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Design Requirements for New Food Delivery and Waste Collection System Onboard Commercial Transport Aircraft

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Abstract*: The objective of this paper is to identify the driving needs for an improved food delivery and waste collection system to be implemented onboard of the commercial passenger transport aircraft. Quality Function Deployment (QFD) method has been applied to establish the design requirements from the point of view of the passengers and airlines. The collected data from conducted public survey and also interview sessions with the experts from the airlines are utilized to construct the House of Quality (HOQ). In short, it has been found that safety and cleanliness are the two top prioritized design requirements for a new food delivery and waste collection system. On the other hand, the type of carriage, overall profile of the system and also the operating mechanism used for the system are top technical design parameters that can influence the successful achievement of the design requirements. Findings from this study will be further utilized to generate design options for the improved food delivery and waste collection system.

***Keywords*: House of Quality, Quality Function Deployment, in-flight food delivery, commercial aircraft, waste collection.**

I. INTRODUCTION

Today, air transportation has already become one of the main modes of travel for many people in their daily life. This is reflected by a progressive increase in the number of airline passengers in the last few decades. In 2018, an estimated total of 4.3 billion aircraft passengers is transported throughout the world [1]. As the demands for passenger air transportation are growing, the market competition between airlines has become fiercer. Passengers can now afford to be selective in choosing their travel provider and airlines with a better service are often more preferred [2]. In conjunction with this situation, airlines have been searching for innovative ideas to differentiate their offered flight services with the competitors in order to attract more potential passengers. Among some of the revolutionary ideas that have been considered or proposed include standing passenger cabin concept [3] and automated carry-on luggage system [4].

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One of the aspects of the offered airlines' services that can have significant effects on their passengers' flying experience is the onboard cabin services. In general, airlines that provide high quality services usually have a positive market image and very good re-flying intention by their passengers [5]. The link between service satisfaction of aircraft passengers' and their loyalty to the airlines has been highlighted [6]. In addition, the findings from a conducted survey among passengers of five European airlines have shown that food and beverage services during flight can notably influence positive flying experiences [7]. This notion creates an opportunity for airlines to capture more shares of the passengers' market by providing the better in-flight cabin services, especially the meal services that will essentially include the process of food delivery and also waste collection. Unlike cabin features like in-flight entertainment system or passenger seat design that are improved over time, the food delivery and waste collection process has effectively remained the same since beginning of commercial passenger air transportation industry. Although a few changes have been made in onboard food storage capabilities to enable servings of hot foods and drinks, service features of food delivery and waste collection are essentially still maintained until now.

All current airlines use mostly similar method in providing their onboard meal service, which is through the use of service trolleys or carts to carry and serve foods and beverages along the cabin aisle. The cabin crew will push the trolleys or carts to serve the passengers in every seat row down the aisle. The foods and beverages are prepared and stowed in cabin galley area and the trolleys or carts are used to transport them to be served to the passengers. The cabin crew will make another round through the cabin aisle with the trolleys or carts for the waste collection once the passengers finish their meals in the allocated timeframe. If there are still some remaining waste to be collected before landing, cabin crew will have to manually gather them up by walking through the aisle once again with garbage bags. It is observed that this heavily manual process, as summarized in Fig. 1, can indeed be improved to increase its efficiency.

Based on findings from a conducted online survey, issues or problems with the current in-flight food delivery and waste collection services from the viewpoint of airline passengers are listed as follows [9]:

- The long waiting time for some passengers before they are served by the cabin crew because the serving starts in other rows

- The disturbance to some passengers who are resting in their seats during the serving of meals by the cabin crew to other passengers seated in the same row (similarly also during waste collection later)
- Preferred meal option is no longer available for passengers who are among the last to be served
- Some passengers miss their in-flight meals as cabin crew are not able to serve them in time because of flight turbulence
- Passengers are unable to go to the lavatory during the meal serving and waste collection process as the service carts used by the cabin crew are blocking the aisle

Fig. 1. Current food delivery and waste collection process [8]

There have been attempts or ideas to introduce a different process for in-flight meal service. An example is the patented "moving cabinet" design by Umanoff Martin in 1965 [10]. In addition, there is also another patent with similar operational concept that has been filed by Kraly in 1971 [11]. Both of the designs are still manually operated where the serving cabinet containing the foods and beverages to be served to passengers moves along a designated track, pushed by the cabin crew. In the meantime, one of the latest conceptual design inventions regarding in-flight food services is the semi-automated system by Appolt et al. in 2016 [12]. From the system description, this design concept is equipped with a conveyor that moves decentralize of the cabin aisle. Operation of the system is such that the foods and beverages are transferred from the storage below the cabin floor using the conveyor but the cabin crew are still required to pass them to passengers, hence the system is not fully automated in nature. Despite these proposals of a new system for improving in-flight food delivery and waste collection process, none of them has successfully made it to the actual implementation or commercialization. Therefore, it is believed that the gap for improvement of this system is still open for a better solution.

In order to derive a new appropriate system design, it is essential to conduct the proper requirements analysis as part of the design and development process. The goal of this study is to establish driving design requirements for a new in-flight food delivery and waste collection system to be implemented in the commercial transport aircraft. This aim is accomplished through the application of the Quality Function Deployment (QFD) method.

II. METHODOLOGY

The measure of goodness for a product or system design is typically made in relation to how much it really matches the users' desires and also expectations [13]. With this notion, it is essential to appropriately capture all driving requirements of the product or system to be designed and developed in the early stage. This can ensure that the needs and preferences of all stakeholders have been properly considered by designers while making important design decisions. Some studies that highlight this design requirements elicitation step in product or system development include Wang and Tseng (2011) [14], Nilsson and Fagerstrom (2006) [15], and Ericson et al. (2009) [16]. One of the most common and popular methods that has been used for design requirement analysis is Quality Function Deployment (QFD), which essentially summarizes all product design information gathered in this step into a single graphical representation known as the House of Quality (HOQ) to help designers in making important design decisions [17]. It is a method that collects vaguely expressed quality requirements from the market and uses them to actual product design works [18]. Example use of QFD in product design and development process can be seen in many research works like for standing aircraft passenger seat [19], school furniture [20] and also for personal computer [21]. In this study, QFD method is applied for the development of improved in-flight food delivery and waste collection system for application onboard commercial transport aircraft. The QFD method revolves around construction of HOQ as depicted in Fig. 2. Among the primary elements of HOQ are customer needs (WHATs), engineering characteristics of the product design (HOWs) and also the correlations between the WHATs and HOWs [22]. QFD method is a means where all customer requirements and preferences for the product design to be developed are translated into the related technical design parameters that can be controlled by the designers to achieve them.

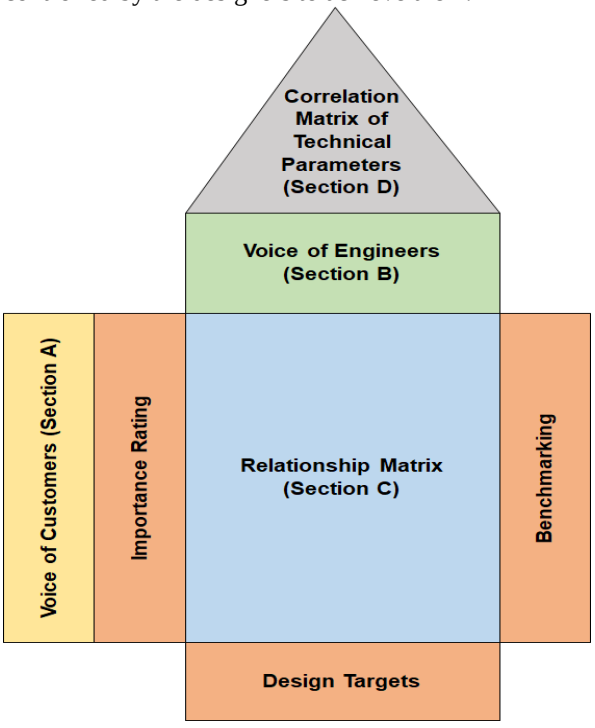


Fig. 2. Typical HOQ diagram

Referring to HOQ diagram in Fig. 2, identified customer needs and requirements are listed in Section A (also known as the "Voice of Customers"). On the other hand, the technical design parameters that can be used to satisfy those customer needs and requirements are listed in Section B (also known as the "Voice of Engineers"). Correlations between each of the customer needs and each of the technical design parameters are mapped in the middle section of the HOQ (i.e. Section C), which is also known as relationship matrix. On the roof part of the HOQ diagram (i.e. Section D), the correlation among the technical design parameters are presented. The information from this part of the HOQ helps designers to know positive or negative impact on improving or changing one parameter to others, and the subsequent consequences to the achievement of customer requirements. Moreover, there are also sections within the HOQ where importance rating for each customer requirement, benchmarking results of competing products and also the targeted value of each technical design parameter are presented for reference.

Fig. 3 illustrates the research methodology followed in this study while conducting the QFD process. To identify design requirements and their level of importance for new in-flight food delivery and waste collection system in the commercial passenger transport aircraft, several data collection methods have been applied that include focus group, public survey and also expert interview. These are the standard methods that are often used to establish the customer needs [23]. The collected data is then analyzed to fill up Section A of the HOQ in Fig. 2. Based on these identified design requirements in Section A of the HOQ, all relevant engineering design parameters that can satisfy the requirements and their interrelationships with each other are derived by brainstorming technique. The results will be used to fill up the top part of the HOQ: engineering design parameters in Section B whereas their inter-relationships in Section D. In the meantime, another brainstorming session is done to map the design requirements with engineering design parameters that can affect its attainment for Section C of the HOQ, either positively or negatively. In order to benchmark with existing systems or designs that have been developed for a similar purpose of performing the food delivery and waste collection onboard the aircraft, three reference systems have been selected to represent current best concepts and the rating is assigned for each of them based on the identified customer requirements.

III. RESULTS AND DISCUSSION

The identification of customer needs and requirements are obtained from conducted public survey and expert interviews with aviation regulatory body and also airlines. Firstly, public survey has been conducted at two major international airports in Malaysia: Kuala Lumpur International Airport (KLIA) and Penang International Airport. Throughout the survey conduct, 559 volunteered respondents, who can be taken as frequent air traveler, have participated. Furthermore, inputs from the local aviation authority and also airline operators are obtained from direct face-to-face interview sessions. For this study, experts from Civil Aviation Authority of Malaysia (previously known as Department of Civil Aviation Malaysia), AirAsia Airlines and Malindo Airlines have been separately interviewed. From the data collected from the public survey and interviews, the design requirements or preferences on the new in-flight food delivery and waste collection system for commercial transport aircraft can be summarized as tabulated in Table I. Moreover, the importance rating for each of the identified requirements can also be assigned based on the information obtained from both the public survey and the interview sessions, which are as presented in Table II.

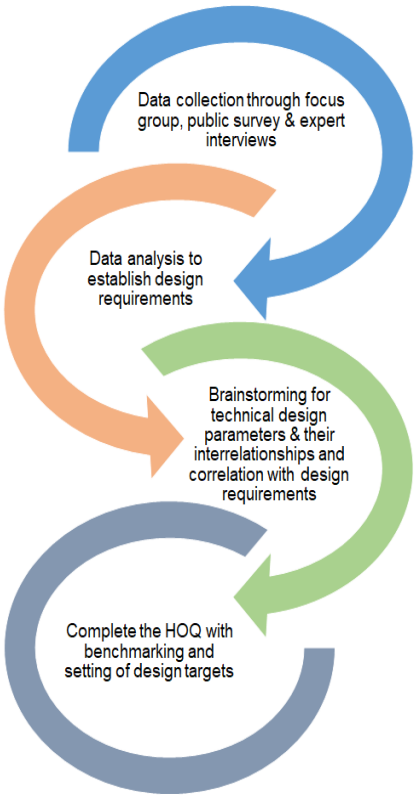


Fig. 3. Methodology framework for this study

Table-I: Identified customer requirements for in-flight food delivery and waste collection

Category	Requirement	Brief Description
Passenger Requirements	Flexible time of receiving food	Able to serve food at passengers' own leisure and not at a fixed time
	Flexible time to manage waste	Able to collect waste at passengers' own leisure and not at a fixed time
	Low wait time	Able to deliver the food almost immediately after the passengers' request
	Privacy	Able to deliver the food and collect waste without discomforting other passengers
	Passenger feel safe	Designed for passengers' safety use by reducing the accidental risk
Authority / Airline Requirements	Safety	Meet regulatory requirements
	High reliability	Able to abstain the load of the whole system and the foods/beverages
	High cleanliness	Able to easily maintain the hygiene of the food carriage
	Low weight	Designed for light weight device
	Low operational cost	Able to provide a low maintenance expenses

Table-II: Relative importance of customer requirements

Customer Requirements	Importance Rating
Passenger feel safe	4
Privacy	4
Flexible time to manage waste	3
Low wait time	3
Flexible time of receiving food	3
Safety	5
Reliability	4
Cleanliness	5
Weight	4
Operational Cost	4

It should be noted that rating scale used for the importance of the design requirement is ranging between 1 and 5, where a rating of 1 means that it is least important while a rating of 5 means that it is perceived as very important to the customers. From Table II, it can be seen that safety and cleanliness have been rated with the highest importance rating. This indicates that the participants of the public survey and also the experts consulted through the interview sessions put the big emphasis on the new in-flight food delivery and waste collection system to be of a high safety standard to avoid any accidents or any malfunctioning that can jeopardize or harm the passengers. In addition, since the system will be dealing with foods and also wastes, it is reasonable for the passengers for wanting it to be of a high cleanliness for a good hygiene and avoid any health hazards from unclean or infected foods.

A brainstorming session is then conducted to derive some ideas on how to achieve these established design requirements through the system design parameters. The requirements have been grouped into few main categories and the corresponding technical design parameters of the in-flight food delivery and waste collection system or mechanism are identified. This is presented in Table III.

Table-III: Technical design parameters

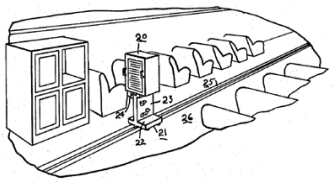
Design Requirements Group	Technical Design Parameters
Operational	Method
	Mechanisms
	Type of user interface
	Storage management
	Speed
Height	Comfortability
	Location
Concept	Overall profile
	Type of carriage
Cost	Lightweight
	Maintenance management
Structure	Fatigue performance
	Structural Strength
	Structural stiffness

Once these design parameters have been finalized, another round of brainstorming process is done to establish their inter-relationships with each other and also their correlations with all of the design requirements. The latter is then used to fill up the correlation matrix at the heart of the HOQ, which is shown in Fig. 4.

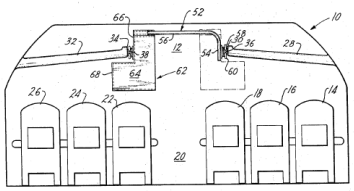
○ = Strong = 9 ⊙ = Fair = 7 •• = Weak = 1	Importance	Method	Mechanisms	Type of user interface	Storage management	Speed	Comfortability	Location	Overall profile	Type of carriage	Lightweight	Maintenance	Fatigue performance	Structural Strength	Structural stiffness
Passenger feel safe	4			○			○	○	⊙	⊙					○
Privacy	4	○	○	○	○			○		⊙					
Flexible time to manage waste	3	○		○	⊙				○	○					
Low wait time	3	○	⊙		○	○		○	○	⊙					
Flexible time of receiving food	3	○		○	⊙				○	○					
Safety	5		⊙				○	○	○	⊙		○	○	○	○
Reliability	4	⊙	○	⊙	⊙	⊙	○	○	○	○			○	○	○
Cleanliness	5	⊙	⊙		○					○					
Weight	4	••	○						○	○	○		○	○	○
Operational Cost	4	⊙	○	⊙	○					○		○	○	○	○

Fig. 4. Constructed correlation matrix for the HOQ

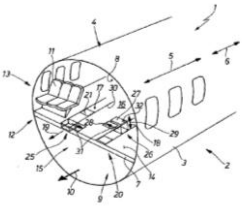
For benchmarking section of the HOQ, three prior patents of system design that have been proposed to improve in-flight food delivery and waste collection onboard the aircraft have been identified and assessed. These three system designs are illustrated in Fig. 5 and they are rated in accordance with each of the established design requirements.



(a) Patent US3179208 (April 20, 1965) [10]



(b) Patent US3558086A (January 26, 1971) [11]



(c) Patent US20160200439A1 (January 22, 2016) [12]

Fig. 5. Benchmarked prior system designs

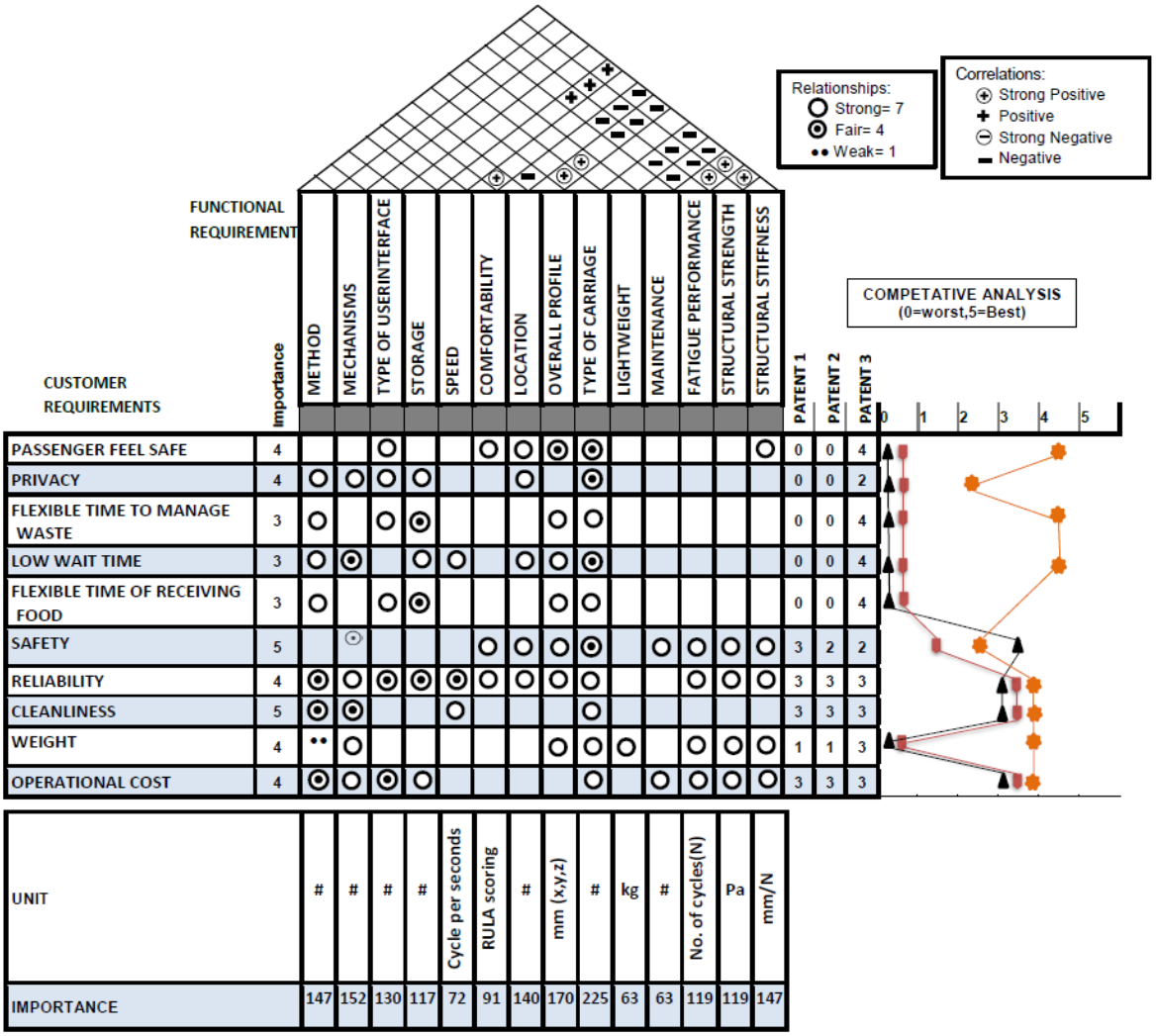


Fig. 6. House of Quality (HOQ) for new in-flight food delivery and waste collection system or mechanism

The final complete HOQ for the in-flight food delivery and waste collection system or mechanism is depicted in Fig. 6. It can be observed that "type of carriage" emerges as the most important technical design parameter with importance rating score of 225. This means that high attention should be made to the type of carriage design for the system as it is highly related to the successful achievement of the design requirements. In the second place, the "overall profile" of the system obtained an importance rating score of 170. This essentially reflects the strong relationship that it has with several of the requirements. Furthermore, the "mechanism" to be applied for executing the intended tasks of in-flight food delivery and waste collection comes in third in the ranking of the important technical design parameters, which is reasonable since it also has relationship with many of the established system design requirements. On the other hand, it can also be seen that the system that is under Patent US20160200439A1 has appeared to be the best suited to established customer requirements among the three chosen benchmarked designs. Hence it can be taken as the reference benchmark in the design and development process of the new in-flight food delivery and waste collection system.

IV. CONCLUSION

As air transportation grows over the years, it is also crucial to airlines to strengthen their strategies to remain competitive in the market. Improving passenger's satisfaction is the heart of the airlines business and this will lead to loyal passengers. In-flight services are important because of their huge potential to provide a good level of passengers' satisfaction. Looking at the current in-flight food delivery and waste collection system used onboard commercial transport aircraft, there are indeed rooms for improvement that can be approached to offer much better cabin services. To appropriately design and develop the improved system, the design requirements have to established properly. The QFD method has been applied in this study for this purpose and the resultant HOQ diagram can be utilized by the designers to make design decisions on the new system. In short, safety and cleanliness have been found to be the two top system requirements. Meanwhile, based on established design requirements, several important technical design parameters have been identified, which include type of carriage, overall profile and mechanism. Available information summarized inside the constructed HOQ can be referenced and utilized in future concept generation of the new improved in-flight food delivery and waste collection system.

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