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New Product Development and Design for Mass Customization using House of Quality Template

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Abstract: This study aims to explain a House of Quality (HoQ)-based approach that integrate technical needs and customer requirements as a useful procedure in mass customization and to demonstrate a HoQ template prototype, for the purpose of managing product design and development activities efficiently. HoQ is a procedure to determine the characteristics of new product development that combines technical requirements and customer desires. In the current mass customization era, this is a useful practice in providing tremendous variety and individual customization, at competitive prices. Among the problems faced in product development is the lack of information and communication technology (ICT) application to manage the technical needs and customer requirements so that the acceptability of the products can be maximised and customer requirements could be fulfilled. The implementation of ICT in product design and development activities are required to ensure smooth running of these activities. This study employs systems development life cycle methodology in developing HoQ template application. The application was tested to evaluate the reliability and usability of the system. The House of Quality Template prototype was proposed to ensure new product design and development activities are managed properly. The prototype was tested using two software quality dimensions, namely usability and application environment. The responses from a group of users show that the application performs the deliberate function properly. This study seeks to find solution and help industry to increase the efficiency of new product design and development activities especially in mass customization paradigm.

Keywords: House of quality, mass customization, new product, new design, template

INTRODUCTION

Currently, competition in industry has become increasingly intense. With the trend of globalization, businesses and companies face the challenges of both local and international competitors. To overcome this competition, many companies focused on finding benefits in their products or services. Survival of a company relies heavily on the ability to identify new customer needs and develop and enhance the product market. Delivery of innovative products to market is regarded as a key element for a company to face competitive challenges.

The notions of customer focus have spread through various industries especially manufacturing of consumer products sector. The previous mass production age has been replaced by mass customization (Fralix, 2001). Nowadays, customers are no longer happy with cheap products that do not meet their preferences (Teichert and Wartburg, 2005; Xuan *et al*., 2004). Among the challenges in product development sector is to efficiently manage the technical needs and customer preferences. Producers require that various ranges of products could be designed and produced. The newly produced and developed product should fulfill customer requirements, thus the acceptability of the products can be maximized (Gassmann *et al*., 2006).

In order to satisfy changing customer needs, offering product according to custom is not enough. Fartash *et al*. (2012) suggest that customer needs and expectations need to be met through product innovation. This innovative product development process requires an understanding of changing customer wants and needs and procedure of fulfilling these needs (Stock, 2011). Therefore, there is a need to learn and use procedures that can help a company in this case. These procedures will help to acquire a deep knowledge of customer needs and satisfaction and then develop products with innovative features.

House of quality (HoQ) is a procedure that provides a visual tool for developing a product or process design based on requirements of customers. Bouchereau and Rowlands (2000) found that the HoQ can provide enormous benefits, but it's not an easy tool to use. According to Ebrahim *et al*. (2009), among the problems faced in product development is the lack of

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ICT application to manage the technical needs and customer requirements so that the acceptability of the products can be maximised and customer requirements could be fulfilled. The implementation of ICT in product design and development activities are required to ensure smooth running of these activities.

The purpose of the study consisted of two parts and they were:

- Introducing a HoQ-based approach to integrate technical needs and customer requirements for the purpose of increasing acceptability of new products development and design in supporting mass customization.
- Demonstrating systematically a prototype of HoQ template, which had been successfully developed and tested for the purpose of translating customers' needs, integrating customer needs and technical requirements as well as analyze the two requirements.

MASS CUSTOMIZATION AND HOUSE OF QUALITY

Manufacturing has moved from craft era into mass production with the advent of the industrial revolution and interchangeable parts (Fralix, 2001). Mass production offers standardization where everybody get the same products at lower price. Mass production era does not sustain for long time. Customers are no longer satisfied with low costs offered by mass production era. They demand products that fulfill their requirement, at the same low costs. Mass customization has been adopted in industry in the 1980s. It is a concept where highly customized products are delivered at costs comparable with mass production (Barlow, 1998).

There are many ways in defining mass customization. It could be defined as “the ability to provide individually designed products and services to customers through high-process flexibility and integration” (Fogliatto *et al*., 2003). Wu (2005) suggests mass customization means that “products can be produced with low cost, high quality and in time as mass production”. Another definition suggests mass customization as “providing tremendous variety and individual customization, at prices comparable to standard goods and services...with enough variety and customization that nearly everyone gets exactly what they want” (Pine, 1993).

Zipkin (2001) associates mass customization with three key capabilities i.e. elicitation, process flexibility and logistics. These capabilities are required in today’s high competition market. Elicitation suggests that customer plays important role to give their feedback and comments on new products. Process flexibility involves designing the product to be comprised of multiple modules that can be mixed and matched to yield customized products. Logistics concerns with distribution and delivery of the right product to the right customer.

In mass customization, customers are considered as early as the design stages (Nambiar, 2009). This is to ensure partnership and cooperation between customer and producer and lower the risk involved in introducing new products. Customer requirements should be effectively translated into the design and subsequently into the product in order for the product to achieve market success.

Mass customization suggests producer to produce a wide product variety. With various requirements from customers, modularity helps in providing highly customized products. Producer requires an efficient and effective means to realize sufficient product variety, while satisfying a range of customer demands in support for mass customization (Tseng and Jiao 1998). Now, the question arises as to how a producer provides a variety of customized products that fulfilled customer requirements. This is the concern of producer to ensure that the acceptability of the products can be maximised and customer requirements could be fulfilled.

House of quality (HoQ) is a procedure that provides a visual tool for developing a product or process design based on requirements of customers. This is all about getting the right information of what customer wants and ensure that these requirements are fulfilled by what the company has to offer.

The application of HoQ to support mass customization has been widely researched. For example, Ni *et al*. (2007) shows the application of QFD in selecting supplier in mass customization era. Olhager and West (2002) show an example of applying HoQ for linking manufacturing flexibility to market requirements. The approach creates a framework for modeling the deployment of the need for flexibility from the customers’ viewpoints into manufacturing flexibility at various hierarchical levels. It helps manufacturing system to design a new and wider range of products. Wang and Lin (2007) introduce a defect tracking method based on HoQ for every mass customization production system module. The algorithm helps to identify and track defect which directly connects manufacturing technologies with quality defect.

Jafri and Suhaimi (2001) suggest the integrated use of the HoQ with Value Engineering method (VE). This procedure allows the needs of customers to be translated into technical requirements and design. Wan Yusoff *et al*. (2011) examine the use of the HoQ and rapid prototyping technology to improve the design of sleepy alarm to prevent drivers from sleeping. HoQ was used to analyze and evaluate the criteria and features in this product that can be improved.

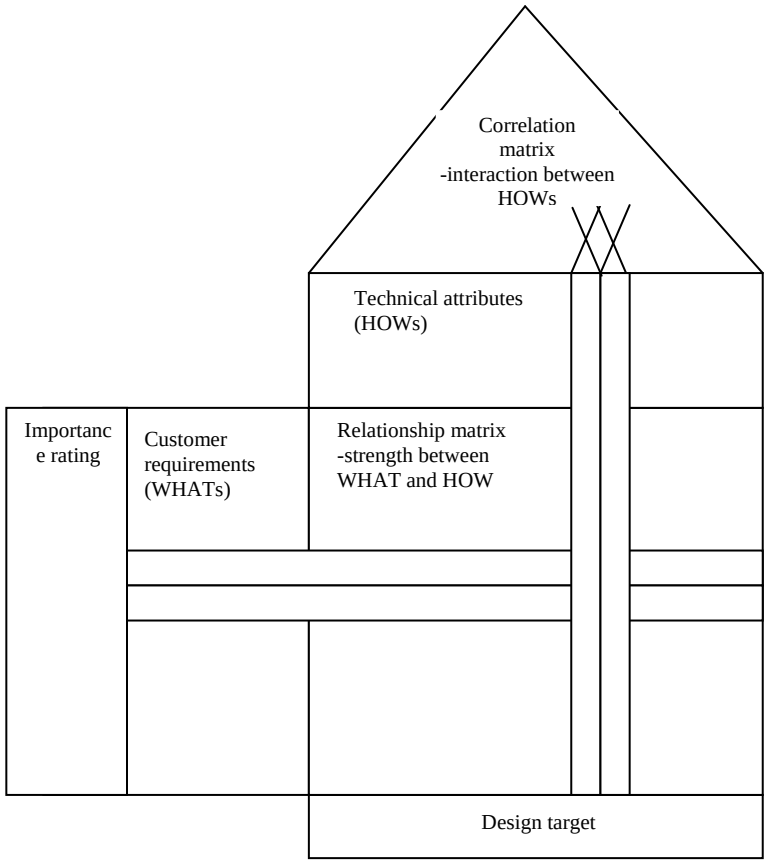


Fig. 1: Structure of house of quality

HoQ is a procedure to determine the characteristics of product development that combines technical and customer requirements. This conceptual map provides the means for inter-functional planning and communications between producer and consumer. Successful implementation of HoQ allows organization to enjoy following advantages (Bouchereau and Rowlands, 2000; Han *et al*., 2001; Kumar *et al*., 2006; Maier, 1995; Zairi and Youssef, 1995): reduction in the design cycle time and warranty claims, whilst identify the competition that exists in the market and generate an optimal customer-oriented and higher quality design.

HoQ is a structured method used in the process of planning and development of products to set specifications needs and wants of customers and evaluate the technical characteristics of a product or service to meet the needs (Cohen, 1995). HoQ is also synonymous with Quality Functional Deployment (QFD). It was developed in the late 1960s in Japan by Akao (1990). It was first applied in the Mitsubishi Kobe Shipyards in 1972 to ensure customer satisfaction (Akao, 1990). The purpose of HoQ is not just to meet customer expectations as much as possible, but also strive to exceed customer expectations as a means of competitive strategy.

HoQ procedure consists of three general levels of quality, where all the activities conducted at each level can be applied in a project. The levels are: 1. Collecting customer voices. 2. Compiling HoQ. 3. Analysis and implementation. The first level is done through data collection to obtain the voice of the customer. This process requires customer data that was presented as an attribute of a product or service. General qualitative data are obtained from interviews and observations of customers while the quantitative data are obtained from the study questionnaire.

The second stage involves the compilation of HoQ. A house consists of a matrix containing customer requirements, technical attributes and correlation matrixes. All five elements are arranged at this stage. In determining the needs of customers a few things need to be decided such as determining who the customers are, what the customer wants and needs and how to manage the needs and requirements.

Figure 1 presents main elements in HoQ. The first element concerns with customer requirements. This element require producer to determine who the

customer are, collect data of customers needs and requirements, organize the needs and requirements and create affinity diagrams. The second element involves giving rating on customer requirements. The third element concerns with technical response, the non-technical data of customer's requirements are transformed into technical format, so that the requirement is embedded in the product. The fourth element is about the relationship between technical attribute and customer requirements. The final element is regarding technical correlation, i.e., the relationship between items in technical attribute.

The third stage involves the analysis and implementation of HoQ. In this implementation stage, it is crucial to conduct the action of the plan to ensure that it will be able to develop products or services that have powerful features to meet customer requirements.

METHODOLOGY

The development of House of Quality Template Applications adopts Systems Development Life Cycle (SDLC) methodology. SDLC was chosen because it provides a systematic procedure of software development. SDLC model has five important phases: planning, analysis, design, implementation and testing. This study was conducted in 2010 and the test was performed in Industrial Computing laboratory, Universiti Kebangsaan Malaysia.

In the planning phase, a preliminary study was conducted to determine the problem, main objective and scope of application development. The main goal of the analysis phase is to research the system requirements. In-depth study of the current platform and HoQ template application was carried out to understand the real problems and solutions of the application. All required functionality and application specifications are described in detail, for example what users want in HoQ application to achieve the objectives of the application.

In the design phase, researchers began to plan the logical and physical designs of the application. This include designing template interface, database, required menu, data input and output and the functioning of the system to reflect the actual state of the template before it is developed. Flow chart was developed to illustrate the process. For example, the main function in the application is shown in Fig. 2.

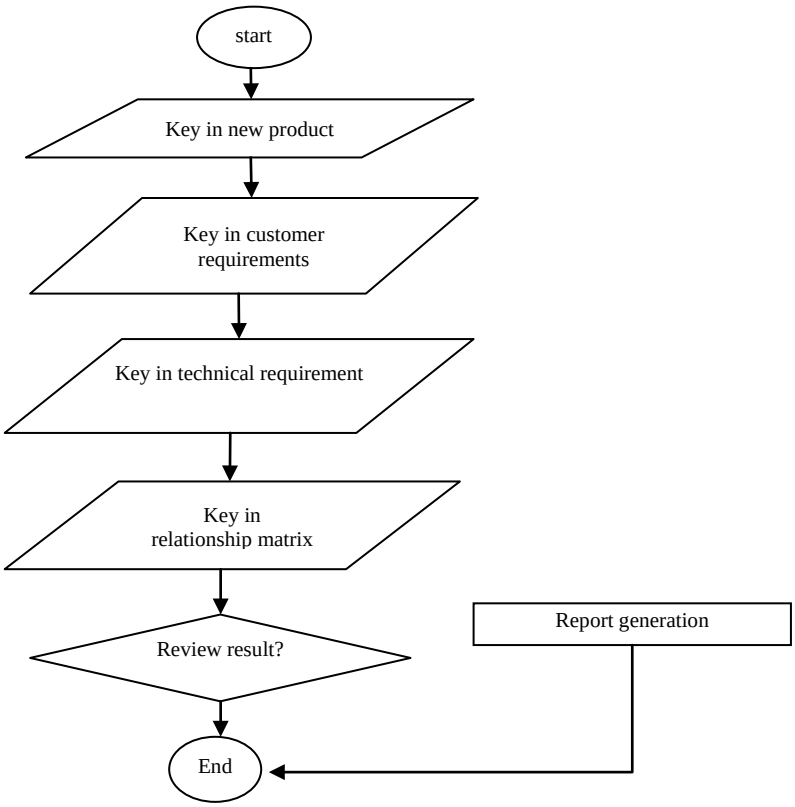


Fig. 2: Flow chart of house of quality development

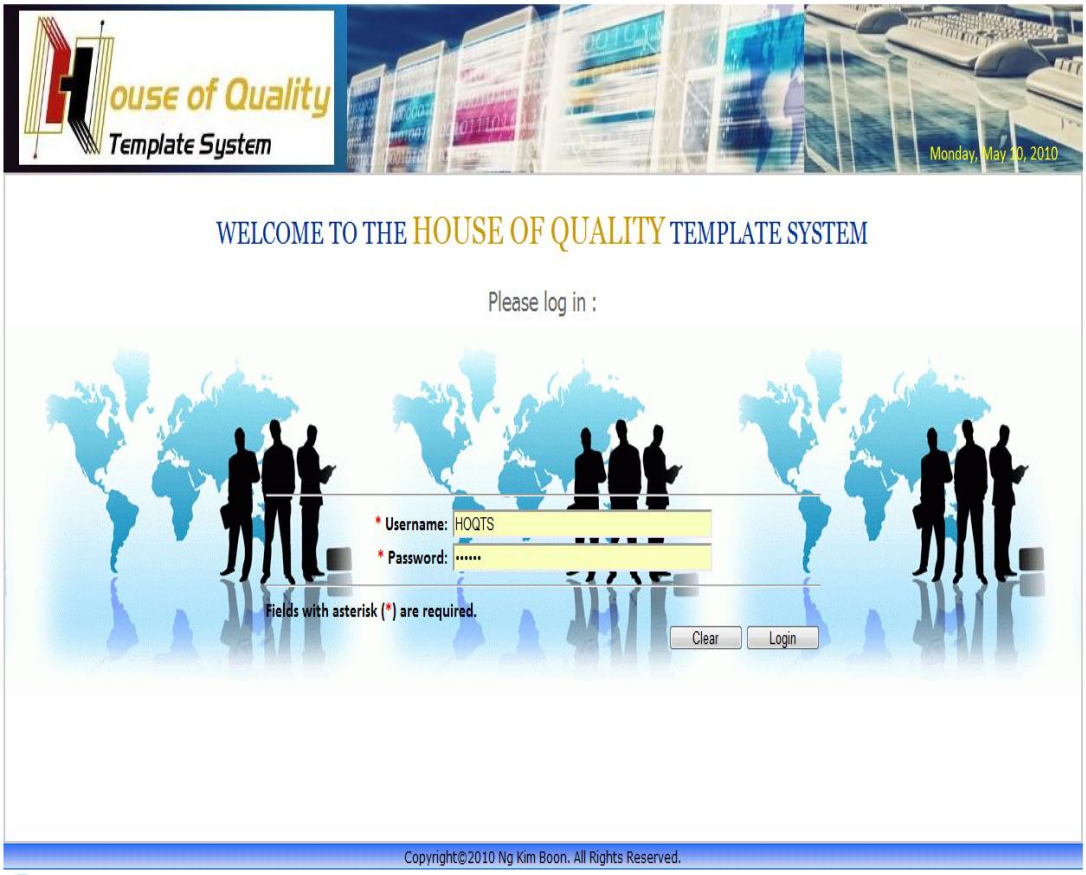


Fig. 3: Log in interface

As presented in the flow chart, the application presents a simple function of HoQ. The reason is due to the main problem of using HoQ i.e., in managing and analyzing large relationship matrices (Boonyanuwat *et al*., 2008). Therefore the application involves both limited numbers of customer requirements and limited numbers of technical elements. A big project might be reduced into a set of sub-projects, so that the relationship matrices could be simplified and analyzed thoroughly.

During the implementation phase, hardware, software, databases must be prepared to be executed in developing the application. Programming, coding, database linking, integrating and testing take places to complete the application and to detect any errors that may arise.

In the testing phase, various tests and evaluation were carried to ensure the application fulfills the function and fits user requirements. The application was also evaluated by six users that represent the potential industry practitioner views. The evaluation instrument was adopted from Hairulliza *et al*. (2007). Responses from this group of users were reviewed to examine the quality of the application.

IMPLEMENTATION AND DISCUSSION

This research aims to propose a template prototype for HoQ, for the purpose of managing product design and development activities efficiently. The function and interface design for this application considers important requirements in new product design. The application is designed to integrate technical needs and customer requirements. The interface design emphasizes minimal use of text and simple and easy-to-understand menu. The interface plays an important role as an effective communication link between the application and users.

Figure 3 shows an interface to access HoQ template application by inserting the registered username and valid password. This function acts as security to allow only registered users to access to this application. Among the important function in this application is the design of new product itself. Information on new products or services need to be included in the application. Figure 4 shows an interface to add new product information. Users should give identification of the product or services by entering proper title, number of customer requirements and number of technical requirements.

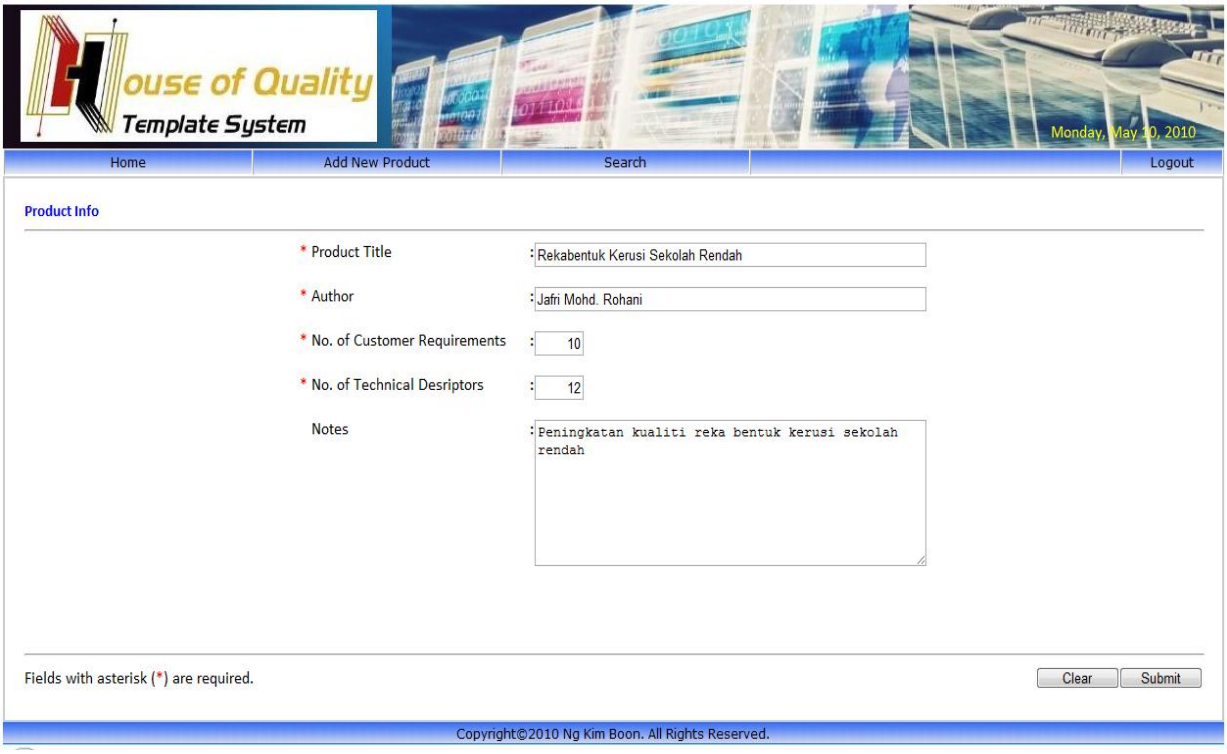


Fig. 4: New product information

Fig. 5: Customer requirement

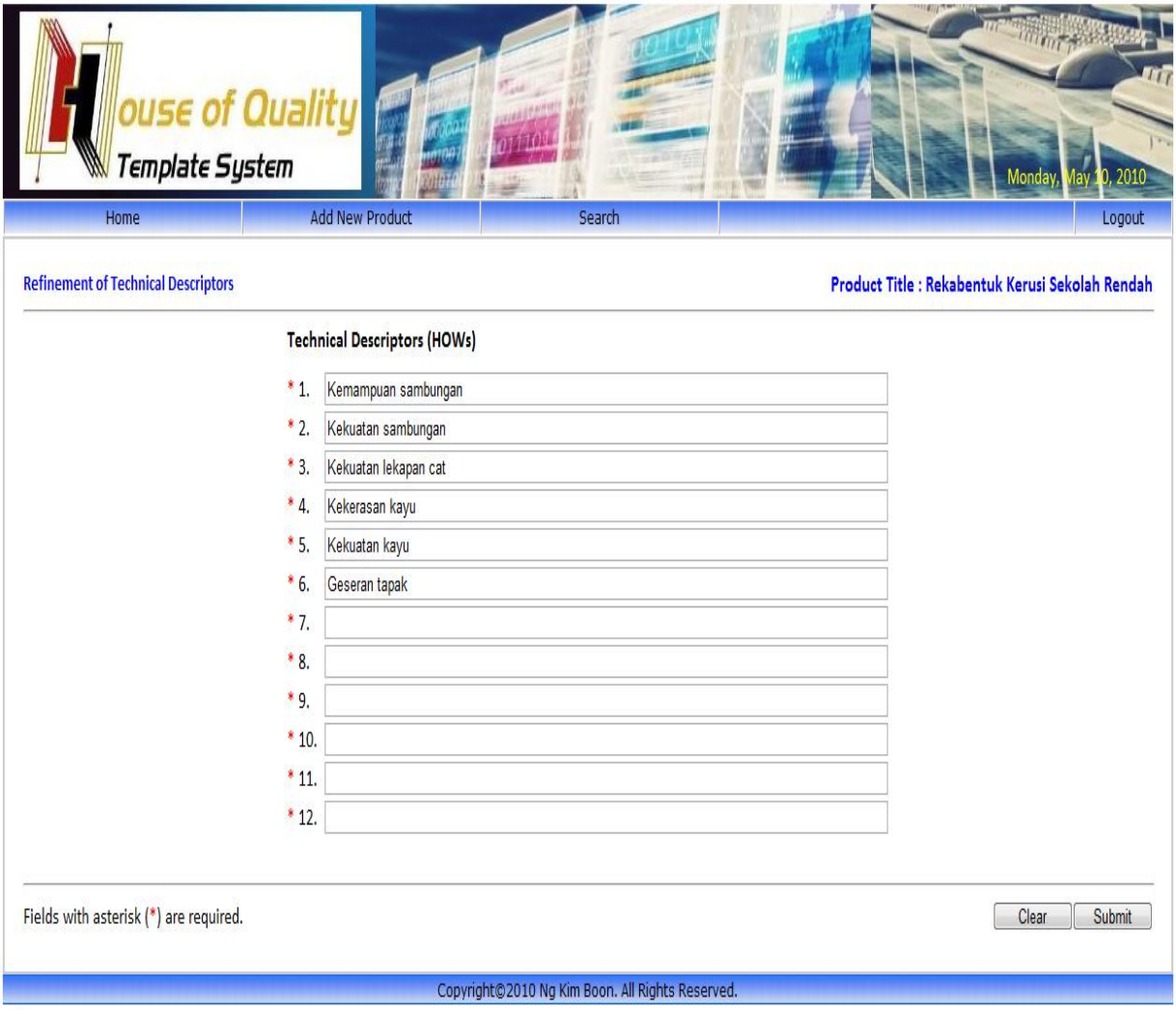


Fig. 6: Technical attribute

After all the required information are gathered, users might proceed to include customer attributes (qualitative data) products or services obtained from interviews and observations of customers. This interface is shown in Fig. 5. The technical requirement component is presented in an interface in Fig. 6. Users are required to enter the technical attributes (qualitative data) of new product or service. It is derived from transforming the non-technical customer requirements into these technical data to meet those needs.

New product design and development may achieve market success with the ability of producer to effectively translate customer requirements into the design and subsequently into the product. By using this template, it helps producers to be concerned about customers as early as the design stages (Nambiar, 2009). Customer requirements are sought in the design stage as an attribute or benefit that the customer will receive from the product or service.

By ensuring that customer is given enough attention as early as possible, this will help producer to fulfill customer requirements and to lower the risk of new products being rejected. The process of transforming customer requirements into the language required to implement a product is a critical element that makes HoQ a powerful tool (Chen and Chen, 2002). The HoQ template provides this facility to manage the technical needs and customer requirements so that the acceptability of the products can be maximised and customer requirements could be fulfilled.

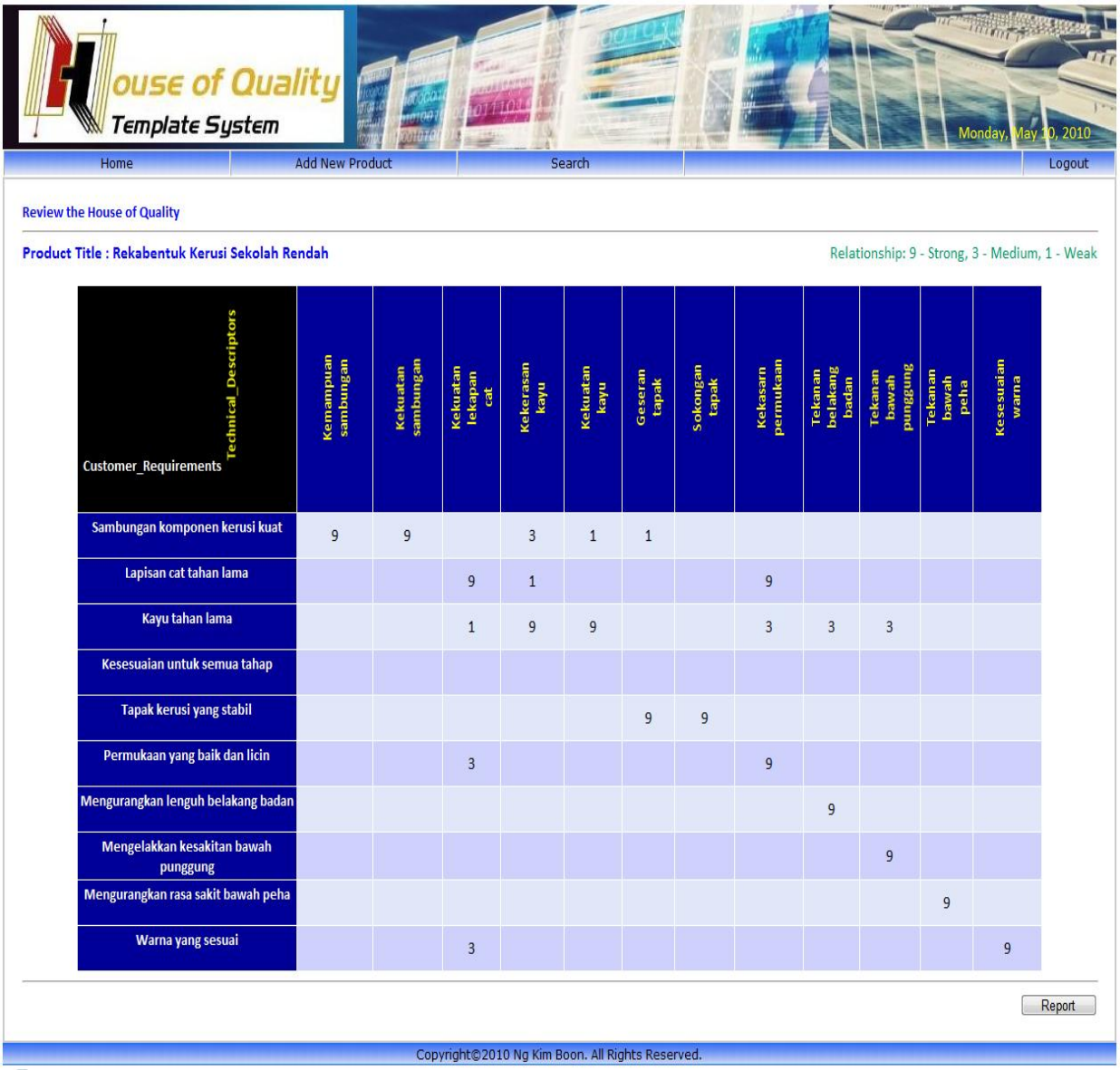
The HoQ template highlights the analysis of relationship between items in the two components:

Fig. 7: Correlation matrix

customer requirements and technical attributes. The relationship matrix is presented in an interface in Fig. 7. This function enables users to determine the interaction matrix of the products or services. It is used to show how much the product features given by the engineering characteristics might affect the individual customer needs.

Users need to select the strength of relationship between elements in the two components from drop down list. This information also measures the importance of technical requirements on behalf of the customer. The given value of the relationship matrix composed of 9 to measure a strong relationship, 3 for moderate, 1 for weak and leave empty space for no relationship.

The interface in Fig. 8 shows a review of HoQ result. It provides users with an analysis of the strength between customer requirement and technical attribute items. Users might revise the house by adding new items for both customer requirement and technical attribute components. Users might also modify the relationship matrix by changing the relationship value. Users might



Customer_Requirements \ Technical_Descriptors	Kemampuan sambungan	Kekuatan sambungan	Kekuatan lekapan cat	Kekerasan kayu	Kekuatan kayu	Geseran tapak	Sokongan tapak	Kekasarn permukaan	Tekanan belakang badan	Tekanan bawah punggung	Tekanan bawah peha	Kesesuaian warna
Sambungan komponen kerusi kuat	9	9		3	1	1						
Lapisan cat tahan lama			9	1				9				
Kayu tahan lama			1	9	9			3	3	3		
Kesesuaian untuk semua tahap												
Tapak kerusi yang stabil						9	9					
Permukaan yang baik dan licin			3					9				
Mengurangkan lenguh belakang badan									9			
Mengelakkan kesakitan bawah punggung										9		
Mengurangkan rasa sakit bawah peha											9	
Warna yang sesuai			3									9

Fig. 8: House of quality review

Table 1: Evaluation of house of quality template

Item	1 Not exist	2 To a small level	3 To a great level	4 Completely
Reliability				
Producing correct result			5(83.33%)	1(16.67%)
Ensuring correct input from user			5(83.33%)	1(16.67%)
Presenting standardize output			4 (66.67%)	2 (33.33%)
Easy to follow instruction			4 (66.67%)	2 (33.33%)
Usability				
Functioning properly			5(83.33%)	1(16.67%)
Adequate input			6 (100%)	
Adequate output		2 (33.33%)	4 (66.67%)	
Application environment				
User friendliness			3 (50%)	3 (50%)
Easy information access			4 (66.67%)	2 (33.33%)
Interesting interface			4 (66.67%)	2 (33.33%)

generate a report and share the information in formal meeting, thus the application provides this function.

By modifying the result of HoQ, users might be able to design a new and wider range of products. As suggested by Olhager and West (2002), applying HoQ helps producer for linking various range of products to customer requirements. HoQ template provides platform for users in modeling the deployment of market requirements from customer's viewpoints into series of new products. In mass customization era, a range of customer demands require attention from producer. HoQ template helps producer to generate an optimal customer-oriented designs that provide sufficient product variety in support for mass customization.

To evaluate the quality of the application, the prototype was tested among a sample of six users. The users were chosen from those who are familiar with HoQ to explore and evaluate the system. The background of the users are the following: all of the users are in their final year of undergraduate study in Industrial Computing programme, Universiti Kebangsaan Malaysia, four of the participants are female and the other two are male.

The instrument used for evaluation consists of three aspects of software quality, namely reliability, usability and application environment. Responses from users were gained by asking them to fill in the instrument after given enough time to access the application. The results from the analyzed responses are presented in Table 1. The results show that there are elements in the prototype that require improvement. These include providing sufficient input and output for the template.

CONCLUSION

Today, virtually every company conducting business operations in manufacturing or service sectors are concerned with customer needs. One of the factors that triggered this was the competition that exists among wide range of products available in the market. Mass customization also plays an important role, where highly customized products are delivered at reasonable costs. This has encouraged companies to improve their quality products to meet the needs and wants of the customers before the product is marketed.

HoQ is a useful method to produce quality products that fulfill the requirements of customer. The use of ICT in the application of HoQ is a wise step to better manage the technical needs and customer requirements. This ensures that the acceptability of the products can be maximised and customer requirements could be fulfilled. The implementation of ICT in product design and development activities are required to ensure smooth running of these activities.

This study has discussed how a HoQ-based approach could be used to integrate technical needs and customer requirements as a useful procedure in mass customization. The study also has demonstrated a HoQ template prototype, for the purpose of managing product design and development activities efficiently.

HoQ template application is expected to help the industry to better understand customer requirement and satisfaction, as well as to develop a systematic products development process. This application also allows the industry to use the HoQ procedure more easily. It involves the collection of customer voice related to products that reflect customer's tastes and desires.

In future, the breakdown of customers requirements by the level of customer desire need to be considered in the HoQ template. Hierarchical segmentation of customer requirements by desire of customers based on Kano analysis would ensure an optimal balance between the customer sacrifice and flexibility of production (Jung and Park, 2008). This research might also be extended by utilizing ICT in other application of HoQ, such as in selecting supplier in mass customization era (Ni *et al*., 2007).

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