Conceptual Design of Vertical Passenger Seat for Standing Cabin in Commercial Transport Aircraft

Ahmad Redzman Mohamad Noor and Fairuz I. Romli
Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, Malaysia
Email: redzman.nor@mimos.my, fairuz_ir@upm.edu.my

***Abstract*—The competition between airlines today is changed towards the affordability of their air transportation service. The airlines are competing to lower their offered flight ticket prices as to capture high demands from leisure and business travelers, who are also price-sensitive customers. Theoretically, by having more passengers onboard the aircraft, the flight ticket price can be lowered since the imposed operational costs can be shared by more passengers per flight. The standing cabin concept has been proposed where the passengers are transported in a cabin of an aircraft in an upright position, similar to standing on buses and trains. This paper explores the conceptual design of vertical seat for the passengers to be applied in such standing cabin concept.**

***Index Terms*—passenger seat, vertical seat, standing cabin, aircraft cabin**

I. Introduction

Aircraft has become an essential means of transportation in recent years. Instead of just a luxury option like in the past, air transportation is now a common travel option for people from different walks of life. This changing market has forced the airlines to transform their operational service approach to suit with the currently different economic and social background of their potential customers. Of late, it seems that the low-cost airlines have been successful in dominating a large portion of the flying passengers market. These carriers, which primarily focus on price sensitive leisure and/or business travelers, are able to capture the market by providing a more affordable air transportation service in comparison with the big, full-service airlines. For instance, low-cost airlines have already captured 25% of the domestic US travel market by 1999 [1]. In Europe, low-cost carriers transported about 20.7 million passengers in 2000 and the annual numbers have increased since [2].

The rise of low-cost airlines signifies the high demands for cheap air transportation options. The main competitive aspect of the low-cost airlines is their offering of much cheaper ticket fares in comparison to the full-service airlines that are serving similar flight routes. Many ways have been explored to reduce to operational flight costs, hence the price of the flight ticket that is being charged to the passengers. For low-cost airlines, the operational model was pioneered by Pacific South West, which was then copied by Southwest in 1973 [3]. This model suggests several measures to lower operational costs. Among others, the low cost airlines mainly target the short-haul flight routes and utilize only one type of aircraft, which will reduce their maintenance cost and maximize the flexibility of their crew. Plus, the frequency of their flights is often maximized to fully utilize their available fleet. For example, utilization rate of a Boeing 737-300 aircraft by British Airways is about 7.1 hours per day while the same aircraft has a utilization rate of 10.7 hours per day by low-cost carrier, easyJet [1].

As the trends shows that more people are keen to travel by air due to cheap flight tickets as offered by low-cost airliners, the challenge nowadays is to ensure that the ticket price is low despite the rising cost of jet fuel and other operational costs. In fact, there are still potential commercial air traveler market segments that are left untapped as the current ticket prices by the low-cost airlines are still regarded as high compared to the other modes of transportation. In many instances, the prices of using buses, taxis or ferries are cheaper than the flight ticket offered by the low-cost airlines, which causes the airlines to lose some of their potential customers.

One way to lower down the flight ticket price is to increase numbers of passengers that can be accommodated within the aircraft cabin during the flight. This can be achieved through the so-called standing cabin concept where the passengers are proposed to be transported in a cabin in their upright position. A conceptual design of a seat for the standing cabin is shown in Fig. 1, which largely takes the cue from how a transport bus or subway operates on the ground. According to this notion, the price of the flight tickets can be reduced by having more passengers in the cabin. The results of a preliminary study on this cabin concept for the Malaysian domestic market have also supported this [4]. A new design of passenger seats will be needed to be utilized with this new cabin concept, which is expected to be thinner and lighter because the passengers will be in a standing position instead of sitting during flight. With this regard, this paper aims to propose a conceptual design of the vertical seat that can be used in the implementation of the standing cabin onboard commercial transport aircraft.

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Figure 1. Standing cabin concept [5].

Figure 2. SkyRider prototype cabin [10].

II. Design Considerations

Spring Airlines, a low-cost carrier in China, was among the first to seriously pursue the standing cabin concept as initially back in 2009. The airline was exploring the idea to introduce a standing-room only for some of its Airbus A320 aircraft fleet, which was projected to increase the cabin capacity by about 40% more passengers than the conventional cabin design and reduce the cost by as much as 20% [6]. As explained by the President of the Spring Airline, "For a lower price, passengers should be able to get on a plane like catching a bus, no seat, no luggage consignment, no food, no water" [7]. The same idea was picked up by another low-cost carrier in Europe, Ryanair. In 2012, the airline has obtained approval from the regulatory body to operate a series of 100 trial flights, in which the last five rows of seats within their aircraft's passenger cabin were removed to allow up to about 50 passengers to stand for their one-hour flights [8]. Ticket price of the standing seats for the test flights was offered at only £2 per person.

Indeed, the idea of a vertical passenger seat for the aircraft cabin has been around back since 2006, which is visualized to be comprised of a vertical bench with shoulder harnesses and arm rests [9]. Back in 2010, the Aviointeriors Company that is among the leading aircraft seat and interiors manufacturers has unveiled a standing seat design known as SkyRider at the Aircraft Interiors Expo Americas in Long Beach, California. The SkyRider, which is illustrated in Fig. 2, is designed as an ultra-high density seat to allow the possibility for low-cost airlines to reduce their ticket prices while still maintaining a sound profit. Even with the reduced seat pitch, an adequate passengers' comfort level is expected as the seating position is much like "riding a tourist motor-scooter" [10]. During the expo, this seat was said to be in the final testing stage. With this seat, passengers will not be in their full standing position but more like sitting on a saddle. As stated by the personnel of Aviointeriors Company, the seating position is comfortable for flights with duration up to three hours as many cowboys ride around eight hours daily on their horses without feeling any discomfort in the saddle [11].

It goes without saying that safety is always the paramount issue in commercial aviation industry. To ensure this, the seat design and the standing cabin arrangement have to meet the currently applied standard enforced by the aviation regulatory bodies. As of today, no vertical seat design or standing cabin arrangement has been approved for commercial transport use. In fact, during the literature review for this research, no study that has been officially published on vertical seat designs for standing cabin is found in the public domain. However, it is encouraging to note that such standing seats are not illegal by current standards of several governing aviation bodies. For instance, Federal Aviation Authority (FAA) does not entail that a passenger must be in sitting position during takeoff and landing procedure, as long as the passenger has been properly secured [12]. In addition to that, Air Transport Association (ATA) does not officially impose any specific standards for seat comfort or seating configurations [12]. All in all, it seems that the standing cabin concept is very much a possibility for future commercial short-haul flights.

For such very-high-density seating concept, it must be able to ensure that the passengers can evacuate the cabin within the allowable time limits during emergency. On top of that, the seat design also has to undergo several required tests to ensure that it can to provide the necessary protection and passengers' restraint for satisfying the crashworthiness requirements. The material used in building the seats also needs to be tested and has to comply with the required criteria like non-flammable and non-toxic. In a nutshell, the seat design needs to comply with the requirements for the aircraft seat as outlined in the FAR/JAR Part 23 Regulation.

Since this paper revolves around the concept development of the vertical seat only, these requirements are theoretically considered during the derivation of the alternative concepts. Further and higher-level simulation and testing will be done once the best design concept has been chosen.

III. Conceptual Design of Vertical Seat

In this study, three alternative concepts of vertical seat have been derived. They are developed based three different main goals with regards to the possible standing cabin arrangement. For Concept 1, as illustrated in Fig. 3, the seat is designed for airlines to maximize the use of the available passengers' cabin space. In this case, the passengers will be in their full standing position throughout the flight. However, the support structure is designed such that it can be declined within certain range of angles to increase the passengers' comfort.

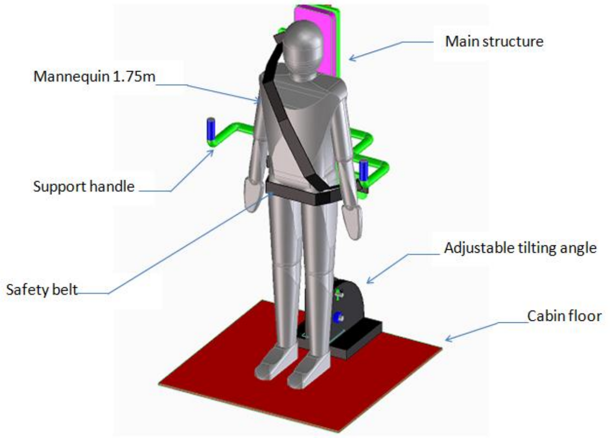

Figure 3. Concept 1 design illustration.

Essentially, Concept 1 design is comprised of two primary components. The first one is the main structure that supports the passenger's body while he or she is standing. It is designed with a cushion backing that can be adjusted to certain angles such that the passenger can lean against it comfortably. On top of that, the passenger can also adjust the height of the cushion backing and apply the flexible section of the cushion segment that can be turned into a "small stool". Secondly, this vertical seat concept is developed with a second main structure that is functioning as a support handle to help the passenger to firmly maintain his or her standing position. The passenger can grab this handle during takeoff and landing, and also when there is turbulence during the flight. To further safeguard the safety of the passenger, the seat will be installed with the safety belts. Overall, the fabrication process for this Concept 1 seat design structure is anticipated to be rather simple since most of its components are made from the existing standard parts like the square tube and others. Furthermore, its installation into the passenger cabin is also not expected to be complicated due to its simple design structure. However, the downside of this design is that it comprises a lot of small components that may affect its assembly time and maintenance.

Another proposed design concept of the vertical seat is as shown in Fig. 4, which is addressed here as Concept 2. The motivation behind this design is to enable more seats in the aircraft but the cabin arrangement will not be cramped as the one with Concept 1. Concept 2 design only has one primary structure looking like a cocoon that will support the passenger while he or she is standing. A cushion pad is installed around the upper back of the passenger's body for comfort while they are leaning against the seat structure during flight. The design is also equipped with safety belts and the seat is permanently fixed onto the cabin floor. Unlike Concept 1, the cocoon has a contour shape that extends to both sides of the passenger's body, providing them with a little bit of privacy during flight and also perhaps a better feeling of safety. The cocoon design is very simple and its installation into the cabin is not expected to be difficult. However, the contour shape of this cocoon-like structure might require special manufacturing process, which can increase its cost.

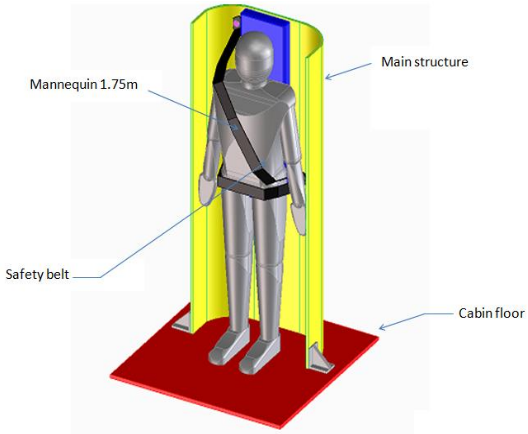

Figure 4. Concept 2 design illustration.

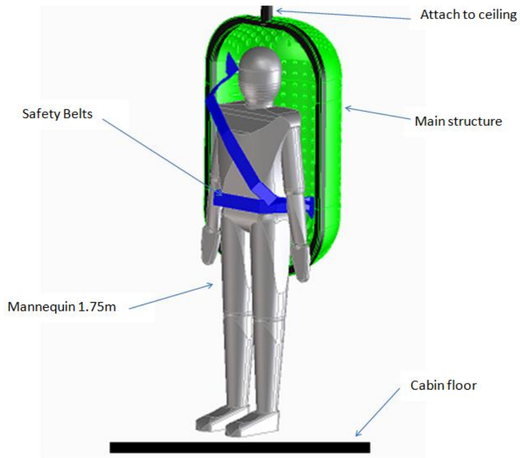

Figure 5. Concept 3 design illustration.

Lastly, Concept 3 design consists of one main structure that looks like a vertical cradle to support the passenger while he or she is standing. As indicated in Fig. 5, the main frame of the cradle is rigid and the backing of the cradle is expected to be made from flexible material such as net or meshing. The main structure will be permanently fixed to the cabin ceiling instead of onto the cabin floor like the previous two design concepts. Safety belts are also installed to protect the passengers. With this vertical seat concept, it enables the cabin to be cramped with as many passengers as possible. Nevertheless, the main drawback of this design lies in its required attachment to the cabin ceiling. This condition entails a major redesign of the current fuselage structure since the loads from the seats will be sustained by different parts of the fuselage rather than the cabin floor.

TABLE I. QUALITATIVE EVALUATION SCALE

Description	Mark
Worse	-
Similar	=
Better	+

TABLE II. COMPARISON BETWEEN THE CONCEPTS

Design Criteria	Concept 1	Concept 2	Concept 3
Manufacturability	+	+	DATUM
Ease of Installation	+	+	
Safety	+	=	
Passenger Comfort	-	=	
Cost	+	=	
Design Simplicity	+	=	
Maintainability	+	=	
TOTAL	6+, 1-	2+, 6=	

Based on several design requirements and characteristics that have been identified from the literature reviews done for this study, these three different vertical seat concepts can be compared to each other to select for the best one. Evaluation is done through a simple Pugh matrix and the qualitative scale used for this assessment is shown in Table I. The comparison table is as shown in Table II and it should be noted that the comparative assessment is being made with Concept 3 as the reference baseline. It can be observed that Concept 1 emerges as the best concept with the highest evaluation score.

As can be seen in Table II, seven design characteristics are considered as the main selection criteria. Manufacturability is measuring how easy the concept is to be manufactured for the seat production. Due to its simple design and the use of many standard parts instead of requiring customized parts, Concept 1 has an advantage over the other two concepts. Furthermore, the ease of installation criterion refers to the expected level of complexity to install the seats in the current aircraft cabin. It is obvious that Concept 3 has a big disadvantage here since its attachment to be cabin ceiling requires a major modification to the fuselage structure. In terms of the safety factor, Concept 1 has a slight advantage in the sense that its simple design is expected to enable the passengers to move around easier and faster than in the case of the other two concepts, especially for emergency evacuation situations. However, with regards to passenger comfort, both Concept 2 and Concept 3 can provide a better sense of privacy to the passengers during the flight. As for the last three selection criteria, which are cost, design simplicity and maintainability, it is anticipated that the much simpler design of Concept 1 will give it an upper advantage in these areas against the other two concepts.

With this assessment result, Concept 1 is chosen to be the seat design concept to be further developed and analyzed for the standing cabin concept. More detailed design analysis will be executed as part of future works for this research study. A three-view drawing of Concept 1 vertical seat design is shown in Fig. 6.

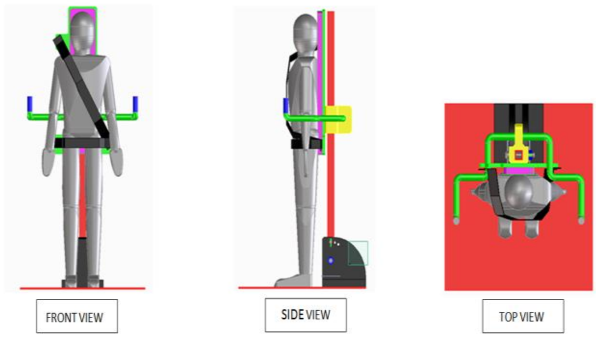

Figure 6. Three-view drawing of concept 1 vertical seat design.

IV. CONCLUSION

Due to the increasing operational cost of flights, airlines are looking on new ways to reduce prices of their flight tickets as the market demands for cheaper air transportation options are on the rise. One way that has been suggested to address this is by maximizing the possible number of passengers that can be accommodated within the cabin for each flight. By doing so, the flight costs can be theoretically better distributed among the passengers, hence lowering the ticket prices. The standing cabin concept is studied to enable more passengers onboard and for this cabin concept to work, it requires a new vertical seat design. By having the flying passengers standing rather than sitting allows more passengers onboard and also reduces the weight of the seats. Vertical seat is expected to be lighter and consume less space than the current seats. However, due to passenger health concern, the standing cabin concept might work only for short flights.

In this paper, three different concepts of vertical seat design have been developed and studied. After simple assessment to compare them is done, the best design is chosen to be Concept 1. Though the concept selection process is rather simple, the evaluation takes into account the necessary design criteria of the vertical seat to be implemented in the real cabin. The next step of this research is to develop more details on Concept 1 seat design and analyze its suitability for implementation and use in commercial transport aircraft cabin.

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Ahmad Redzman Mohamad Noor graduated from the University of Portsmouth, England in 1998 with a Bachelor degree in Mechanical Engineering (Second Class Upper). He currently works as a Senior Engineer at MIMOS Berhad, Malaysia while at the same time is pursuing a Masters degree in Aerospace Engineering at Universiti Putra Malaysia, Malaysia.

Fairuz I. Romli received his PhD degree in Aerospace Engineering from Georgia Institute of Technology, USA in 2009. He currently works as a Senior Lecturer in Department of Aerospace Engineering, Universiti Putra Malaysia, Malaysia. His recent research interests include design methodologies and tools, optimization studies and also air traffic management.