Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2017, 4(7):184-192**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Increasing the Thermal Comfort, Ergonomics and Safety of Helmet by Using of Quality Function Deployment Method: A Case Study in Indonesia

Humiras Hardi Purba[1], Herteguh Prayogo[1], Mukhlisin[1], Riyadi Wibowo[1], Mashuri[1], M. Yudith Pradipta[1], Siti Aisyah[2]

[1]School of Industrial Engineering, Mercu Buana University, Jl. Menteng Raya No. 29 Jakarta, Indonesia

[2]College of Industrial Management, Ministry of Industry, Republic of Indonesia, Jakarta

Abstract Due to rapidly growing population, traffic congestion and lack of parking space, two wheelers are the most popular mode of transportation. The occurrence of traffic accidents is not uncommon, especially among two-wheeled-vehicle riders. There are four causes of traffic accidents: human being, vehicle, road, and environment. From the human factor, the main cause is the riders' disregard for traffic rules and signs. The most common cause of deaths is head injuries due to not wearing a helmet or wearing a non-standardized helmet. As per Indonesian traffic rules, it is mandatory to wear the helmet for safety while riding two-wheeled-vehicle. There is a need for a helmet which meets the requirement of thermal comfort, adjustable interior, better visibility and pleasing aesthetics. QFD was generated and the product specifications were obtained to meet the requirement. Concept sketches were generated incorporating features like adjustable head form, air vents and exhaust fans for thermal comfort. Motor cycle helmet is conceptually designed, modeled and built incorporating features for improved thermal comfort, visibility and with adjustable interior form considering rider's ergonomics. Steady state airflow simulation on the helmet interior was carried out with a head form of the rider (95 percentile male) to assess the air flow pattern and temperature distribution. A better configuration is to provide exhaust fan on the rear end of the helmet along with air vents to extract the heat from the helmet.

Keywords Helmet, Traffic Accident, Head Injuries, QFD, Thermal Comfort, Visibility, Adjustable Interior

Introduction

In the developing countries like Indonesia, it is very difficult to the middle-class people to afford the luxurycars for daily needs. Hence the two wheeler motor cycles are very necessary for them. Due to this, the use of motor cycle is increasing steadily. About 80 percent of accidents occur involving motorcycles in Indonesia. The number of accidents in 2015 increased from 2014, from 77.439 cases to 84.099 cases [1]. Hencethe safety of the motor cycle rider is an essentialrequirement.

The two wheeler motor cycle rider is mostlikely to sustain serious injuries during the accidents.The human head is very vulnerable to injury. It mainly needsconsideration to acceleration/deceleration androtational forces because it is freely mobile in threedimensions and occupies a relatively unstable position,being secured only by the neck muscles and ligaments.Many accidents cause harmful injuries to the biker on roads. Mostly death occurs due to a collision at the brain of biker due to avoid the helmet while driving. In the accidental condition primary treatment to the victim delays. This leads increasing the number of deaths in road accidents [2]. Accidents occur when two or more vehicles collide to each other. Collision avoidance of vehicles can be enough to avoid accidents. The velocity of the vehicle cannot be controlled in the situation of an accident. But safety factor can be increased to save lives [3].

One of the effective countermeasures to prevent headinjuries in motorcycle crashes is the use of a protectivehelmet. The helmet can be played a vital role if it is full with useful technology [4]. The helmets have

beenfound to decrease the risk of head and brain injury by70 to 88% and facial injury to the upper and mid-faceby 65% [5]. Thetraffic injury is recently recognized as one of the majorhealth problems in the developing countries. Trafficaccidents are more severe and require critical care thatcauses eventually high medical costs and economiclosses. It may also cause permanent disabilities of thevictim [6].

Literature Review

Helmet serves to protect the head from a head injury when the accident occurred. But not all types of head injuries can be protected absolutely only with the use of helmets. Helmets are capable of providing special protection for severe head injury (severe HI) with certain conditions. In the medical injury,the head is divided into 3 big groups [7] and is measured by the index of GSC (Glasgow Coma Scale). The Glasgow Coma Scale (GCS) was developed to standardize the assessment of neurologically compromised patients, to assist in triaging severity of injury, and to direct management decisions for an individualized plan of care[8] as follows : (i) Mild Head Injury, classified into mild HI if the GCS scale is 13-15, with the characteristic that there may be a loss of consciousness (fainting) of less than 30 minutes or retrograde amnesia, no skull fracture, no cerebral or hematoma contusion, (ii) Medium head injury (Moderate HI), classified into HI modes if the GCS scale is 9-12, with the characteristics of loss of consciousness or retrograde amnesia over 30 minutes but less than 24 hours and may have a skull fracture, (iii) Severe head injury (Severe HI), classified into HI severe if GCS scale 3-8, with characteristics of loss of consciousness and / or amnesia over 24 hours and may experience cerebral contusions, lacerations or intracranial hematoma.

A completely systematic approach and overarching planning method for the fulfillment of customer demands is the Quality Function Deployment, hereinafter simply called QFD [9]. The customer wishes, needs, and notions are identified in the QFD methodology and serve as the basis for the entire product development.The QFD process begins with the determination of the customer requirements and ends with the realization of the processes necessary for the production[10]. The QFD methodology is generally understood as a work style and a working philosophy with the aim to completely satisfy the customers. The focuslies on two key issues: WHAT does the customer want and HOW can it be achieved? For this purpose, all employees' knowledge and skills are involved inthe strategies and actions to achieve this aim, therewith avoiding an aberration [11].QFD consequently pursues the ultimate objective:Success for the customers, the employees, and the entrepreneur.This is supplemented by the following goals: (i) Customers' enthusiasm, (ii) Intensification of teamwork, (iii) Clear, coordinated and measurable goals, (iv) Reduce losses in the value chain, (v) Fewer and shorter development steps, (vi) Systematic documentation, (vii) Incorporation of expert knowledge and (viii) Quality development and improvement [12].The success of the company lies in understanding the customer needs, expectations and anticipating the changes required in existing or new products being offered (Soota et al., 2008). To convert customer needs and requirements into quality characteristics, QFD is the best method as well as to develop a design quality for a product. Quality Function Deployment (QFD) is a powerful development tool, with a wide range of applications, for achieving product development, thus improving the productquality, reducing the time to market along with the design and manufacturing costs[26].

The initially increased effort with which the method needs to be introduced to the company can be considered disadvantageous [13].With QFD, it is possible to achieve a high level of customer satisfaction since customer demands are included in the development process from the beginning.Innovative solutions are, however, not increased by the use of this method but only in this way it is possible to develop a competitive advantage and thus to secure high market shares.Quality Function Deployment (QFD) is a quality tool that helps to translate the Voice of the Customer (VOC) into new products that truly satisfy their needs. This paper will review QFD to understand how it works and to discuss its practical applications. The first part of the paper will present an overview of QFD and explain the methodology. QFD will be defined and explained by means of an example and a number of benefits and implementation problems will be revealed [14]. Thus, an opportunity was created for QFD to come to fruition as a method to check the design itself for adequacy in meeting customer requirements and to translate those requirements into production [15].

QFD is a method for structured product planning and development to specify clearly the customer's needs, and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs[16].QFD gives include a better understanding of customer demands and design interactions.Early manufacturing involvement during the design process reducing iterations and focusing the design while fostering teamwork [13].Several studies have been conducted to evaluate the protective performance ofhelmets during direct head impact, with constant–rate compression and drop–impact tests which are typically used to investigate the protective contributionof individual helmet components [18] and [19]. The effectiveness of mandatedmotorcycle helmet use in Taiwan by applying logic modeling approach and before-and-after

comparisons [20]. The helmet design variations in terms of different variablesother than headform linear acceleration and suggested that the model hadoptimized cost, weight and helmet size [21].

Methodology

One concept of motorcycle helmet design is how to meet the security needs, and comfort for the wearer. For realizing this concept we collect data both Gemba and libraries and also analyze competitor products.The methodology in this paper using : (i) Literature survey to know the requirement of the helmet by customer, safety standards and ergonomics of the motorcycle riders wearing helmet, (ii) GEMBA study (interview and questionnaire) to understand the requirements of the motor cycle rider helmet,(iii) Analyze the factors of customer need (Voice of Customer) for choosing a motor cycle helmet, so can be made a helmet design in accordance with the needs of consumers, (iv) Analyze competitor products by benchmarking to know the strengths and weaknesses of competing products. To create the QFD for the design requirement of the motor cycle helmet base on previous analysis factor. (v) Make QFD of House Quality Concept with the calculation and determination of the weight of the factors involved voice of customers, technical requirements, and competitors and also interrelationship of them (vi) Analysis based on QFD and create new design concepts based on the weight of the target design.

Using QFD can result in the development of better products at a price that the customer is willing to pay, based on its application in different companies [30]. The following advantages and benefits from QFD, there is customer satisfaction [27], reduction in product lead times [28], improved communications through teamwork [29] and better designs (Mehta, 1994). In addition, Bicknell and Bicknell (In Chan and Wu (2002a)) reported that tangible benefits when QFD is properly used are: a 30-50% reduction in engineering changes, 30-50% shorter design cycles, 20-60% lower start up costs, and 20-50% fewer warranty claims[24]. For data collection focused on two things: data related to product and user/consumer. The product study was conducted with a study of literature and surveys to helmet dealers related to helmet products, such as strength, helmet, standard shapes and sizes, paint/color, rope locks, materials (inside and outside), and maintenance. A user study is done by making questionnaires distributed to helmet users to collect data related to what factors make consideration in using motorcycle helmets (customer need) such as comfort (ergonomics), conditions when using helmets (temperature and hearing), Size, weight and material type[22].

Surveys were conducted to find outproduct quality which needs improvement and survey to know the 'Voice of the Customer' (VOC) about product satisfaction. Data collected from the surveys was interpreted in terms of customer needs. Customer needs were organized according to their relative importance. Relative importance was subjectively allocated to customer needs on a scale 1-5. The scale 5 indicates the most important need and the scale 1 indicates the least important need. The ranking was carried out on the basis of customer feedback obtained from the customer survey.In order to proceed on to the next product development stage, the information obtained from the surveys about customer requirements, technical descriptions, and relative importance was used to build the House of Quality (HOQ) [26]. Here are some examples of questions used in the questionnairefor users as follows: (i) Do you drive a motor cycle? (ii) Why are helmet needed when driving a motor cycle? (iii) What is your opinion about the helmets which are available in the present market? (iv) What makes you buy this particular helmet? (v) How is the visibility from your helmet? (vi) How do you feel about your helmet during the night journey? (vii) How far your helmet is comfortable to you? (viii) What is the level of comfort you expect from a new generation helmets? (ix) Any accessories or facilities you are looking for thenew generation helmets? (x) What is your expectation about the exterior of thehelmet? (xi) Does the weight of your helmet is optimum or you are feeling more weight? (xii) Any other problem you are experiencing in your helmet? (xiii) Anything in your helmet which you feel very comfortable? Anything in your helmet which you feel very difficult to use?Some examples of questions used in the questionnairefor dealers as follows: (i) How many brands of helmet you are selling? (ii) Which brand is moving fast in the market and why? (iii) Which brand helmet is moving slowly and why? (iv) What type of helmet people like most? (v) According to your which facility can improve thesales of the helmet? (vi) What is the main complaint in the helmet from the customers? (vii) Any accessories or facilities you are looking for the new generation helmets? (viii) Which helmet has got the maximum facility andmoving fast in the market?[22].

Result and Discussion

Helmet performance cannot be separated from an understanding of head, neck and brain injury due to impact. So that way design is should be focused on protecting of head, neck, and brain also other technical aspects such as aerodynamics and reliability. These various aspects result in optimized structures that are suitably tested using standard testing procedures and equipment that is, as yet, still not validated fully with detailed, fidelity, clinical, morphological and physiological data [25]. From the data of consumers who successfully collected then

further performed data processing based on the concept of QFD. Basically, there are have 7 steps that must be done in QFD, there isaffinity diagram, tree diagram, the weighting of customerneed, competitive benchmark, technical requirement (how's), interrelationship what's and how's, and design target and the house of quality [23].

Step 1: Affinity Diagram is used for grouping customer issues based on data needs (voice of customer) to focus more on problem-solving product design (motorcycle helmet design).

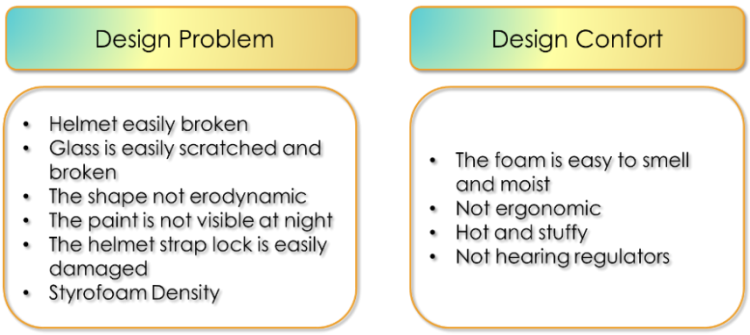

Figure 1: Affinity Diagram for Helmet

Step 2: Tree Diagram is used for plotting the issue-issue from that has been grouped in step 1 to determine the satisfaction aspects of customer needs in the improvement effort product design (Motorcycle Helmet).

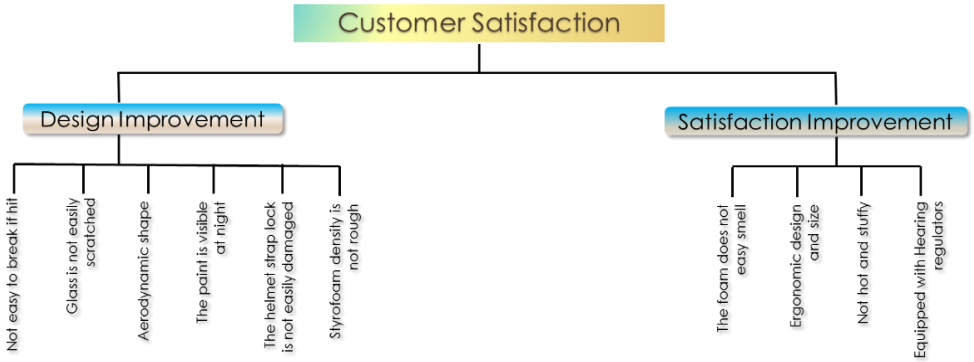

Figure 2: Tree Diagram for Helmet

Step 3: Weighting of Customer Need is used for conducting customer need priority to the product (motorcycle helmet), to know the level of customer interest to the product [23].

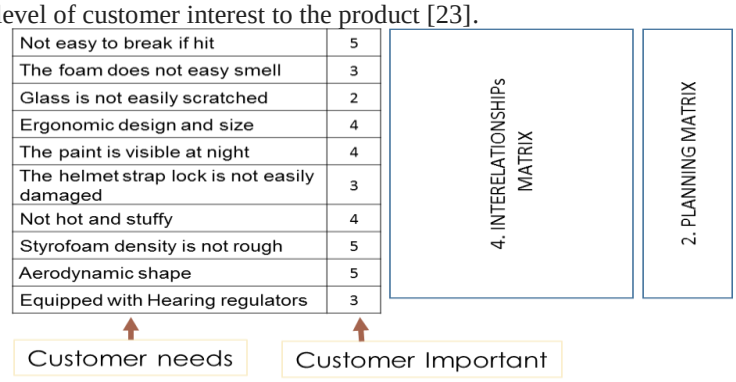

Figure 3: Weighting of Customer Needs (Voice Of Customer)

By using scale 1-5, and based on brainstorming results in Product Development that customer needs are most important with scale 5: not easy to break if hit, styrofoam density is not rough, and aerodynamic shape. This is related to safety issues, comfort (for setting the head position), and the appearance and surface of the helmet is not restrained the wind in the opposite direction with the rider

Step 4: Competitive Benchmark is used for conducting benchmarks with competitors' products (BMC & INK) based on survey results and brainstorming product development team to see the position of the product to competitors.

Customer needs		Interelationship	Planning Matrix							
Not easy to break if hit	5		4	4	2	5	1,2	1,4	8,4	15
The foam does not easy smell	3		3	5	3	4	1,2	1,1	4,0	7
Glass is not easily scratched	2		4	3	3	4	1,0	1,2	2,4	4
Ergonomic design and size	4		3	4	3	4	1,2	1,2	5,8	10
The paint is visible at night	4		2	2	2	3	1,2	1,3	6,2	11
The helmet strap lock is not easily damaged	3		4	4	3	4	1,0	1,1	3,3	6
Not hot and stuffy	4		3	4	3	4	1,2	1,2	5,8	10
Styrofoam density is not rough	5		2	4	2	4	1,4	1,3	9,1	17
Aerodynamic shape	5		3	3	2	3	1,0	1,2	6,0	11
Equipped with Hearing regulators	3		2	2	2	3	1,2	1,1	4,0	7

CS Rating our textbooks	CS rating competitior BMC	CS rating competitior INK	Our Planned CS Rating	Improvement Factor	Sales Point	Overall Weighting	% of total weight

Figure 4: Competitive Benchmark

By using scale 1-5, and based on brainstorming results in Product Development, that the top three percentagesin total benchmarking are: helmet not easy to break if hit (15%), styrofoam density is not rough (17%),aerodynamic shape (11%). This shows that from the competitor side these three factors are very dominant in making the product design plan.

Example for calculation (*helmet not easy to break if hit)*

Improvement Factor : ((Our Planned CS Rating - CS Rating our textbooks) *0.2)+1

: ((5 – 4)*0.2) + 1 = 1.2

With using same case

Overall Weighting : Weigh Customer Voice * Improvement Factor * Sales Point

: (5*1.2*1.4) = 8.4

% of total weight : (Overall Weighting Customer needs / Total Overal Weighting Total)*100

: (8.4)/(8.4+4.0+2.4+5.8+6.2+3.3+5.8+9.1+6.0+4.0)*100 = 15

CS Rating our textbooks, CS rating competitor BMC, CS rating competitor INK, Our Planned CS Rating, and Sales Point there is input related with product development brainstorming and data collection.

Step 5: Technical Requirements (HOWs), to determine from technical aspect for product development plans to meet customer needs.

Technical Reqierement (HOWs)

Customer Need (WHATs)		Temperature control	Adjustabl inside foam	Visibility Rider	Size and Shape	Materials	Planning Matrix							
Helmet easily broken	5						4	4	2	5	1,2	1,4	8,4	15
The foam is easy to smell and moist	3						3	5	3	4	1,2	1,1	4,0	7
Glass is easily scratched and broken	2						4	3	3	4	1,0	1,2	2,4	4
Not ergonomic	4						3	4	3	4	1,2	1,2	5,8	10
The paint is not visible at night	4						2	2	2	3	1,2	1,3	6,2	11
The helmet strap lock is easily damaged	3						4	4	3	4	1,0	1,1	3,3	6
Hot and stuffy	4						3	4	3	4	1,2	1,2	5,8	10
Styrofoam Density	5						2	4	2	4	1,4	1,3	9,1	17
Not aerodynamic	5						3	3	2	3	1,0	1,2	6,0	11
Not hearing regulators	3						2	2	2	3	1,2	1,1	4,0	7

Interelationships

CS Rating our textbooks	CS rating competitior BMC	CS rating competitior INK	Our Planned CS Rating	Improvement Factor	Sales Point	Overall Weighting	% of total weight

Figure 5: Technical Requirement (HOWs) Applied to the HOQC

Step 6: Interrelationship WHATs and HOWs, to determining the level of relationship (relation) between customer needs and needs in terms of technical aspects

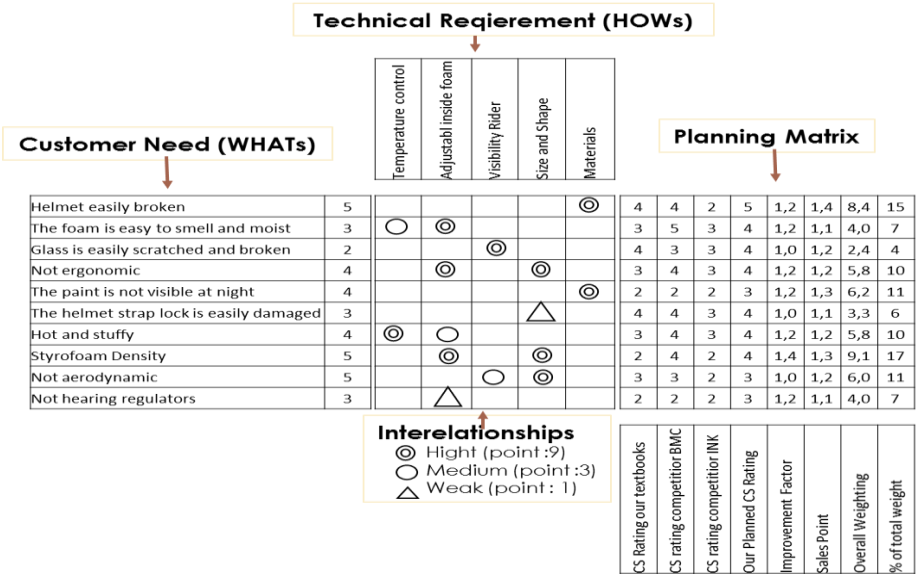

Figure 6: Interrelationship between WHATs and HOWs

By using score : 1 (week), 3 (Medium), and 9 (high), based on brainstorming results in sectionsProduct Development obtained a high correlation is in several things, there are helmet is not easy to break vs.material (point 9), foam easily and humid vs adjustable, inside foam (point 9),glass easily scratched and broken vs visibility, rider (point 9), less ergonomic vs adjustable inside foam, and size and shape (point 9), the paint is not visible at night vs material (point 9), hot and airless vs temperature control (point 9), styrofoam density vs adjustable inside foam, and size and shape (point 9), and less aerodynamic vs size and shape (point 9).

Based on the above factors, the relationship between the customer need and the technical requirement is more focused on the safety of the rider (points 1, 3, 5, 8) and convenience (points 2, 4, 6, 7) see figure 6.

Step 7: Design Target and House of Quality, calculation, and weighting of design targets to determine priorities in conducting product development related to customer need (WHATs), technical requirement (HOWs) and benchmarking result to competitors so that the products produced in accordance with customer needs and able to compete with competitor products.

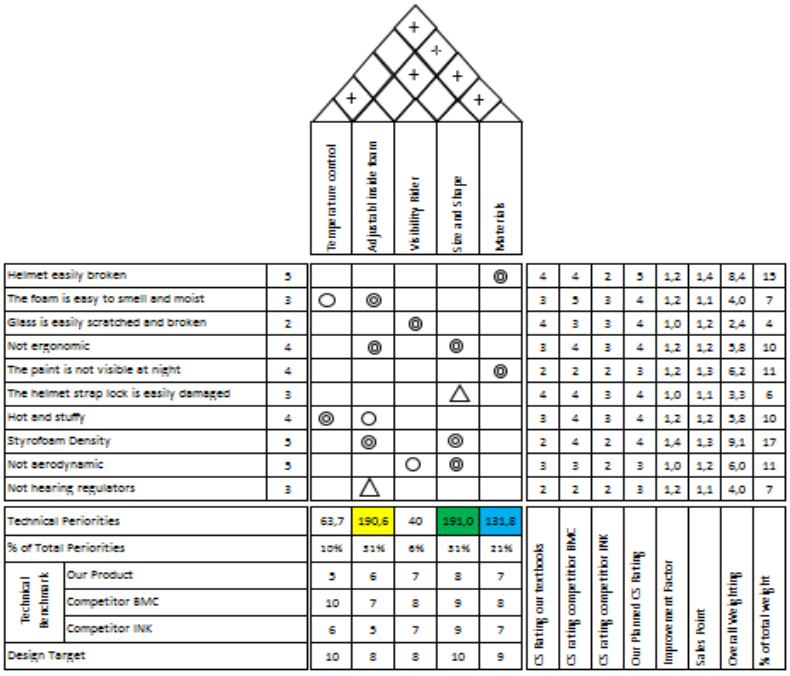

Figure 7: The Completed HOQ

To determine relative importance or technical priorities of each the state technical requirement (HOWs) and customer need (HOWs), in QFD a simply we can multiply each of interrelationship rating of the technical requirement weak, medium, or high (1, 3, or 9) from the interrelation matrix with Overal weighting value in the planning matrix and then sum the column. For total priorities calculate by dividing individual technical priorities value by sum of all technical priorities value, and multiple 100.
Technical priorities calculation : (9*4.0)+(9*5.8)+(3*5.8)+(9*9.1)+(1*4.0) = 190.6
%-of Total periorities : (190.6)/(63.7+190.6+40.0+191.0+131.8)*100 = 31%
With the same calculations we can put the values as the matrix, figure 7
From the comparison result data in QFD House, Product Design Motorcycle Helmet will be done with the following criteria:

1. Helmet is made with a temperature controller more equal to BMC products as the best competitors (10)
2. Inside foam can readjust as effort to give comfort of the wearer because of the size of the inside of the helmet related to the head can be adjusted, and this will be better than both competitors BMC and INK (8)
3. Visibility rider will be made referring to the best competitor that is BMC because it concerns the safety of the rider, and for now BMC better than INK (8)
4. For size and shape, the product will be made better than the competitors because concerning safety and comfort (ergonomics), so it is expected to be able to attract customers better than competitors (10)
5. Use of materials will be used better than both competitors, the material chosen is light/weight with coated phosphor paint so will it lit up at night. in addition to providing protection to the user also against another vehicle so the accident will be very small.

Prototype Design Product

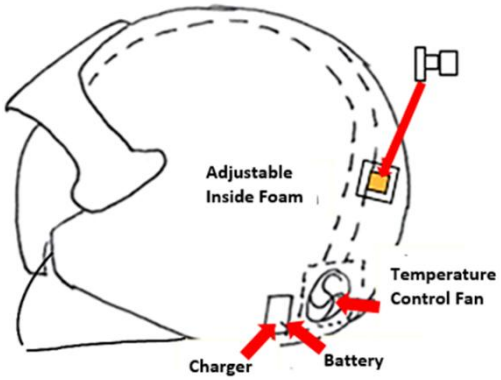

Figure 8: Prototype Design Product Helmet

Product Design Helmets are made of strong and impact resistant material, painted using a phosphor coating that can provide light against dark conditions. Equipped with an inner foam control so that it can adjust to the size of the head, equipped with a temperature controller by using a small fan on the back with battery charger drive and will light up in accordance with the needs of the wearer, helmet glass is designed according to eye sight with scratch resistant material, The inside uses a foam with a better density so as to neutralize the unwanted odor and can be removed so that it can be washed/cleaned at any time.

Conclusion

Since the percentage of accidents occur involving motorcycles (80%) and the number of motorcycle accident increase from year to year, then one of the most effective countermeasures to prevent head injuries is the use of a protective helmet. Motor cycle helmet has been designed, modeled and built to suit therequirement of riders by considering ergonomicsand thermal comfort. The proper ventilation and the exhaust fan reducesthe thermal discomfort to the rider. The adjustable head form helps to suit the helmetto the riders of different head shapes. The visibility of the helmet has been improved bygiving a wide angle of visors. There are some recommendations for work in the future. The selection of exhaust fan location can be carried out. Structural analysis can be carried out to know thebehavior of helmet during accidents. Adjustable foam technology can be extended at therear side of the helmet. Suitability of blower fan instead/along withexhaust fan can be a review.

Electronic devices can be incorporated to automatethe exhaust fan. The solar panel can be introduced to power the exhaustfan.

From the results of QFD analysis, the largest values of technical priorities for helmet design is 191.0. It's mean that the design should be focused on interrelationship the size and shape of aerodynamic and ergonomic helmet shape, styrofoam density and also helmet strap lock. The position of helmet products designed against other competitors is more emphasis on the convenience of the user, among others the existence of temperature regulator (values 10), foam needs with the size of the user with good density (flexibility and adjustable) foam (values 8), better vision (values 8), the number of available sizes and shapes are diverse (target design values 10), and the use of quality materials (values 8).

References

[1]. Http://www.liputan6.com/news/ibukota, 2017.

[2]. Chan, Ching-Yao. (2002) On the detection of vehicular crashes-system characteristics and architecture, Vehicular Technology, IEEE Transactions, 180-193.

[3]. Alexander, Lee, and Max Donath. (1999) Differential GPS based control of a heavy vehicle, Intelligent Transportation Systems. Proceedings. (1999) IEEE/IEEJ/JSAI International Conference on. IEEE.

[4]. Ali, Mohammad, et al. (2013) Predictive prevention of loss of vehicle control for roadway departure avoidance, Intelligent Transportation Systems, IEEE Transactions, pp. 56-68.

[5]. Praveen Kumar Pinnoji and Puneet Mahajan. (2007) Finite element modeling of helmeted head impact under frontal loading, Vol. 32, Part 4, pp. 445-458, Transportation Research, and Injury Prevention Programme, Indian Institute of Technology, HauzKhas, New Delhi.

[6]. Chia-Yuan Chang., Chih-Hsiang Ho ., and San-Yi Chang. (2003) The Design of a helmet, ME 499/599.

[7]. Nasution, ES. (2010). Characteristics of Patients Head Injury Due to Motorcycle Accident, pp.5, www.repository.usu.ac.id.

[8]. Maserati, Fetzick, Puccio. (2016). The Glasgow Coma Scale (GCS) Deciphering the Motor Component of the GCS. Journal of Neuroscience Nursing, 48(6):311-314.

[9]. Kamiske G.F. (2004) Pocket Power: Prozessoptimierungmit Quality Engineering, Munchen, Wien: Carl HanserVerlag.

[10]. Spath D., Linder C., Seidenstricker S. (2011) Technologiemanagement:Grundlagen, Konzepte, Methoden,Stuttgart: Fraunhofer Verlag.

[11]. Deutsche Gesellschaft f¨ur Qualit¨at e.V., Frankfurt. (2001)QFD – Quality Function Deployment, Berlin, Wien,Z¨urich: Beuth Verlag GmbH.

[12]. Klein B. (2012) QFD – Quality Function Deployment-Konzept, Renningen: Expert Verlag.

[13]. King B. (1994) Doppelt so Schnell wie die Konkurrenz, 2nd ed. Schweiz: gfmt Verlag.

[14]. D.J. Delgado & E.M. Aspinwall, (2003) QFD Methodology and Practical applications –A Review, Proceedings of the Ninth Annual Postgraduate Research Symposium, School of Engineering, The University of Birmingham, 1-5.

[15]. Akao, Y., ed. (1990). Quality Function Deployment, Productivity Press, Cambridge MA, Becker Associates Inc.

[16]. Cohen, L. (1995) Quality function deployment – How to make QFD work for you, Addison Wesley LongmanInc., USA.

[17]. Shahin, A. (2008) Quality Function Deployment: A Comprehensive Review, Department of Management, University of Isfahan, Isfahan, Iran.

[18]. Http://en.wikipedia.org/wiki/Motorcycle_ helmet#Full_face.

[19]. Bosch, van den, H. L. A. (2006). Crash helmet testing and design specifications Eindhoven: Technische Universiteit Eindhoven DOI: 10.6100/IR613094.

[20]. Kazuaki Yamashita, Juntaro Matsuo, Yutaka Tochihara, Youichiro Kondo, Shizuka Takayama and Hiroki Nagayama. (2014) Thermal Sensation and Comfort during Exposure to Local Airflow to Face or Legs, Journal of Physiological Anthropology and Applied Human Science, 24: 61–66.

[21]. M.A. Forero Rueda and L. Cui, M.D. Gilchrist. (2012) Optimization of energy abs-orbing liner for equestrian helmets, University College Dublin Belfield, School of Electrical, Electronic and Mechanical Engineering, Dublin 4, Ireland.
[22]. Mithuni, Umes, and Pathan (2013) Conceptual Design of Motor Cycle Helmet to Meet The Requirement of Thermal Comfort, Ergonomics, and Safety, Sastech Journal, Volume 12, Issue1: 66-67
[23]. Goetsch, D.L. and Davis, S.B. (2010) Quality Management for Organization Excellence, 6th_ed., Upper Saddle River, NJ: Pearson Education Inc., pp. 296-311.
[24]. Jaiswal (2012) Case Study on Quality Function Deployment (QFD), ISSN: 2278-1684 Volume 3,Issue 6: 31
[25]. Childs, Antony Bull, and Ghajari (2013) Helmet Performance and Design, pp. v, DEG Imperial College, Department of Mechanical Engineering, London.
[26]. Hamidullah, R. Akbar, S. Noor, W. Shah & Inayatullah (2010) QFD as a Tool for Improvement of Car Dashboard, University of Engineering and Technology Peshawar, Pakistan, Journal of Quality and Technology Management Volume VI, Issue 1, June.: 1 - 3
[27]. Kauffmann, P., Unal, R., Fernandez, A. and Keating C. (2000) A model for allocating resources to research programs by evaluating the technical importance and research productivity, Engineering Management Journal, Vol.12, No.1, 5.
[28]. Hauser, J. R. and D. P. Clausing, The House of Quality, Harvard Business Review, May/June 1988.
[29]. A Griffin and JR Hauser (1992) Patterns of Communication among Marketing, Engineering and Manufacturing, A Comparison between Two New Product Teams, Management Science 38 (3), 360-373.
[30]. Hales, R. and Staley, D. (1995) Mix target costing, QFD for successful new products, Marketing News, 29(1), 18.