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Research paper

Ergonomics assessment of current aircraft passenger seat design against Malaysian anthropometry data

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Abstract

There have been many complaints from aircraft passengers regarding the cabin comfort level during flight. One of the main cabin aspects that influence the level of passenger comfort is identified as the passenger seat. In this study, the representative of the current aircraft seat design is evaluated against anthropometry data of Malaysians. This is done to establish whether there is any mismatch between the seat design and the anthropometry of the Malaysian passengers such that it contributes to the low cabin comfort experiences. Based on the findings, it can be generally concluded that the current aircraft seat needs to be better and more ergonomically designed to match with the Malaysian anthropometry in order to potentially provide more comfortability for the Malaysian aircraft passengers.

Keywords: *aircraft seat; anthropometry; ergonomics; passenger seat; Malaysian*.

1. Introduction

As air travel becomes more accessible to people due to availability of cheaper flight ticket prices and improved aircraft performance that increases the coverage of flight services, issues of passenger comfort have been a subject of high interest. Flying onboard the aircraft, especially in long-haul flight, can cause physiological and also psychological discomfort to the passengers [1]. For instance, having to remain seated for a long duration of time can lead to few health problems like oedema or deep vein thrombosis [2]. Hence, it is vital to provide passengers with adequate comfort throughout the flight to avoid any significant health risk to them.

In general, comfort is not simply the absence of discomfort and it has been also associated with pain and biomechanical factors, as well as relaxation, luxury and well-being [3]. A conducted survey among the aircraft passengers has indicated that seat comfort is the most important factor that influence their level of cabin discomfort [4]. The seat design is vital to the passengers' comfort as it is the place they spend most of their time during the flight [5]. Among others, seat comfort can be linked to several factors like legroom, quality of upholstery, seat pitch, seat width and possible angle of recline. As reported by Hinninghofen and Enck (2006), the results from many surveys on the charter and economy class flights have found that seat comfort and leg room have been rated as the two least satisfactory characteristics of air travel [6].

In the meantime, ergonomics involve design of products, services, systems or processes with user interaction in mind, which often translates into a positive comfort perception by the user. In other words, it is the applied science of designing and arranging things that people use such that they can be utilized with maximum level of efficiency and also safety [7]. The incorporation of principles of ergonomics can facilitate the provision of comfort, safety and ease of use for products, services, systems or processes [8], including the aircraft passenger seat. The key information for application of ergonomics is anthropometric data of interested group of people or target users. Anthropometry is the part of ergonomics that deals with the measurements of the body dimensions, its capability and limitations of human ability, and this can vary depending on some factors like ethnic group, age and sex [8]. This data is imperative to ensure and assess whether the design is a good fit with the body conditions of the target users.

These days, with the rise of low cost airlines, lower ticket prices usually come with reduction in cabin comfort and complimentary services. Although the cabin arrangement and seat design are both in compliance with the governing aviation regulations that set the minimum standard for aircraft passenger cabin for safety purposes (i.e. FAR Part 25), some passengers still feel a significant level of discomfort. Hence it seems that there is a probable need to review and update the seating standards for airlines such that passengers' comfort can be adequately provided. With this in mind, two main objectives of this study are to review the ergonomics suggestions for a comfortable aircraft seat design and to evaluate how current aircraft seat design fares with the proposed guidelines in context of Malaysian passengers.

2. Ergonomics guidelines for aircraft seat

Ergonomics or human factor is a science of understanding human and the system elements or workstation surrounding him. In other words, ergonomics is the discipline that studies the environment around human and how to increase optimal human performance. One of the basic factors in ergonomics science is comfort and it is focused on the user's experience and emotional behaviour. On the whole, it can be taken that ergonomics is concerned with how the product and its design process are adapted with the human body and the environment. The end users' experience and their level of satisfaction should be considered in the design process, especially with regards to parameters such as dimensions, materials, shapes, etc. that contribute towards the design comfortability. If the user is

unsatisfied with the product, it can negatively affect their comfort [9].

In current literatures, there are numerous suggestions with regards to determination of appropriate seat design parameters through use of anthropometric data. In this study, essential design parameters for the aircraft seat have been identified as tabulated in Table 1.

Table 1: Essential design parameters of aircraft seat and their proposed ergonomics measurement

Parameter	Description and Corresponding Anthropometric Parameter
Seat Height	• Vertical distance measured from the footrest surface to the back of the right knee [9] • Anthropometric measurement - popliteal height [10, 11, 12]
Seat Width	• Measurement from the popliteal to the posterior edge of the buttocks while the subject is in sitting position [11] • Anthropometric measurement - Hip breadth [13] + clothing allowance
Seat Depth / Length	• Measurement from horizontal distance between the behind point of the buttock plate and the back of the right knee (the front edge of the seat to the lumbar support region of the backrest). The knees position should be parallel and 90 degrees [9, 11] • Anthropometric measurement - buttock-popliteal length [13]
Armrest Height	• Measurement of vertical distance between the sitting surface and the underside of the elbow [10, 12, 14]. The subject should sit erect and looking straight ahead with relaxed shoulder and upper arms [9] • Anthropometric measurement - elbow rest height [11, 13, 15]
Armrest Width	• The measurement of the width of the armrest • Anthropometric measurement - forearm width [16]
Armrest Depth / Length	• Measurement at the horizontal distance from the back of the elbow to the tip of the middle finger, with the hand extended and right elbow located in 90 degrees position [10, 17]. This distance can also be calculated as forearm-hand length minus hand length [9] • Anthropometric measurement - elbow-wrist length height [11, 13]
Distance Between Armrests	• Measurement of maximum horizontal distance across the lateral surfaces of the elbow surfaces of the elbow with the elbow in fixed and resting position against the body [15] • Anthropometric measurement - elbow-to-elbow breadth [13]
Seat Pitch	• Measurement of distance from a point on the seat in one row to the same point on a seat in the front or behind row [18]
Backrest Height	• Measurement of vertical distance from the sitting surface to the top of the shoulder (acromion) with the subject seated [10, 17] • Anthropometric measurement - shoulder height and acromial (shoulder) height [13, 19]
Backrest Width	• Measurement of horizontal distance across the upper arms between the maximum bulges of the deltoid muscles [10] • Anthropometric measurement - shoulder breadth [13]
Backrest Lumbar Height	• Measurement of vertical distance from sitting surface to the level of the waist, the subject should be in the sitting position [10] • Anthropometric measurement - waist height [10]
Headrest Height	• Measurement of vertical distance from the chin to the top of the head [10] • Anthropometric measurement - head height [20]
Headrest Width	• The measurement of maximum breadth of head above the ears [10, 20] • Anthropometric measurement - head breadth [13]

It should be noted that these suggestions take into account only the suitability of the seat design with respect to body anthropometric details of the passengers and do not emphasize on the length of the sitting duration. This ensures that passengers can feel comfortable regardless of the flight duration. Based on the literature reviews, proposed ranges of values for the essential seat design parameters are found. The minimum and maximum of the proposed values for the parameters as suggested in literatures are summarized in Table 2, which can be applied to the aircraft seat design assessment.

Table 2: Proposed range of values for seat design parameters

Seat Design Parameter	Minimum Proposed Value	Maximum Proposed Value
Seat Height	• 30.48 cm to 35.56 cm [21]	• 31.2 cm to 48.8 cm [14]
Seat Width	• 43 cm [16]	• First, business and economy class seats are suggested around 59.5 cm, 50.5 cm and 49.5 cm, respectively [22]
Seat Depth	• 38 cm to 40 cm [23]	• 39 cm to 55 cm [24]
Armrest Height	• 16 cm to 23 cm [24]	• 20 cm to 25 cm [25]
Armrest Width	• 4 cm [26]	• 7.62 cm [21]
Armrest Depth / Length	• 16 cm to 23 cm [26]	• 27 cm to 39 cm [16]
Distance Between Armrests	• 54 cm for non-adjustable seat and between 39 cm to 54 cm for adjustable seat [16]	
Backrest Height	• 18.5 cm to 21.5 cm [27]	• 64.26 cm up to shoulder and 75.44 cm with headrest [21]
Backrest Width	• 33 cm [23, 26]	• 52 cm [28]
Seat Inclination	• 0° to 5° [27]	• 5° to 15° [29]
Backrest Inclination	• 90° to 115° for short backrest and 120° for high backrest [26]	• 105° to 135° for first class and 105° to 128° for business and economy class [22]
Backrest Lumbar / Lumbar Support Height	• 10 cm to 20 cm [27]	• 17 cm to 28 cm for adjustable height and 20 cm to 24 cm for non-adjustable backrest [26]

3. Malaysian anthropometry data

In order to evaluate whether the current aircraft seat design is able to provide an adequate comfort level to the Malaysian passengers, their body anthropometry measurement data have to be established. Figure 1 shows typical anthropometry measurements of the human body used in ergonomics design or assessment. In literatures, there are several published anthropometric data of Malaysians such as those by Karmegam et al. [30], Mohd. Yusuff et al. [31] and also Mohamad et al. [32]. Since its data sampling has a better coverage across ethnicity and age, the latter compilation of anthropometry data for Malaysians is chosen to be applied in this study. Table 3 tabulates the anthropometry measurements and it should be noted that the data are constructed from a total of 1,007 Malaysians with age range of 15 to 80 years old, which is far beyond the minimum sample size of 200 people that is recommended by World Health Organization if the data are to be used for reference standards [14]. Note that the measurements in Table 3 are reported by their 5th, 50th and 95th percentile statistical values.

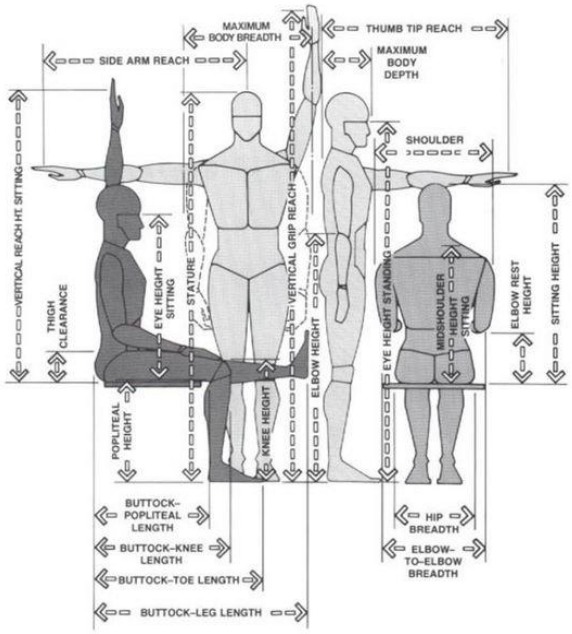


Fig. 1: Human anthropometric dimensions [16]

Table 3: Reference anthropometric data for Malaysians [32]

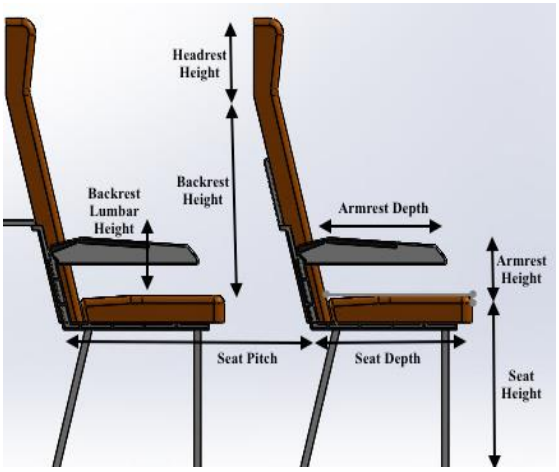
Body Dimension	Value (Cm)		
	5th	50th	95th
Male Model			
Chest Breadth	27.07	35.46	43.85
Crotch Height	63.20	84.19	105.17
Hip Breadth	26.20	37.53	48.86
Stature	157.44	168.61	179.79
Waist Depth	18.05	25.77	33.48
Foot Length	25.37	27.05	28.69
Chest Depth	14.56	21.75	28.95
Popliteal Height	39.12	44.81	50.52
Female Model			
Chest Breadth	23.40	31.78	40.16
Crotch Height	61.60	78.93	96.25
Hip Breadth	26.12	37.83	49.54
Stature	146.66	156.50	166.33
Waist Depth	17.19	23.91	30.63
Foot Length	20.11	22.45	25.00
Chest Depth	13.54	21.50	29.47
Popliteal Height	35.44	42.48	49.52

4. Aircraft seat evaluation for Malaysian passengers

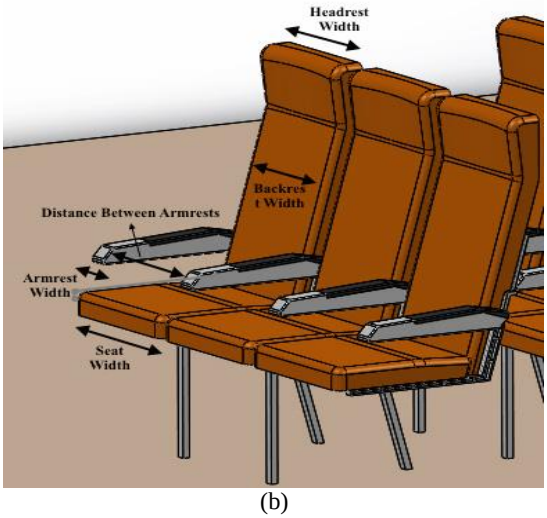
To establish whether there is a mismatch between current aircraft seat design and anthropometry of Malaysians, a reference seat is selected and used. This aircraft passenger seat, depicted in Figure 2, is available in the laboratory of Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia. The seats have been used in a typical economy class seating of commercial transport aircraft and they are believed to be implemented onboard commercial aircraft for with different flight lengths. The essential dimensions of this reference aircraft seat have been measured for the evaluation process. Figure 3 highlights some of the measured seat design parameters. Based on Malaysian body anthropometry data and the proposed ergonomics measurements for seat design parameters, dimensions of this reference aircraft seat are assessed for any possible mismatch. The comparison of values is presented in Table 4.

It is observed in Table 4 that there are some mismatches between dimensions of current aircraft seat and proposed dimensions based on the anthropometry data of Malaysians. This indicates that the current reference seat might not be ergonomically designed to fit Malaysian passengers and might induce some discomfort during the flight. In addition, this also highlights some of the potential improvements that can be done to aircraft seat design to increase the comfort level of passengers inside the cabin.

Fig. 2: Reference aircraft passenger seat



(a)



(b)

Fig. 3: Measured seat design parameters

At this point, possible mismatches between proposed ergonomics dimensions and current seat dimensions have been highlighted but the effects of these mismatches to passengers' comfort level have yet to be established. To properly indicate the comfort level, more detailed ergonomics assessment procedures such as Rapid Upper Limb Assessment (RULA) can be made on the reference aircraft seat design with the Malaysian anthropometry data.

Table 4: Ergonomics assessment of the reference aircraft seat

Seat Dimensions	Current Dimensions	Proposed Anthropometric Measurement	Proposed Dimensions based on Malaysian Anthropometry
Seat Height	45.50 cm	5th percentile of female popliteal height (35.00 cm) + Shoe allowance (4.50 cm for heels)	35.43 cm
Seat Width	42.50 cm	95th percentile female hip breadth (49.50 cm) + clothing (1.00 cm for medium clothing)	49.50 cm
Seat Depth	45.72 cm	5th percentile female buttock popliteal length (38.90 cm)	38.90 cm
Backrest Height	72.00 cm	95th percentile male sitting acromial (shoulder) height (65.61 cm) + 95th male head height (25 cm)	90.61 cm
Backrest Width	45.00 cm	95th percentile of male chest width (52.58 cm)	52.58 cm
Armrest Height	15.00 cm	50th percentile of female sitting elbow height (17.70 cm)	17.70 cm
Armrest Length	41.00 cm	95th percentile of female forearm-hand length - hand length (24.00 cm)	24.00 cm
Width between Armrests	42.50 cm	95th percentile female hip breadth (49.54 cm) + clothing (5 cm for heavy clothes)	54.54 cm

5. Conclusion

A reference aircraft seat has been analysed in this research study with regards to its potential mismatches with anthropometry data of Malaysian passengers. Based on the comparison result between the proposed ergonomics dimensions and the current aircraft seat dimensions, it is concluded that the reference aircraft seat may not be ergonomically fit and suitable to accommodate all of Malaysian passengers and this can influence their cabin comfort level during flight. Some possible improvements have been highlighted from identified design mismatches, which can be improved to alleviate the cabin discomfort from the design differences. A more detailed ergonomics analysis on the reference aircraft seat should also be conducted to properly establish the impact of the identified design mismatches to the comfort level of the passengers.

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