventive maintenance, company has used 17.178 hours per month. Preventive maintenance in this calculation already includes activity of weekly, monthly, quarterly, or half-yearly preventive maintenance. With wrench time (efficiency of maintenance activity or the time in which maintenance operators work), it is 25%. It means that the allocated man hours in six months has reached 30.061 minutes. The calculations can be seen as follows.

Man Hours Consumption for Preventive Maintenance=(Allocated Man Hours from Weekly PM + Monthly PM + Quarterly PM + Semesterly PM) × (1+ (1- Wrench Time)) (9)

Man Hours Consumption for Preventive Maintenance = $(2280+11.822 + 1.646{,}67+ 1429.50) \times (1+(1–25\%) = 17.178{,}17\times175\% = 30.061{,}79$ *minutes*

Allocated Man Hours Consumption for Reactive Maintenance = Total Available Man Power×Target Reactive Maintenance (10)

Allocated Man Hours Consumption for Reactive Maintenance = 42.240 minutes × 30% = 12.672 minutess

Total Man Hours Needed = Man Hours Consumption for Preventive Maintenance + Man Hours Consumption for Reactive Maintenance (11)

Total Man Hours Needed = 30.061,79+12.672= 42.733,79 *minutes*

Reactive maintenance should be added to the allocation of man hours. In this case, the target of reactive maintenance is only 30% or 12.672 minutes. The total of required man hours for maintenance activity is 42.733 hours. Meanwhile, the available man hours are only 42.240 minutes. It means that the company needs additional man hours of 493 minutes. To anticipate this, it can apply overtime or do preventive maintenance outside working hours or add one more maintenance operator.

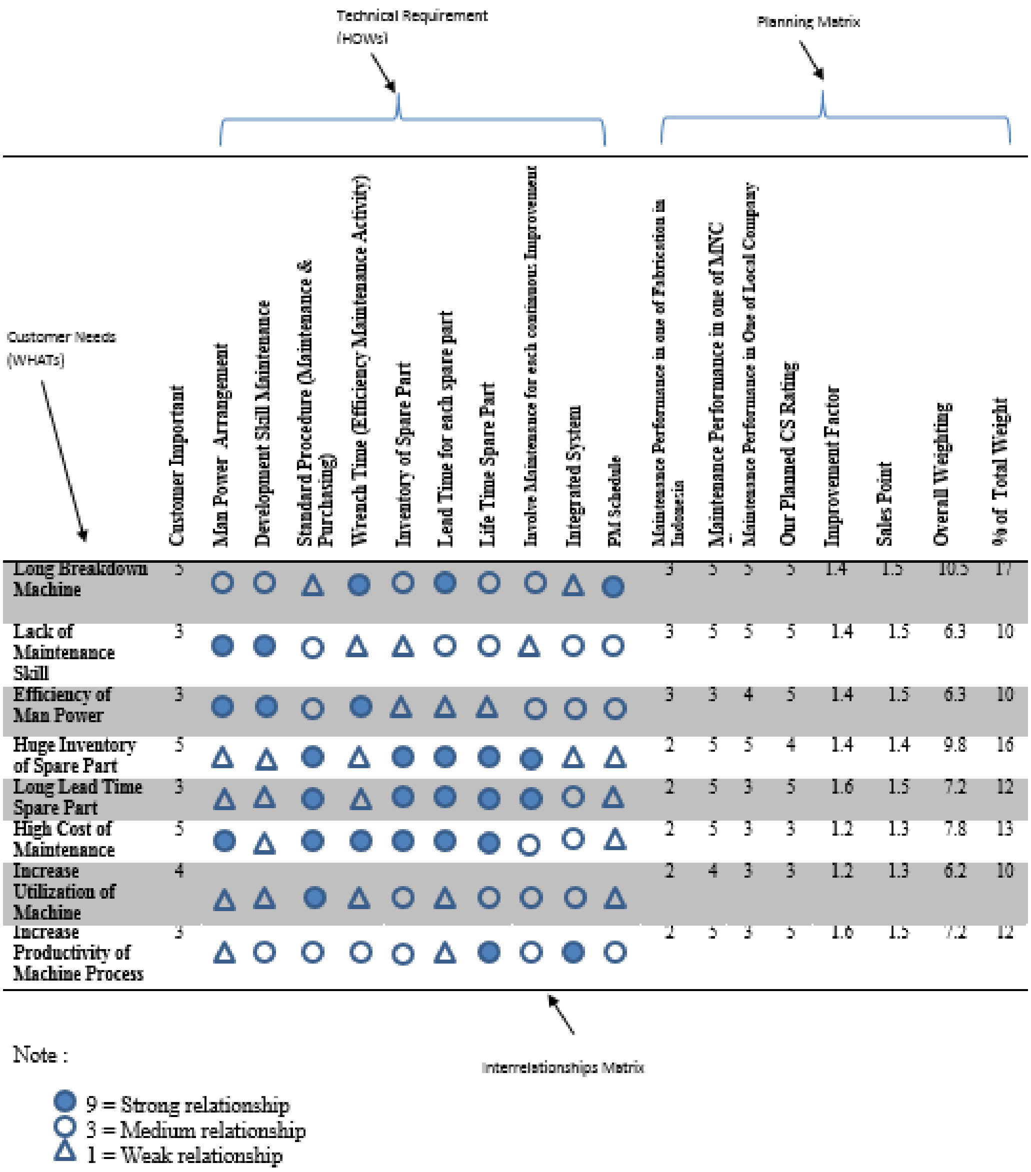

Figure 7 Interrelationship between WHAT and HOW

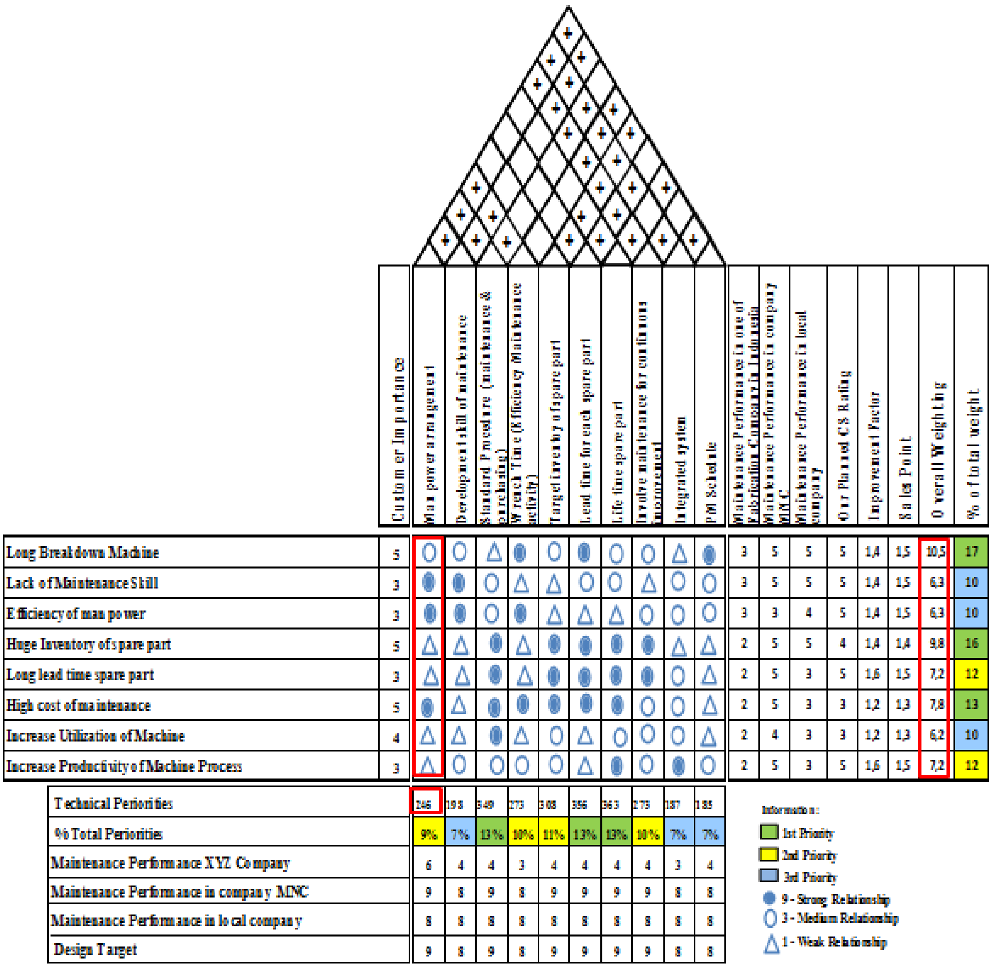

Figure 8 The Complete HOQ

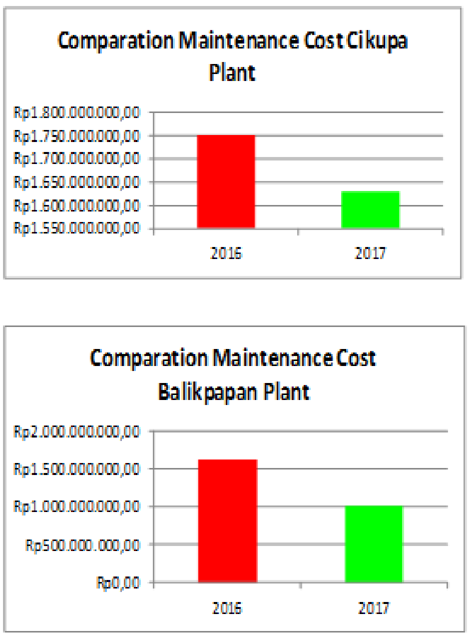

Figure 9 Comparison Cost in 2016 and 2017 (Partial Implementation of TPM)

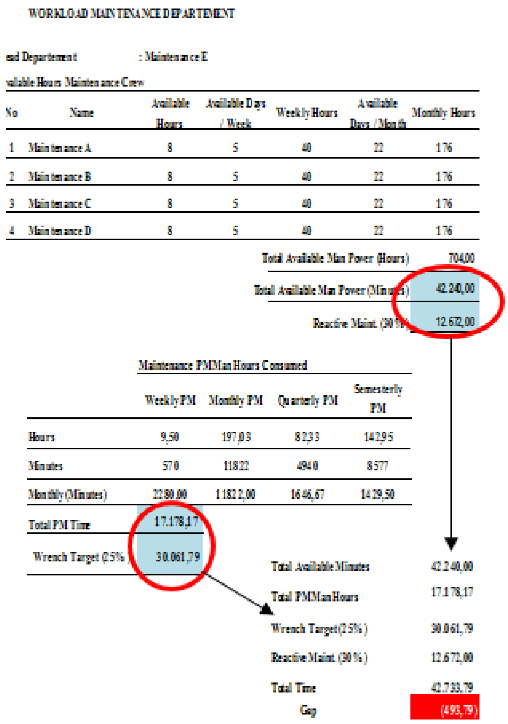

Figure 10 Identify Gap between Maintenance Capacity and workload

IV. CONCLUSIONS

This research shows that collaboration between QFD and TPM is one of methods to improve maintenance performance in this company. QFD method is used to collect VOC and determine the priority of technical requirement. The important thing from this method is it can help the researchers to develop teamwork and participation culture. The impact from this reseach is the reduction in maintenance cost.

To get sustainable from action in this research, the researchers recommend using digital system to collect all data from maintenance and operation activity. The data will be more accurate for continuous improvement in maintenance area.

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