THE IMPLEMENTATION OF QUALITY FUNCTION DEPLOYMENT (QFD) IN TIRE INDUSTRY

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Abstract **-** This research had two main objectives. The first research objective was to make the right design of new product according to customer requirements with the implementation of Quality Function Deployment (QFD) in the tire industry. The second research objective was to enhance competitiveness based on the renewal of marketing strategy and consumer needs, non-explosive prohibition, non-slip tires, no bulgy, and competitive prices. The research was carried out by using costumer satisfaction rating by comparing with the competitor companies. Based on calculation using QFD method, it shows that split liner has the highest percentage of technical requirement in tire industry about 30,57%. The second factor is pattern design about 25,98%. Then, the third factor is compound technology about 22,68%. Therefore, the researchers can recommend several strategies for the quality improvement based on customer needs for the tire industry.

Keywords: Quality Function Deployment (QFD), tire industry

I. INTRODUCTION

Transportation in Indonesia increases every year. It results in every automotive-related industry sector to prepare for the growing demand. The more intense the competition in the business world is, the more advantage that business players must have. It can be used as an advantage to win the competition. The ability of business people to meet the expectations of consumers is needed to win the competition. It is because each consumer has different tastes and desires so that the required product should attract the attention of consumers to buy products or services produced by the company.

In the middle of 20th century, the global competition began to be intensive in the world (Shaik *et al.*, 2015). Because of this condition, manufacturing and service companies needed a way to change the customer's requirement to be technical parameters and values. From this problem in 1970s people in Japan created a method called Quality Function Deployment (QFD) (Rajiv *et al*., 2010). QFD was first introduced by Yoji Akao, Professor of Management Engineering from Tamagawa University (John *et al.*, 2014; Liu *et al*., 2014; Büyüközkan & Çifçi, 2013). In 1975, the Computer Research Committee was appointed by the Japanese Society Control (JSOC). In 1987, a final survey report on the status of QFD applications among 80 Japanese companies was published (Akao *et al*., 1987).

This method works to change the customer's desire to be parameters and values so that it can be applied to the product accurately (Akao & Mazur, 2003; Büyüközkan & Çifçi, 2013; Liu *et al.*, 2014). QFD has now become the method to improve global competitiveness. Improvements to products short time processes become one of the hallmarks of this method. To improve the qualification of the current industry competition is not only the manufactures who want to absorb customer desires and deliver it in the form of products but also service companies. All industries seek to translate customer desires into valuable technical parameters that can be applied to products. QFD can not only transform customer desires into parameters and values for products and services but also bring customer needs down to a detailed level of operation (Akao *et al.,* 1987). Not only customer requirement and operation, but QFD also concerns the quality. By using this, it is expected that the customer's desire towards good quality can also be accommodated by applying method in the company. In the end, the company can understand that modern management techniques become a major part of gaining competitive advantage from the customer point of view (Bottani & Rizzi, 2006).

There are so many benefits found in the QFD implementation by researcher (Andronikidis *et al.,* 2009). The surveyed companies include the following points to use QFD. Those are establishing design standards and planned quality, making competitive bench-marking products, developing new products that differentiate firms from competitors, analyzing and gathering market quality information that communicates quality-related information later processes, designing goals into manufacturing, identifying control points, reducing quality issues early, reducing design changes, cutting development time, reducing development costs, and expanding market share. There is a reason why QFD can be so popular in Japan in terms of manufacturing and services. Many of the benefits have been reported by many researchers regarding the implementation of QDF in real time practice (Sivasamy *et al*., 2016).

Since it was created in the 1970s, this method has been used by many companies around the world (Zhang *et al.*, 2014). Not only in Japan, but it also is popular in global

manufacturer and service industries (Delgado & Aspinwal, 2003). For example, as a source of information for creating quality charts, American companies used personal interviews with customers. Customized customer surveys were designed for QFD implementation and focused on group interviews. In the survey, it was reported that they had interest rate support in the implementation of QFD in the form of sufficient effort to implement QFD with adequate resources, and adequate QFD execution time.

QFD can be applied in various industries besides manufacturing such as transportation construction, electronics, and education and service (Aytac & Deniz, 2005; Vinayak & Kodali, 2013; Chan & Wu, 2002). QFD is a flexible method to be applied in almost all types of industries, even services. Besides being used in many industries, QFD can also be used in various fields such as product design, quality management, decision making and team building (Wolniak & Sedek, 2009). Uniquely, not only product design is set to this method but also the quality. Because quality is a part of customer's desire, by using QFD, the company can also correlate between customer's desires with effort to improve product or service quality. The researchers began to publish the results of the QFD research starting in 1980 (Politis, 2005; Zaim *et al.*, 2014). Lots of advantages were found by these researchers from the implementation of QFD (Gremyr & Raharjo, 2013; Kamvysi *et al.*, 2014; Liao & Kao, 2014). From the researches conducted by using QFD, it can be seen that QFD can help customer in friendly product design, reducing lead time product development, and improving quality and reliability of product created.

The inventors of QFD see customers' desires, and they name it as Voice of Customer (VOC) (Aytac, & Deniz, 2005; Vinodh, & Chintha, 2011). VOC is one of the main items in QFD. This item can translate what the market needs and can be applied to market requirement in the product. The company understands that not all items from VOC can be applied in product. Thus, with QFD, it can filter critical items. In this case, the items will be considered to make big impact on the market and can be applied to the product. Moreover, phase and planning of QFD start from identifying of customer needs, determining product specifications, and checking development plans (Skalak, 2002).

VOC becomes a main ingredient in product and service development. In the QFD, the process requires input and decision made by an expertise team. Then, QFD will be a strategy to understand customer's wants with engineering knowledge and requirements as well as eliminating many of the operating hurdles formed in the company during development products (Chen, & Weng, 2006).

The relationship between data from customer and technical information is important to determine the target value set for each technical requirement. It is to ensure that the next generation products will be truly competitive and satisfy as customer wants and needs (Day, 1993). To use VOC, the selection of competitor and technical requirement will also determine the exact results. Because the results of each section will affect the results of the other parts, the exact parameter selection at the beginning of each section becomes very important to obtain the best result. Moreover, to make good product, QFD also evaluates the result and compares it with other to identify the specific product objectives to be improved (Isac, 2003). After all the requirements are identified, the important thing is to answer what the product design should be done to meet the required requirements and assist trade-off decisions to make a process (Kahraman *et al.,* 2006; Krstić, 2014).

In QFD, there is House of Quality (HoQ) matrix. It is the essence of a QFD method (Raharjo, 2013). This matrix will consist of four main parts (Wu & Shieh, 2008; Kuo *et al.,* 2009). Each is defined by sizes and metrics for measuring success (Sharma, 2003). In addition to the other VoC, there are competitors, positions and relationships which technically can be considered in making HoQ (Liu *et al.,* 2014).

Moreover, customer satisfaction is one of the customer's most desirable targets in the company. Creating customer satisfaction and providing the best service and quality of production may not be easy in the beginning. The company needs to be more familiar with customers' needs and transfer these needs to situations where services and products are generated. An increased customer desire is one of the factors of increasing the complexity of economic, cultural, and social systems. It is not spontaneously, but it requires systematic approaches and techniques that transform this concept into organizational processes (Akao *et al*., 1987).

In short, the main focus of this QFD is to involve customers in the product development process from the beginning. The underlying philosophy is that the customer will never be satisfied with the product although it is a perfectly produced product. The purpose of QFD principle is to ensure that customers' needs and wants are met. It can be applied to the development of product or service and help the internal service group to develop strategies and achieve customer satisfaction. In this research, the researchers will implement QFD method on tire product to assist product development which is expected to be close to customer's desire.

The automotive manufacturing company continues to improve products based on consumer needs. However, is still experiencing delays in the development of new product. In this research, QFD is used to develop new products and determine the strengths and weaknesses of the tire industry. In this case, it can be observed that QFD can be used to help solve problems in various fields, especially in the tire industry.

Tire is a commodity that has a different market. The product depends on the geographical condition, road contours, and weather in the area. The research about QFD in the tire industry has been done in the Iranian state (Akao *et al.*, 1987). The Iranians wanted long-lasting tires which could be used at high speed and resisted the puncture and adhesion in the road. The results were several criteria that companies could use to improve their products such as consumable compound of tires, dimensions of tar, dimension of saydval, and appropriate pattern of tire.

There are two significant points in the application of QFD in the automotive manufacturing company. First, QFD has transformed quality control in the manufacturing process and established quality control for development and design. In other words, QFD has established quality management for product development and design. Second, QFD has provided communication tools for designers. It is a strong help for engineers as they build a system for product development.

Next, there are three main objectives in the implementation of QFD in the tire industry. First, it prioritizes the needs of both spoken and unspoken customers. Second, it translates customers' needs into technical characteristics and specifications based on the VOC. Last, it builds and delivers quality products or services by focusing everyone on customer satisfaction. Since its introduction, QFD has

helped the company in several ways including planning new products, designing product requirements, determining process characteristics, controlling the manufacturing process, and preparing existing product specification documents.

II. METHODS

This research uses the total sampling or complete enumeration. Therefore, the sample size is the same as the population size. Then, the design concept of the new product in this research is grouping the critical components from radial tire.

The primary data are collected by the observation or direct measurement and questionnaire. It includes the consumers' needs, technical requirements, and critical parts. Meanwhile, the secondary data are through interviewing the R&D technology and production management team department in the automotive manufacturing company to collect the product types, specification, demand rate, initial tire design, and production process. The attributes of product that are asked to the respondents are based on pattern of tread rubber, split liner technology, silica compound technology, section width of die tread design, x-ray inspection, and bead wire size design.

The first step in the implementation of QFD method in tire industry is making HoQ. Figure 1 shows the result of QFD matrix in tire industry of the automotive manufacturing company industry. The company engages some competitive bench-marking between its product and competitor's product by sending questionnaires to the customer who its product and competitors' product. In this situation, participants are asked to rate the products on each of the characteristics listed in the customer need matrix. It uses 1 to 5 scale (5 is the most favorable). Then, it calculates the improvement factor for each technical requirement for the new product based on planned customer satisfaction rating and existing customer satisfaction rating.

Next, the radial tire component design consists of bead wire size design. The concept design improvements in bead wire show that each component has standard that mutually minimizes the assembly design of bead filler and bead wire. Then, the initial design of each component is found in the process of R&D Technology department for compound mixing, extruding, bead, inner liner, and cutting. These components have standard that minimizes the manufacturing design of radial tire. Next, the additive composition consists of the determinant of quality, endurance, and uniformity of the tire. Whereas, the section height is the determinant of tire size. All the components affect the final pattern of tread that will determine the ability of tire in moving on the road surface.

The first matrix of the QFD process usually takes VOC by scientifically rating the importance of these wants, needs and desires and technical links. Each way is defined by sizes and metrics for measuring success (Sharma, 2003). To create a quality product, customer needs must be considered. In addition, standards and regulatory requirements dictated by management must be identified.

The evaluation will be done by comparing the results with the main competitor's results, with the identified characteristics using competitive technical evaluation. It is used to compare new products with competitors' products. It is to find if technical requirements are better or worse than competitors. The results of all the items that the analyst has done can help identify important product requirements and assist trade-off decisions to make a process (Krstić, 2004).

III. RESULTS AND DISCUSSIONS

QFD functions such as HOQ are used on consumer products to manage and identify design trade-offs. It involves studying customer requirements. The customer requirements can be in the form of a marketing survey which has been targeted towards a certain marketing. Normally, the purpose of this survey is to find out what the consumers want from the consumers. HOQ serves as a good patch between the customer requirements and the engineering variables.

The term QFD is popular tool used for new product. The calculation of QFD using improvement factor. It is calculated as:

	Customer importance	tread design with chimney technology	bread wire design	Split liner technology	x-ray	silica compound using ZnO delay technology	pattern design	CS Rating PT. XYZ	CS Rating Competitor (B)	CS Rating Competitor (C)	Our Planned CS Rating	Improvement Factor	Sales Point	Overall Weighting	% of total weight
Tire In all condition of street and wheather	5	O	Δ	O		◎	◎	2	5	4	5	1,6	1,5	12	24%
long life time from tire	2				Δ	◎		4	3	4	4	1	1,1	2,2	4%
tire not easy explosive	3		O	Δ	O			3	4	3	4	1,2	1,3	4,68	9%
tire not slippery	4	O					◎	4	5	4	4	1	1,1	4,4	9%
bulgie	5			◎	O			2	4	3	5	1,6	1,5	12	24%
competitive princes	2			◎		Δ		4	1	3	5	1,2	1,3	3,12	6%
Technical Periorities		147,6	54,1	520,9	152,3	386,5	442,8								
% of Total Periorities		8,66	3,18	30,57	8,94	22,68	25,98								
Our Product		7	8	7	8	6	6								
Competitor Michelin		8	9	8	6	7	7								
Competitor Goodyear		5	9	6	7	5	5								
Design Target		8	9	9	8	9	7								

Note:
Δ = Low value (1)
O = Middle value (9)
◎ = Strong value (27)

Figure 1 QFD Matrix

Improvement Factor = {(Planned CS Rating – Existing CS Rating)0,2}+1 (1)

Then, sales point or strategic marketing factor is placed in the planning matrix. A number of sales point about 1 to 1,5 is used to emphasis on the customers' needs. It estimates the marketing importance of the need in the promotion of the new product. It is used along with customer importance and improvement factor in the calculation for overall weighting of the customers' needs. The calculation of overall weighting is based on customer importance, improvement factor, and sales point. The equation is as follows.

*Overall weighting = customer importance*improvement factor*sales point* (2)

After that, it converts the overall weighting to percentages. It is to understand how much of the design or improvement that should be done in each of the customers' needs (Goetsch & Davis, 2013).

*% of total weighting = (Overall Weighting/Sum of Overall Weighting)*100%* (3)

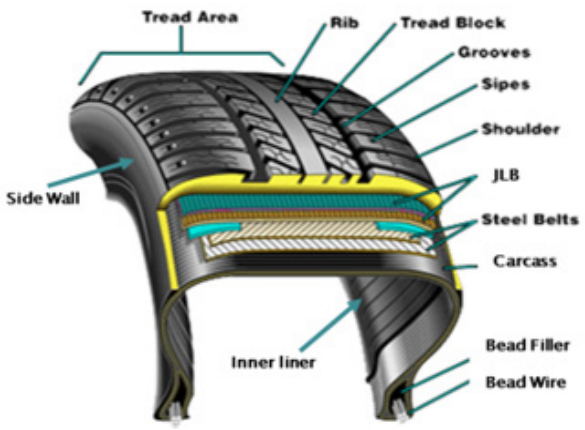

Figure 2 Virtual Tire Design
(Source: Design from PT Hankook Tire)

The tire is divided into several parts as seen in Figure 2. There are tread, belt and textile, casing, inner liner, and bead. Tread is a tire tread that protects the tire from impact, and the puncture of an object from the outside that can damage the tire. Treads make many patterns called patterns. Then, breaker and belt are part of the yarn layer placed between the tread and casing. In ordinary tires, it is made of textiles, while for radial tires, it is made of wire. This protects and reduces collisions occurring on the tread as it is not directly absorbed by the casing. Casing is a tire-forming yarn layer and a framework of tires that accommodate high-pressure air to support the tires. Moreover, bead is a bundle of wire united by a hard rubber and functions like an anchorage attached to the rims.

After the completion, the tire is checked visually whether there is a defect or not. This process does not use the machine, so the accuracy of workers is needed. In addition to visual, the control is also done by checking the balance and using X-rays. The tire may not be 100% balance like a rim, but there are limitations. If it exceeds the limit, there is an error in the production process. In addition, a laboratory inspects tire samples taken randomly to maintain quality.

The results of analysis use the method of QFD in the automotive manufacturing company. The attributes that become a priority for improving service quality (strong in all conditions, long lifetime, hard to explosive, nonslippery, not bulgy, and competitive price). It can be the suggestion for marketing strategy. Based on research conducted using QFD method to improve the quality of car tires, it obtains the priority attribute and technical requirement made by the company (design tread, bead wire design, split liner technology, x-ray, silica compound technology, design pattern). From Figure 1, it can be seen that the highest total priority percentage is split liner technology (30,57%), pattern design (25,98%), and silica compound technology (22,68%). The company can make improvements or design new products by adding split liner technology, pattern design, and silica compound to make strong car tires. Therefore, in all conditions, the tire has long lifetime and competitive price and is not easy to explode, slippery, and bulgy. From these results, it is expected to assist companies in the development of quality service products in accordance with the needs of customers.

IV. CONCLUSIONS

Attributes of the radial tire design based on the consumers' needs consist of six variables. There are pattern of tread rubber, split liner technology, silica compound technology, section width of die tread design, x-ray inspection, and bead wire size design. The relationship of radial tires components uses the product architecture. Meanwhile, the activity of alternative product design, planning, and radial tire design is done by the approach of concurrent technology team by implementing the new right product development. Then, the conceptual design step is done by using QFD to identify the importance weight of radial tire design and part characteristics.

The approach of applying the QFD method in the manufacturing tire industry can analyze customer needs, know what to do by the company, and apply it to product and manufacturing process. The other uses are to improve the products and processes. From the results of the research, it can be concluded that implementing and improving the process of tire manufacturing can be done by using split liner technology, pattern design improvements on tires, and the use of silica compound. The conceptual design of radial tire is done by the second phase of QFD to get five critical parts. The tires which have long lifetime and competitive price, and are hard to explode, non-slip tires, and no bulgy.

The implementation of QFD in the production process will bring positive results in the design and production process as well as the advantages in market development and sales. Moreover, better scheduling and production planning can minimize production process time and delivery time. It also can minimize the frequent changes in designing and producing.

QFD provides a perfect approach to implement quality inspection at every stage of product development. The final result in implementing of QFD method for radial tire and product design structure matrix is to improve the design activity. It is by giving information for the company to integrate the process of each department in the new design planning of radial tire. Thus, it provides a new approach to measure customers' needs and provide products with characteristics required by customers. This can be an excellent tool for planning and controlling the development

process before production especially to be applied in the manufacturing industry of automobile tire.

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