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**ET45-**

# A PARAMETER STUDY OF AN IMPROVED AIRCRAFT PASSENGERS' SEAT TRAY DESIGN USING THE TECHNIQUE OF ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS)

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**Abstract**

In its service position, the aircraft seat tray table is intended to hold food and beverages. It can also be used as a writing pad, a hand rest, a place to store laptops, gadgets, and electronic devices, and a few other things, allowing passengers to continue their activities during the flight without interruption. Most current tray table designs include a little amount of useful area and a locking mechanism in the center for when passengers need to store and used them. There is a need for a new and improved tray table design that can better encourage mobility and functionality, based on the existing concerns with current tray table designs. A conceptual design for an improved tray table is developed in this study using a systematic engineering design process that includes requirements analysis with the Quality Function Deployment method, generation of alternative design concepts with the Morphological Matrix method, and selection of the best design concept with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method.

*Keywords: - Hand rest, ergonomic design, Pareto Diagram, Quality Functional Deployment (QFD), Technique of Order Preference by Similarity to Ideal Solution (TOPSIS)*

## 1. Introduction

According to the World Air Transport Statistics 2020 there has been a decline in the number of scheduled passengers and traffic compared to 2019. This is because since the whole world is fighting a battle of an unscheduled virus that is spreading at an alarming rate. Nevertheless, this does not mean that airlines may not provide additional services in attracting passengers to use their aircraft. Travelers who use trains, bus and aircraft normally being provided with a single tray table that is situated within their confined space specifically for them to use. (Vink & Brauer, 2016).

Current tray tables provide limited usable space which in turn offers no compartment for food keeping and beverages whilst using the laptop, computer books or other electronic items to be used. A typical tray table in an airline is approximately 10.45 inches by 16.15 inches (IATA, 2017) which in use typically rests slightly above the passengers' lap near to its waist. Current tray tables in their service position provide little or less option for positioning whilst the angle of its pitch may interfere with the usage of device and food serving a purpose (Locker,2016).

### *1.1 Problem Statement*

The different types of passengers built which may differ according to their age, size and background in using the tray table often is obstructed in a normal fixed pitched and happens in the upright position. Meanwhile a significant problem exists for wheelchair passengers (Webb,2017).

Clips and reports from CNN Travel state that a passenger was attacked and repeatedly punched on her seat just because she reclined simply because the man behind her was having his meal. (Andrew,2020). Surely this has imparted a big problem for any passenger's comfort. It also states there is main maintenance problem as such the tray needs to be removed and installed if it is left broken.

### *1.2 Project Objectives*

The main objective of the case study is:

i. To establish an important design requirement for an aircraft passengers seat tray.
ii. To develop according to certain parameters of the aircraft passengers seat tray using a systematic engineering design method.

## 2. Literature Review

Based on the ergonomics assessment chart on an aircraft seat, the level of customer comfort is very subjective and may differ between aircraft, country and continents. As discussed by many journals related to anthropometrics

and ergonomics there is a mismatch according to dimensions of aircraft seat(current) and the proposed dimensions of Malaysian data (Romli et al., 2015). This indicates an underlying problem faced by many Malaysian's. Therefore, the parameters to the aircrafts tray table position and its overall dimension include its seat width, pitch, depth, armrest and seat inclination.

### *2.1 Aircraft Tray table*

There exist a few types of passenger's seat tray table, they are the foldable type, displacement type and also the stowable type which is commonly found in most aircraft with different classes and configuration based on the airline. Conventional tray tables fitted in the economy class normally in the working position are not capable of being moved in any lateral position with it being fixed at its hinges. The need to safely stow an aircraft seat tray table and secure them during take-off's and landings indicates that these are critical phases to be observed and followed by all passengers (Ahmadpour et al., 2014).

### *2.2 Tray Table Locking Mechanism*

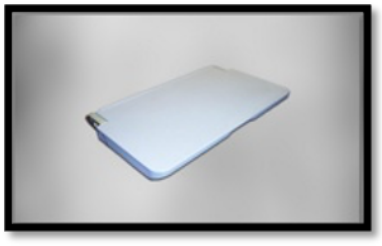
Little changes have been seen in the last decade with the existing tray table employs the same twisting type of locking mechanism in securing the table. This can be seen in most of the economy class arrangement of an aircraft. It is understood that for a normal and able-bodied passenger there would be no problem for them to stow and lock as this mechanism has been the one in particular being used for decades in securing the tray table (P. Vink, et.al., 2012). The thought of having to use this table for an elderly person and disabled people using them poses a problem (Anjani, et al., 2020).

Figure 1: Conventional lock tray table (expressflight.com)

### *2.3 Tray Table Material*

Referring to the aircraft maintenance manual chapter ATA 25 the tray table can be serviced according to the specified time length and cycle and of the aircraft. The components maintenance manual also is used to provide additional and correct procedures to carry out in servicing the tray table. Its material is mostly sandwich together by combining composite and a honeycomb core. The composition of the table consists of glass fiber(phenolic resin) and carbon fiber(epoxy resin) and the heart is a foam core added with a honeycomb structure (Kelly, et.al., 2007).

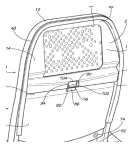
Figure 2: A smooth finish of plastic applied to the table (aerofoams.com)



### *2.4 Latch Mechanism type*

There exists numerous latch available in the market which constitutes to the assembly of an aircraft tray table. Most common types of latches used in securing them is the zodiac latch. It is also found in certain configuration of aircraft tray tables embedded with a strike and latch, magnetic push to open and also draw and buckle type. The different design of latches both contemplates the able and disabled whom needs assistant whilst using the tray table (Garengo, 2019).

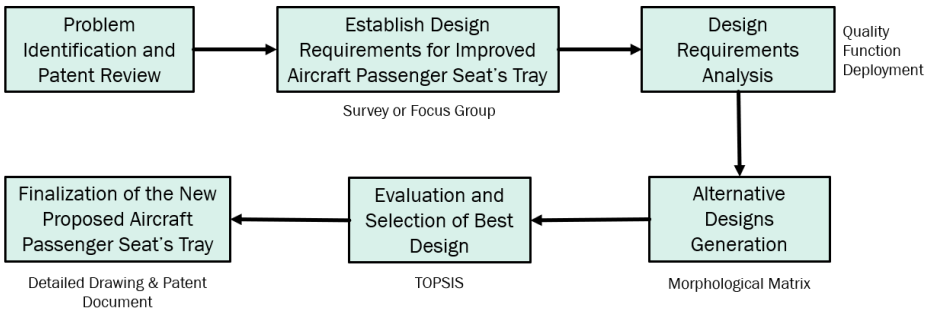
Table 1: Different types of latch mechanism available in the market (enviroflight.com)

| Invention in Market | Description | Safety / Practicality | Cost |
|---|---|---|---|
| Zodiac Latch  (patents.google.com) | Robust design and very commercial specifically for airlines which operates with different classes of flights. | Proven safety feature for the latch mechanism but the drawbacks are its small latch which probably is not user-friendly for disabled and passengers with disability. | Expensive to manufacture which needs to change whole set if a problem occurs. |
| Strike & Latch  (aeromaterial.com) | Simple solution for a normal cupboard or closet type of latch. | Made from thermoset plastics mostly. Moderate safety if use with care. | Cheap to manufacture and maintain. |

## 3. Methodology

Upon observing the project objectives, formulating a design according to the aircraft tray table parameters is desirable and needs to be materialise. Thus, a simple methodology and approach is needed.

Figure 3: Simplified method of conducting the project

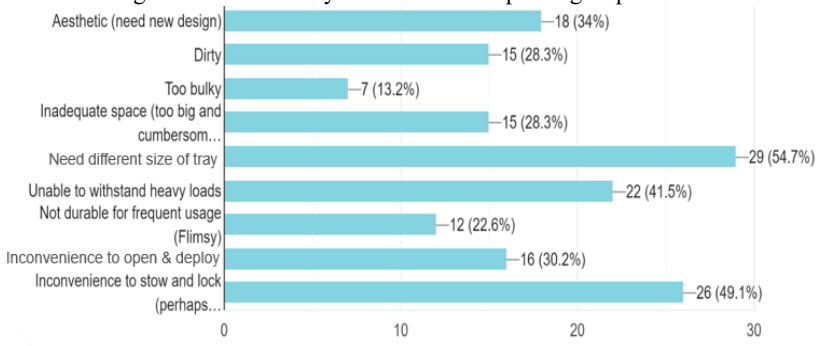



## 4. Finding and Analysis

### *4.1 Establishing Design requirements*

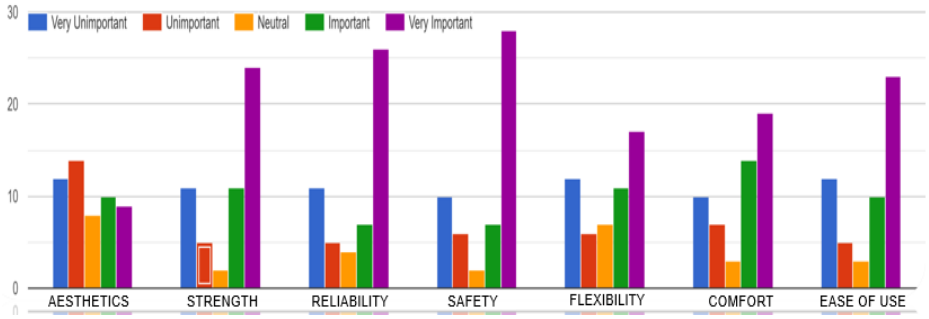
Establishment of the requirement is done using an online survey specifically to capture and record feedbacks on the current tray table in enabling improvements to its overall design is achieved. The types of problems faced by passengers using tray table is shown in the figure below.

Figure 4:Online survey establishment of passengers problems



Customers feedback which establishes the parameters as to enable product improvements being made to the tray table is depicted by the figure below.

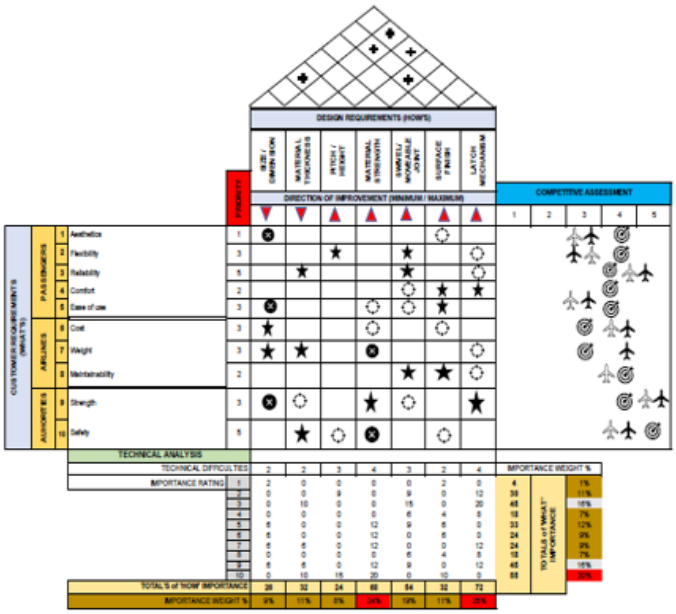
Figure 5:The parameters associated for Quality Function Deployment (QFD) analysis




### *4.2 Design Requirement Analysis*

A matrix-based decision analyzing tool may be used to define a customer needs and further refine their requirements. Therefore, a Quality Function Deployment (QFD) tool comes in handy to determine these parameters as depicted in figure below.

Figure 6: Quality Function Deployment according to the survey generated



### *4.3 Alternative Design Generation*

Morphology Matrix is a tool that generates a myriad of possibilities and solutions for every function of the airline seat tray table which identifies three to six parameter task and selects the possible attributes upon each parameter whilst exploring its combinations with selecting one function for each combination. After the generation of idea is done, the concept is materialized according to the 7 parameters mentioned before.

Table 2: Alternative design generation of idea

| PARAMETER / FUNCTION (TRAY TABLE) | IDEA 1 | IDEA 2 | IDEA 3 | IDEA 4 |
|---|---|---|---|---|
| Size / Dimension | Standard (16.5" x 10.5") | Slightly wider (16.5" x 11.5") | Slightly smaller (15.5" x 10.5") | Longer & wider (17.5" x 11.5") |
| Material Thickness | Less than 1.5cm | Less than 1.3cm | Less than 1.1cm | Less than 1cm |
| Material Strength | Aircraft grade Aluminium | Aircraft grade plastic | Aircraft grade metal | Aircraft grade composite |
| Pitch / Height | Less than 1m | Less than 1.2m | Less than 1.3m | None |
| Swivel / Moveable joint | Mount type (60°,90°,180°)  | Extendable arm (90°)  | Rotating mount (180°,270°)  | Extended flip (90°)  |
| Surface Finish | Plastic powder coating | Polished coloured vinyl | Non-slip mat | Anti-microbial / Anti bacteria & Anti-viral treatment |
| Latch Mechanism | Strike & latch  | Magnetic push type  | Push to open  | Draw & buckle  |

Table 3: Concept generation from idea design

| FUNCTION (TRAY TABLE) | CONCEPT 5 | |
|---|---|---|
| Size / Dimension | Longer & wider (17.5" x 11.5") | Slightly longer and larger in terms of its length(L) and width (W) although it is fitted to an economy type class & configuration |
| Material Thickness | Less than 1.1cm | Complements the longer and larger dimension with thin type table to provide a sleek design |
| Material Strength | Aircraft grade composite | Structurally is the best option considering its strength to weight ratio, lightweight & high structural strength |
| Pitch / Height | Less than 1.3m | Adjustable up to 1.3 m with regards to passenger comfort |
| Swivel / Moveable joint | Extended flip (90°) | Space saving and comfort |
| Surface Finish | Anti-microbial / Anti bacteria & Anti-viral treatment | Prevention and protection since this place harbours harmful bacteria |
| Latch Mechanism | Magnetic push type | Convenient & ease of maintenance |

### *4.4 Evaluating & Selection of Best Design*

The TOPSIS is a tool used to quantify values in finding the best alternative which is closest to the positive ideal solution and it needs to be furthest away from the negative ideal solution. Steps for evaluating the concept detail is as follows:

Table 4: Evaluating each of the 7 parameters scorefor the tray table

**Step #1** : Create Decision Matrix (score is 1 until 5, where 1 is lowest and 5 is highest)

| Weight | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 |
|---|---|---|---|---|---|---|---|
| | FLEXIBILITY | WEIGHT | STRENGTH | MAINTAINABILITY | RELIABILITY | EASE OF USE | SAFETY |
| Concept 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 |
| Concept 2 | 1 | 2 | 1 | 1 | 3 | 2 | 1 |
| Concept 3 | 2 | 1 | 1 | 1 | 3 | 1 | 2 |
| Concept 4 | 2 | 1 | 3 | 2 | 3 | 2 | 3 |
| Concept 5 | 2 | 1 | 3 | 2 | 3 | 2 | 3 |

**Step #2** : Quantify qualitative criteria

| Weight | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 |
|---|---|---|---|---|---|---|---|
| | FLEXIBILITY | WEIGHT | STRENGTH | MAINTAINABILITY | RELIABILITY | EASE OF USE | SAFETY |
| Concept 1 | 3 | 3 | 6 | 3 | 6 | 3 | 6 |
| Concept 2 | 3 | 6 | 3 | 3 | 9 | 6 | 3 |
| Concept 3 | 6 | 3 | 3 | 3 | 9 | 3 | 6 |
| Concept 4 | 6 | 3 | 9 | 6 | 9 | 6 | 9 |
| Concept 5 | 6 | 3 | 9 | 6 | 9 | 9 | 9 |

**Step #3** : Non-dimensionalize the attribute value

| Weight | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 |
|---|---|---|---|---|---|---|---|
| | FLEXIBILITY | WEIGHT | STRENGTH | MAINTAINABILITY | RELIABILITY | EASE OF USE | SAFETY |
| Concept 1 | 0.267261242 | 0.353553391 | 0.40824829 | 0.301511345 | 0.316227766 | 0.229415734 | 0.384900179 |
| Concept 2 | 0.267261242 | 0.707106781 | 0.204124145 | 0.301511345 | 0.474341649 | 0.458831468 | 0.235702260 |
| Concept 3 | 0.534522484 | 0.353553391 | 0.204124145 | 0.301511345 | 0.474341649 | 0.229415734 | 0.384900179 |
| Concept 4 | 0.534522484 | 0.353553391 | 0.612372436 | 0.603022689 | 0.474341649 | 0.458831468 | 0.577350269 |
| Concept 5 | 0.534522484 | 0.353553391 | 0.612372436 | 0.603022689 | 0.474341649 | 0.688247202 | 0.577350269 |

**Step #4** : Assign weighted values for the attributes

| Weight | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 |
|---|---|---|---|---|---|---|---|
| | FLEXIBILITY | WEIGHT | STRENGTH | MAINTAINABILITY | RELIABILITY | EASE OF USE | SAFETY |
| Concept 1 | 0.026726124 | 0.035355339 | 0.081649658 | 0.030151134 | 0.06324555 | 0.022941573 | 0.076980036 |
| Concept 2 | 0.026726124 | 0.070710678 | 0.040824829 | 0.030151134 | 0.09486833 | 0.045883147 | 0.047140452 |
| Concept 3 | 0.053452248 | 0.035355339 | 0.040824829 | 0.030151134 | 0.09486833 | 0.022941573 | 0.076980036 |
| Concept 4 | 0.053452248 | 0.035355339 | 0.122474487 | 0.060302269 | 0.09486833 | 0.045883147 | 0.115470054 |
| Concept 5 | 0.053452248 | 0.035355339 | 0.122474487 | 0.060302269 | 0.09486833 | 0.068824720 | 0.115470054 |

**Step #5** : Establish ideal and negative-ideal solutions

| | +ve | +ve | +ve | +ve | +ve | +ve | +ve |
|---|---|---|---|---|---|---|---|
| | FLEXIBILITY | WEIGHT | STRENGTH | MAINTAINABILITY | RELIABILITY | EASE OF USE | SAFETY |
| Positive ideal solution | 0.053452248 | 0.070710678 | 0.122474487 | 0.060302269 | 0.09486833 | 0.06882472 | 0.115470054 |
| Negative ideal solution | 0.026726124 | 0.035355339 | 0.040824829 | 0.030151134 | 0.06324555 | 0.022941573 | 0.047140452 |

**Step #6** : Calculate the separation distance

| | |
|---|---|
| S1 (positive) = | 0.088918924 |
| S2 (positive) = | 0.098564403 |
| S3 (positive) = | 0.106033003 |
| S4 (positive) = | 0.042146361 |
| S5 (positive) = | 0.035355339 |

| | |
|---|---|
| S1 (negative) = | 0.041715230 |
| S2 (negative) = | 0.052690758 |
| S3 (negative) = | 0.042294337 |
| S4 (negative) = | 0.103746477 |
| S5 (negative) = | 0.126744788 |

**Step #7** : Calculate closeness rating

| | |
|---|---|
| Concept 1 | 0.3193 |
| Concept 2 | 0.3484 |
| Concept 3 | 0.2851 |
| Concept 4 | 0.7111 |
| Concept 5 | 0.7819 |

**Step #8** : Rank the alternatives

| | |
|---|---|
| Concept 1 | #4 |
| Concept 2 | #3 |
| Concept 3 | #5 |
| Concept 4 | #2 |
| Concept 5 | #1 ★ |

FINAL ANSWER

| FUNCTION (TRAY TABLE) | CONCEPT 5 | |
|---|---|---|
| Size / Dimension | Longer & wider (17.5" x 11.5") | Slightly longer and larger in terms of its length(L) and width (W) although it is fitted to an economy type class & configuration |
| Material Thickness | Less than 1.1cm | Complements the longer and larger dimension with thin type table to provide a sleek design |
| Material Strength | Aircraft grade composite | Structurally is the best option considering its strength to weight ratio, lightweight & high structural strength |
| Pitch / Height | Less than 1.3m | Adjustable up to 1.3 m with regards to passenger comfort |
| Swivel / Moveable joint | Extended flip (90°) | Space saving and comfort |
| Surface Finish | Anti-microbial / Anti bacteria & Anti-viral treatment | Prevention and protection since this place harbours harmful bacteria |
| Latch Mechanism | Magnetic push type | Convenient & ease of maintenance |

## 5. Conclusion

When it comes to the project's goal of creating a conceptual design for a new and improved tray table that encourages mobility and utility, the overall success is measured by the application of effective design techniques to solve each challenge. As a result of the unique methodology, all design criterion concerns can be addressed with improvement solutions. This allows for improved performance and a new feature when it comes to the conceptual design phase. The conceptual design of an improved aircraft passenger seat tray was successfully completed using systematic engineering design tools; however, this does not rule out the need for further improvements and modifications; the process can still be refined where their mechanisms can be adjusted move whilst further improving its design and basically to verify them a software simulation can be done by applying design software such as CATIA.

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