Quality Function Deployment for New Standing Cabin Concept of Commercial Transport Aircraft

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ABSTRACT

The main purpose of this paper is to develop the House of Quality (HOQ) for use in the design and development of standing cabin concept for commercial transport aircraft. In short, standing cabin is a new proposed aircraft cabin design concept where passengers are transported in their standing position throughout the entire flight. Quality Function Deployment (QFD) process in this study is focused on the design of the "vertical seat" to be applied inside the standing passenger cabin concept. Data for the HOQ is gathered through an online survey conducted on Malaysian public, including representatives of aerospace-related companies in Malaysia. In addition to that, face-to-face interviews are also conducted with a few experts in the related aviation fields in Malaysia. Based on the obtained information, the HOQ for the seat to be implemented with the standing cabin concept is developed and discussed. The essential design parameters of the "vertical seat" that facilitate in satisfying the expected customer requirements are established from the resultant HOQ and they will be considered in the future development of the seat. It has been found that safety characteristic in the utmost important design requirements ranked by the survey respondents. Furthermore, the main support structure, seat pan, backrest and safety belt mechanism are among the most influential technical design parameters that can be controlled by the designer to ensure successful fulfilment of all driving design requirements for the vertical seat.

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Introduction

The commercial air transportation industry today is very competitive. Faced with many challenges such as fluctuating fuel prices and increasing numbers of competing low cost carriers, new ideas have been sought after by airlines to keep their market competitiveness and maintain the affordability of their air transportation services. One of the proposed ideas is standing passengers' cabin, whereby onboard passengers are transported in an upright or vertical standing position inside the cabin during the entire flight. This idea is based on the notion that increasing the cabin capacity for each flight can reduce the cost per passenger per flight, hence potentially reducing flight ticket prices. It has been estimated that having a standing cabin concept onboard commercial aircraft can help increase the cabin capacity by 40% and reduce the cost by as much as 20% [1]. Moreover, a study done for the Malaysian domestic flight market has indicated a possible reduction of flight ticket prices for as much as 26% [2]. Another published study has highlighted that, though there are still few big challenges to overcome before it can be implemented, standing cabin concept does provide some notable advantages to airlines' operation [3]. The concept seems to work well for flights with duration of one to two hours [4]. Based on the gathered responses from public survey conducted on Malaysian public, it seems that the concept does have considerable market potential to be implemented on domestic flights [5]. This sentiment is also supported by the result of a poll conducted on 120,000 passengers by a European low cost carrier, Ryanair that indicates that more than 42% of the respondents would consider standing in flights if the offered ticket price is half of the normal price or less [6].

The standing cabin concept is not exactly a new idea. Nonetheless, it is rather unfortunate that published study on this matter in the public domain is very little or close to none. Interestingly, Airbus as one of the main aircraft manufacturers in the world, has been exploring similar cabin concept in the past. This is evident from a patent of a cabin design that the company filed in 2002 [7], which is about an aircraft cabin concept equipped with a stand for transporting passengers in upright position as depicted in Figure 1. However, no further technical details on the seat design has been made available to the public. In 2006, low cost airline in China, Spring Airlines has been seriously exploring this cabin concept to be implemented onboard several of its Airbus A320 aircraft [1]. Back in 2015, the airline has reiterated its interest on this cabin idea and reportedly filed for request of regulatory approval for standing sections in its cabin. This is a big step towards the possible implementation of such cabin concept on commercial airliners. Moreover, in 2012, European low-cost carrier, Ryanair has obtained approval from the authority and done a series of 100 flight tests with removal of few rows of seats to accommodate 50 standing passengers for their one-hour flights. All in all, these highlight that there are indeed interest from airlines on the standing cabin concept.

Up until today however, no vertical seat design has been approved by the aviation authorities for use onboard commercial transport aircraft. This can be seen an essential gap to future implementation of the standing cabin concept that needs to be filled. Safety has always been a paramount issue in aviation and therefore, the design of this vertical seat is important since it is providing necessary protection to the passengers. It is also good to note that the standing cabin concept is not illegal by the current standards of governing aviation regulations. For instances, the Federal Aviation Authority (FAA) does not specify that passengers have to be seated during take-off and landing phases whereas the Air Transport Association (ATA) does not impose any specific standard for seating comfort or arrangement inside the cabin. It is adequate as long as the passengers have been properly secured by a certified mechanism.

Figure 1: Illustration of standing cabin in a pattern filed by Airbus [7]

In the absence of approved vertical seat design for the standing cabin concept, this paper explores the design and development process of a suitable seat by establishing its design requirements and parameters through the use of quality function deployment (QFD). The main outcome from this study is the completed House of Quality (HOQ) diagram for the vertical seat that can be referenced during the later design and development phases.

Quality Function Deployment (QFD)

QFD is a consolidated and powerful tool that has been applied to improve the design or development process of products and services with regards to the customer satisfaction. It is used to effectively translate customer requirements (known as "voice of customers") into the related engineering characteristics of the product (known as "voice of engineers"). This tool is developed by Dr. Yoji Akao in 1966 as a method to transform qualitative demands of product users into relevant quantitative parameters, deploy functions forming quality and deploy methods to achieve design quality into subsystems, component parts, and elements of the manufacturing process [8]. In other words, QFD is intended to be a tool to translate customer needs into technical requirements through integration of ideas or feedbacks from people in different disciplines or functions within a company such as design, engineering, manufacturing, marketing and others [9]. This situation enables a significant improvement in the product design and development process as it can reduce potential design changes, enhance cross-functional communications, improve product quality and reduce both product development time and cost. Furthermore, effective application of QFD can also facilitate in the evaluation of impact values from the customer requirements through prioritization of the requirements based on their importance and increase the potential savings of time and resources throughout the product design and development process [10].

An essential part of QFD is a diagram called House of Quality (HOQ). This diagram stores and summarizes a lot of information about the product design and development that is gathered from QFD process. HOQ diagram looks like a house and consists of several main sections, as depicted in Figure 2, which also includes a brief description for each section.

Methodology

In order to construct the HOQ diagram for the vertical seat of the standing cabin concept, several information is needed. For the customer requirements and their importance ratings, a public survey has been conducted to gather the data. In addition, several design requirements from the perspective of airlines and aircraft manufacturers are also added based on information obtained from interview sessions with the experts. Secondly, for competitive assessment of the competitors, several new seat designs that have been proposed including current typical passenger seat are compared with regards to the established customer requirements. Furthermore, derivation of related design technical parameters, their interrelationships with each other and their relationship with the customer requirements is further strengthened from interviews with the experts, who have helped to validate and also provide different perspectives on design and development of the vertical seat. Among others, these include viewpoints of regulation, manufacturing and also operational profitability, which are different from the perspectives of the passengers. Using all data obtained from these avenues, the HOQ for the vertical seat can be properly established.

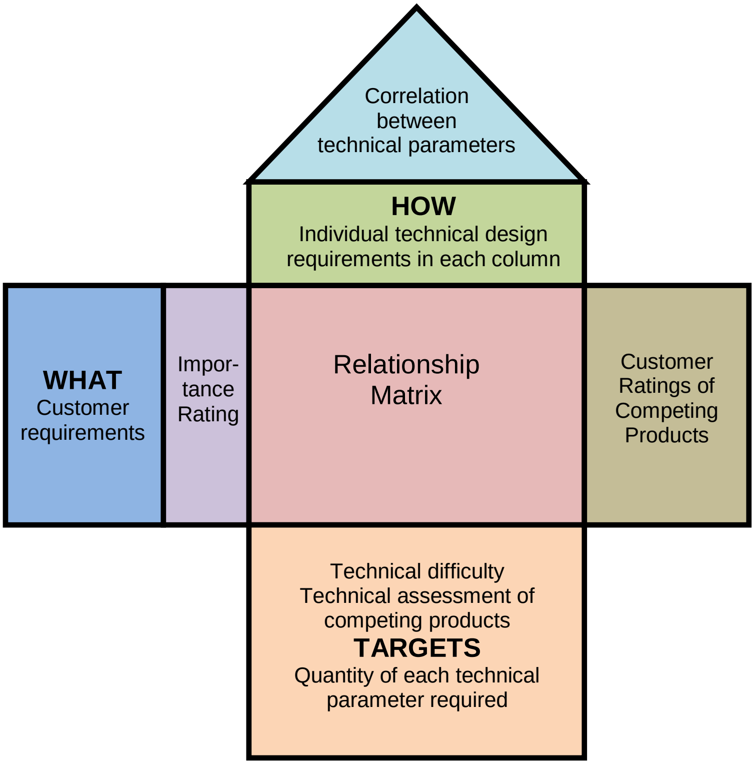

Figure 2: "House of Quality" diagram

Public Survey

An online survey questionnaire has been developed to obtain responses from the public and also several targeted respondents from the industry regarding the vertical seat design. In total, 218 responses have been recorded and out of that, five of the survey participants are from the manufacturing industry while six are from airlines. The participation of people from the industry enables the coverage of design aspects from the viewpoint of the manufacturer and aircraft operators. It should also be noted that the targeted survey respondents from the public were those who are frequent air travellers between the ages of 20 to 30 years old. This is based on predicted group of potential air transport passengers who would be open to try the standing cabin concept in future based on the survey study in Ref. [5]. The distribution of survey respondents is depicted in Figure 3 based on the background category.

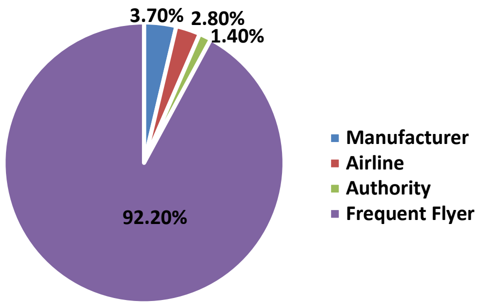

Figure 3: Percent distribution of online survey respondents

In brief, the survey is made of 13 questions, with 11 of them are of multiple-choice type while the remaining two are subjective-type questions. These questions are grouped into four primary sections: demographic details, flying experience, perception and design requirements for the standing cabin concept, and acceptance of the idea. The breakdown of the questions for each category is shown in Table 1.

Table 1: Breakdown of survey questionnaire

Section	**Question Number(s)**	**Remarks**
Demographic Details	1 – 6	Questions in this section are designed to establish the demographic background of the respondents including age, gender, income, etc.
Flying Experience	7 – 8	Questions in this section are designed to establish whether the respondents are frequent flyers and their tendency for using air transportation in their travel.
Perception and Preference for Standing Cabin Concept	9 – 11	Introduction to the standing cabin concept is done in the beginning of this section. Questions in this section are designed to obtain feedback from the respondents regarding their perception and also performance expectation or preference of the standing cabin concept.
Acceptance of the Concept	12 – 13	Questions in this section are designed to establish the respondents' acceptance level of the concept and their overall view of the concept idea.

Face-to-Face Interviews

In addition to online public survey, two face-to-face interview sessions have been arranged with related personnel to obtain information from viewpoints of the manufacturers and also aviation regulatory bodies. The first interview session is done with several representatives of Department of Civil Aviation (DCA), Malaysia to obtain some valuable feedbacks and comments regarding the feasibility of this aircraft cabin concept from the point of view of aviation authority. On the other hand, the other interview sessions are conducted with representatives from manufacturing sector. In this study, several industrial experts from Composite Technology Research Malaysia (CTRM) have been interviewed to get some insights on the feasibility and viability aspects for the vertical seat concept from industrial perspectives. Figure 4 shows these conducted interview sessions.

These interview sessions with representatives of governing authority and also the manufacturing industry is important because the standing cabin concept is new and never been implemented before on commercial transport aircraft. Therefore, their experiences and also industrial judgements can be of great value to the reliability of this study since there is no existing reference as yet.

Figure 4: Interview sessions with experts conducted for this study

Results and Discussions

In the distributed public survey questionnaire, respondents are asked to rate several design aspects of the vertical seat that are thought to be essential for a successful implementation of the standing cabin concept. Additionally, few representatives from the industry are also asked for their expert opinions on several characteristics that are more related to manufacturing and regulation aspects, which may be of little concern for the passengers. Ultimately, there are 12 different requirements that are considered for the vertical seat design and they are tabulated in Table 2, along with their resultant importance rating from the respondents. It should be noted that the rating of 10 signifies that the design requirement is of utmost importance to customers while a rating of 1 corresponds to the lowest level of importance.

Table 2: Established design requirements and their importance rating

Design Requirement	Importance Rating
Safety	10.0
Strength	8.4
Stability	8.2
Weight	8.0
Cost	7.5
Manufacturability	7.4
Comfort	7.4
Maintainability	7.3
Easy to Use (User Friendliness)	7.2
Profitability	6.8
Ease of Installation	6.7
Aesthetic	5.7

As can be observed from Table 2, safety, strength, stability and also weight have emerged as the top most important design requirements. This is quite expected as safety has always been a paramount concern in commercial air transport industry. After this "voice of customers" has been established, experts from the local industry and aviation authority are engaged to come up with appropriate technical parameters of the vertical seat design that will aid in satisfying all requirements. Eight experts from manufacturing sector are engaged through an interview to discuss and elaborate on manufacturability, maintainability, ease of installation and weight requirements. Furthermore, six experts from the airline industry are interviewed for cost and profitability requirements whereas three experts from local aviation authority have been enlisted to help with safety requirements for the standing cabin. Engagement of these experts is essential to verify the established technical parameters and their interrelationships with each other and with the design requirements due to their mass experiences in the industry.

The competition benchmarking is done by taking several existing new seat designs that have been proposed and also the current standard seat that is used in the aircraft cabin nowadays. In this particular study, the considered competing seat designs are the Skyrider (a high-density seat design produced by the Aviointeriors Company, a leading aircraft seat manufacturer), the so-called "bicycle seat" recently proposed and patented by Airbus, the standing cabin support concept that has been previously patented by Airbus and last but not least, the representative of the conventional seat design currently used in aircraft cabins. The comparison of these existing or proposed seat designs against the established design requirements is summarized in the competitive analysis section of the HOQ diagram. It should be noted that the rating scale used here is of 1 to 5, where a rating of 5 means that the seat greatly fulfils the customer's expectation for that particular design requirements whereas a rating of 1 refers to the highest deficiency between the current performance of the seat design with the expectation of the customer.

The resultant HOQ diagram for the vertical seat to be applied in the implementation of the standing cabin concept is shown in Figure 5. From this diagram, it can be concluded that several technical design parameters of the vertical seat such as its main support structure, seat pan, backrest and safety belt mechanism are very important and influential to satisfy the established requirements. In other words, careful attention has to be placed in the design of these parameters to ensure that the resultant vertical seat design can easily satisfy all driving requirements. Furthermore, by looking at the competitive analysis section, it can be deduced that the SkyRider seat by the Aviointeriors Company appears to be the current best state-of-the-art seat design among the considered competing designs. Hence it is good to use this SkyRider seat as the reference benchmark when designing and developing the vertical seat for standing cabin purposes.

Conclusion

QFD is a very useful tool to be applied in product design and development process. It helps to systematically streamline the storage of product design information and establish interrelationships between the design requirements and also technical design parameters that can be controlled by the designers to satisfy them. This will facilitate the decision-making process during the development process and avoid costly mistakes in interpreting the customer needs and requirements. In this particular study, QFD is applied to the design and development of the vertical seat for use in revolutionary standing cabin concept on commercial transport aircraft.

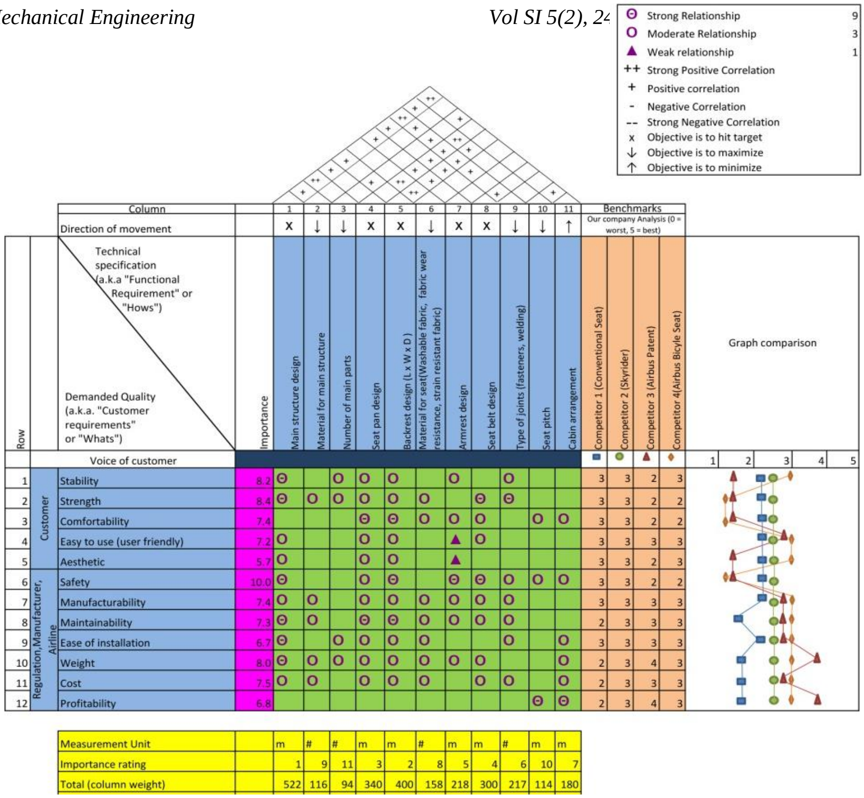

Figure 5: Resultant HOQ diagram for vertical seat in standing cabin concept

Based on the resultant HOQ for the vertical seat, it can be observed that safety characteristic of the seat design plays the highest importance in comparison to other requirements. This has been rather expected due to high emphasis of safety in aviation industry in general. As for the technical design parameters of the vertical seat that will have influential effects in satisfying the requirements, they can be shortlisted as the main support structure, seat pan, backrest and safety belt mechanism. These are the parameters that must be given great consideration while designing the vertical seat. Moreover, the SkyRider seat design by Aviointeriors Company can be taken as the reference benchmark for the vertical seat design with regards to the current satisfaction level of the customer requirements.

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The information contained in the HOQ can now be used as a guidance for the next design and development phase, which is the generation of design concepts for the vertical seat.

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