ENGINEERING BETTER COMFORT IN LONG HOUR FLIGHTS

ENGN2225 Portfolio

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Contents

Introduction

Nowadays, air travel is becoming increasingly popular as people travel for leisure, work or study. When researching for a suitable airline, it is found cabin comfort heavily influences the customer's decision (Vink et al., 2012). Therefore, this project examines the interior design of a plane cabin from an engineering system's point of view and identifies possible improvements to increase passenger comfort. The focus will be on the economy class of a 9 hour flight because it is the class most people travel in.

This is done through improving the design of the seat. This is because the passenger spends most of their travel time on it. The proposed design is an alternative seat layout called StepSeat which provides more legroom and angle of reclination. This design is chosen by evaluating all the possible designs using the weighted evaluation matrix. StepSeat is chosen for its ability to improve customer comfort as well as being economically viable for companies to adopt it. Nevertheless, design validation procedures are devised to ensure the final design satisfies customer requirements before mass production. In order for this design to be adopted, a convincing case must be made to the companies. This is done by increasing the public's interest and showing the low cost of the design.

Aim

This project strives to make recommendations on the interior of a plane cabin in order to improve a passenger's long hour (around 9 hours) flight experience.

Motivation

Travelling by planes is becoming a more common form of transport (Vink et al., 2012). In Vink's paper, he found two ways to increase an airline's financial margin. It was to increase the number of passengers by 1% or reduce the maintenance cost by 14%. It is clear that the former is more viable as decreasing maintenance cost will jeopardise the safety of the aircraft. He also found that comfort is strongly correlated with a passenger's decision in flying with the airline again (Vink et al., 2012). Therefore, it is clear that comfort is an important factor for both the customer and the airline.

Solution

Figures 1 & 2 A model of StepSeat and comparing the density of StepSeat with the conventional economy seats (Jacob-Innovations, 2014b)

From going through the systems engineering design process, it was decided that changing the seat will best improve the passenger's comfort. The design is called StepSeat and is designed by the company Jacobs-Innovations LLC. The main characteristics of this design are the extra step in alternating rows, the 45º reclination of the backseat and the foldup chairs. *(Jacob-Innovations, 2014b)*

Design Communication

It is important to convince the companies of the design for it to be implemented. As customers often have a different view of a design problem than engineers (Ramstrom, 1965), it is important to focus on elements of the design that companies are interested in. A presentation followed by a Q&A session should be done to communicate the design. The meeting should focus on customer interest and cost of design because companies are only interested in these. To show customer interest, prototypes of both Conventional and Step Seat should be made so the testing done for comfortable seat and legroom can be done on 1000 participants. This will provide results that StepSeat is a better design.

In addition, a promotional video should be uploaded onto the internet through popular social media such as reddit, tumblr, facebook and Twitter. As visualisation is an effective way to communicate a design (Henderson, 1991), a CAD drawing of the drawing should be done. The drawing can then be put against the current seat design and its improvements can be highlighted by talking about elements such as legroom and improve back angle in the video.This will encourage the public to support this design. This can again show the amount of interest in the product.

A detailed report should be written about the cost of the design. This includes a bill of materials and production cost to show the cost of producing StepSeat is equal or less than the conventional seat design. By showing companies that at the same cost they can increase the amount of passengers, it will become appealing for them to adopt it.

Having described the solution and how it can be communicated to be implemented, the design process used to arrive to this design will be described in the rest of the report.

System Function Integration

In order to understand customer and design requirements, a passenger's activities during a 9 hour flight should be examined. In order to ensure all activities are considered, a functional flow-block diagram (FFBD) is used. It is shown in the figures below. The entire diagram is split into two figures where the bottom section shows the second level flow blocks and the top section shows the first level. The reference blocks and colour dashed arrows show where the second level flow blocks are meant to be linked to.

As seen from the top level diagrams, the passenger's activities are versatile during a flight but they are mostly constricted by the flight's schedule and is done at the passenger's seat. There are many repetitions in activities through each OR group of activities. Each group represents the list of activities a passenger can do at a particular period of the flight schedule. The dot point below show the relationships:

- 2.0-6.0 plane is not moving and boarding passengers
- 8.0-14.0 plane moves to runway and lifts off
- 15.0-26.0 flight period
- 27.0-32.0 plane descends
- 33.0-37.0 plane lands and moves to assigned terminal

An AND gate is used with the first and last group of OR gate to show that the function associated with the AND gate must be done with one of the activities in the OR group. The passenger cannot browse the IFE-In-Flight entertainment system- until the plane starts to move

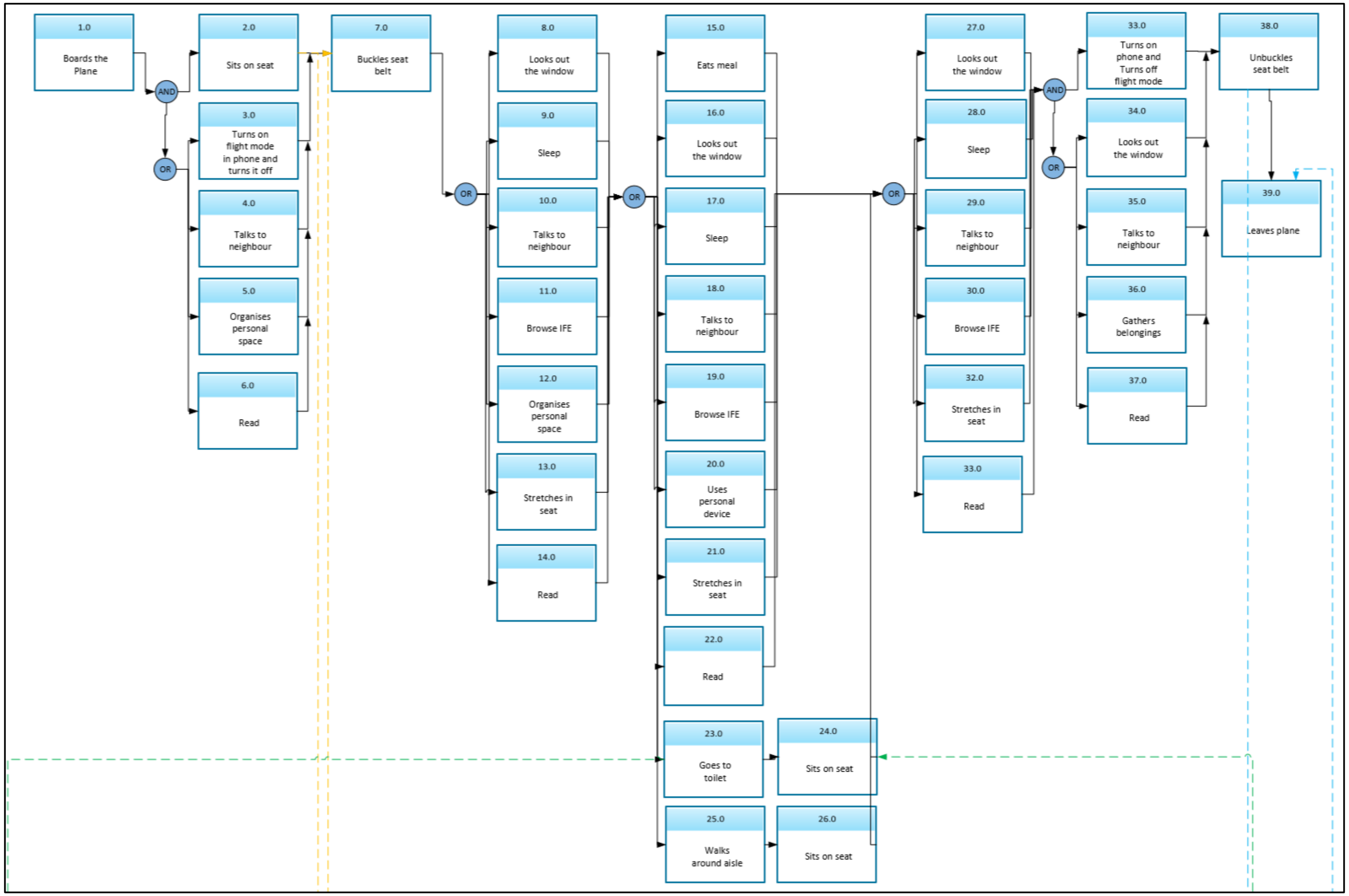

Figure 3 FFBD of a passenger's activities during a long hour flight

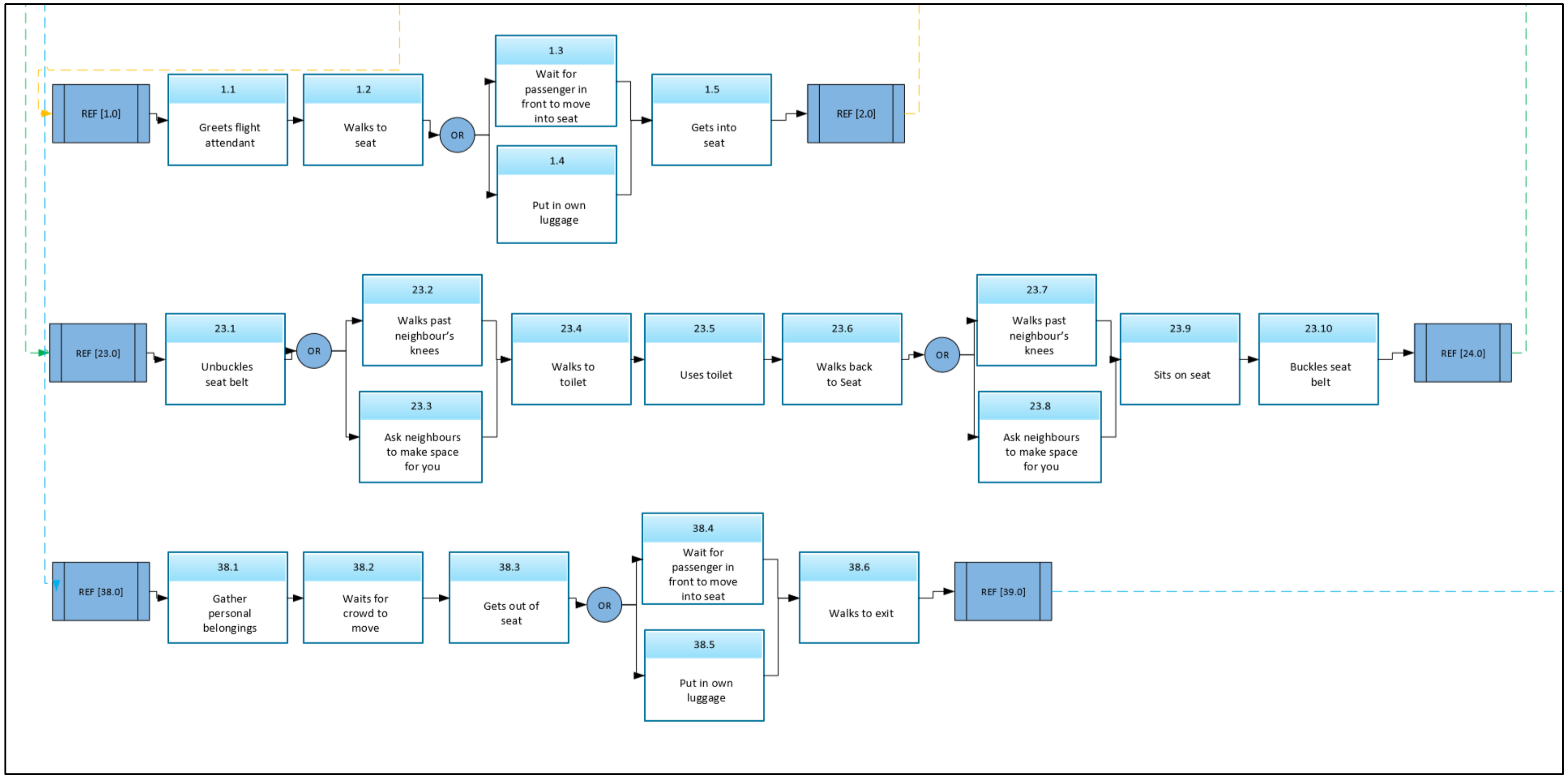

Figure 4 Bottom section of FFBD

because that is when everything in the plane is switched on. Personal device can only be used during the flight period.

There are very few periods when the passenger is not at their own seat. The passenger can only move out of their personal space during this period as well. The second level flow block diagram shows the flow for visiting the toilet. The flow for walking around aisle is very similar where only functions 23.4-23.6 are changed to one walking up and down the aisle function.

The FFBD highlights the importance in improving the personal space of the passenger during the flight as it is where they spend the majority of their travel time. It also provides some hints for possible design requirements such as more legroom and easy to access luggage space. Functions 23.2, 23.3, 23.7 and 23.8 show an increase in legroom will mean passengers that are not sitting at the aisle seats will not have to inconvenient other passengers when getting out of their seat. Functions 1.3, 1.4, 38.4 and 38.5 show that the boarding and disembarking processes can be speed up if the storage space is easy to use. This is because passengers will take less time to put in their luggage hence decreasing other passenger's wait time.

Subsystem Integration

Having understood the passenger's activities and their wants during a long hour flight, the focus is now shifted onto understanding how the cabin design interacts with the passenger through a Functional Block Diagram (FBD). Before a FBD is drawn, the elements of the cabin which will be explored in this study will be scoped in the system definition below.

System Definition

Table 1 System Boundary Chart

Internal	**External**	**Outside**
Climate	Other Passengers	Turbulence
Seat	Power	Weather
In-flight entertainment system	Passenger	Engine vibrations
Information to passengers		
Crew		
Storage		
Flight Services		
Brightness		

Cabin related elements that can affect a passenger's comfort are categorised in the System Boundary Chart above. The internal variables contain elements of the cabin design which can be controlled and designed. The external variables are the inputs and outputs of the system. Power is the input to the system because it keeps the electronic systems in the cabin running. Passengers are external because they interact with the cabin elements in their activities during the flight. The outside variables are the elements that affect passenger comfort but are outside the scope of this project. Weather and turbulence are variables that cannot be controlled. Even though turbulence is caused by the weather, turbulence is different here since it causes the stability of the plane while weather influences the trajectory of the flight and the view from the passenger's window. Engine vibrations can cause constant background noise in the cabin but is outside the scope of this project because it involves the mechanics of the structure of the aircraft.

Functional Block Diagram

The functional block diagram presents the variables defined the System Boundary Chart into more elements. The pilot is part of the crew as the way he/she flies the aircraft will affect the passenger’s comfort. The PA system is part of the information to the passengers instead of the crew because passengers get notify of the flight’s path and emergency information from it. Brightness is its own subsystem as it affects the customer’s comfort as shown when developing customer requirements. The windows let light in and wall colour affects the passenger’s perception of brightness. Flight services contains the things that are provided to the passengers during the flight which can improve comfort.

The FBD reasserts that most of the passenger’s activities is at their own seat space. For brightness, the passenger applies force to open the window shutters next to them and to turn on their overhead lights respectively. Hence, the passenger gets luminosity in return. The IFE provides digital media at their seat which encompasses movies, music, TV shows and games. The passenger applies force to the remote control to select the entertainment he/she wants. For the seat, the passenger applies force to adjust the seat which in return gets the appropriate support which is a force. More space becomes available when the luggage is put in storage. By applying force to use the available flight services and eat the meals, the passenger gets warmth and nutrients from the blankets and meals respectively. Similarly, the passenger gets ventilation and the correct temperature by using force to adjust the personal air conditioning. The passenger press the crew button so an attendant comes and provides service. The passenger can also talk to other passengers which are external the system so they can move past others or just to talk to them. As each subsystem provides something different to the passenger, it is not possible to remove a subsystem since its service cannot be replaced by another subsystem.

Other subsystems interact with subsystems other than the passenger. The seat and storage provide space for each other as an increase in under the seat space also increases the amount of storage space. The crew also applies force to use the PA system and adjust the central air conditioning system. Finally, the power keeps all the electronic and electrical systems working.

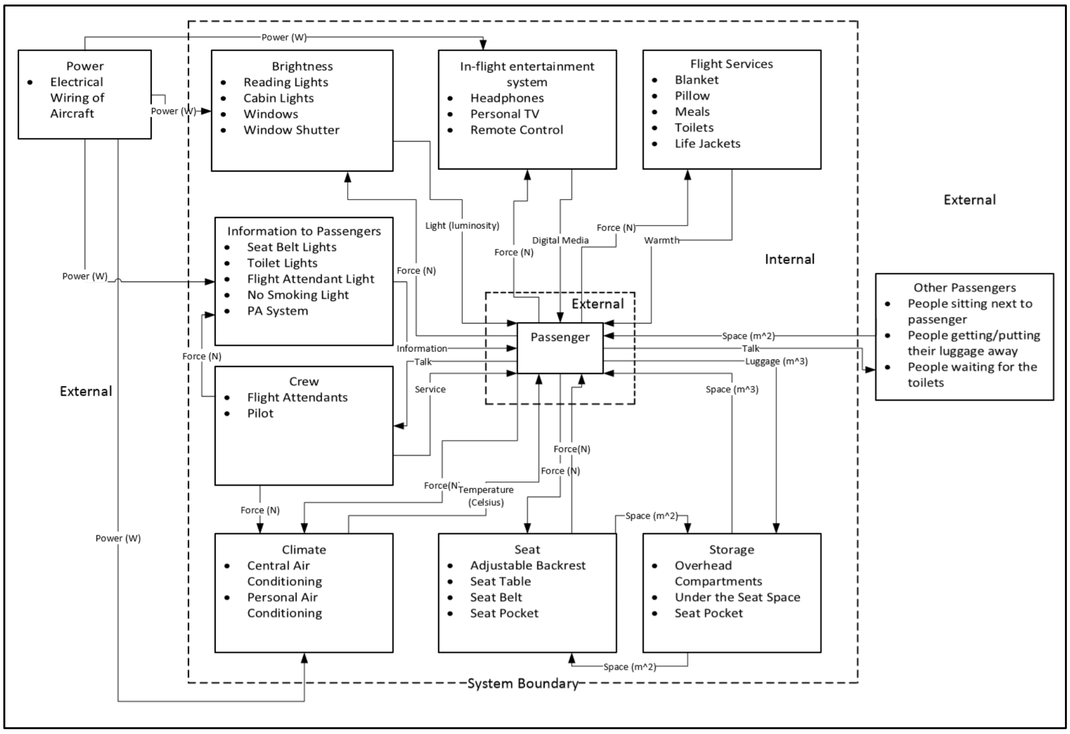

Figure 5 FBD of aircraft cabin

Requirements Engineering

Having a done a detailed examination of the activities of a passenger in a long haul flight, a list of requirements are generated to ensure the design will satisfy the needs of the passengers and improve their comfort in long-haul flights. Comfort is the only customer requirement (CR). Therefore, various design requirements (DR) for comfort are examined and a pairwise analysis is conducted to rate their importance. All of these will help identify elements that will improve a passenger's comfort the most. A house of quality is then conducted on the five most important design requirements.

Design requirements

As comfort is subjective and different for everyone, it will be useful to base the DR on a survey. In Vink's paper, more than 10,000 internet trip reports and 153 passengers were surveyed to identify design requirements to improve comfort while travelling in economy class. From looking through all of the reports and interviews, the main comments made in regards to a comfortable flight were "enough/much legroom", "cleanliness of the interior", "good seat" and "in-flight entertainment"(IFE) (Vink et al., 2012). "Nice crew" was also mentioned but this is outside the scope of this project because the aim is to improve comfort from the plane's interior. A pairwise analysis is used to rate the importance of these design requirements found by Vinks. Other weaker comments were also included because they also make up the DR.

Pairwise Analysis

Table 2 Pairwise Analysis

Design Requirements	Legroom	Cleanliness	Seat	IFE	Climate	Air Quality	Noise	Toilet	Luggage Room	Score	Rank
Legroom		1	1	1	1	1	1	1	1	8	1
Cleanliness	0		0	1	1	1	1	1	1	6	3
Seat	0	1		1	1	1	1	1	1	7	2
IFE	0	0	0		1	1	1	1	1	5	4
Climate	0	0	0	0		1	1	0	0	2	7
Air Quality	0	0	0	0	0		1	0	0	1	8
Noise	0	0	0	0	0	0		0	0	0	9
Toilet	0	0	0	0	1	1	1		0	3	6
Luggage Room	0	0	0	0	1	1	1	1		4	5

The ratings are based on Vink's results. Legroom and passenger seat is the most important because the passenger spends the majority of their flight sitting. Therefore, passengers often have knee pains as a result from bending it for too long in the small amount of available space. (Vink et al., 2012) Even though IFE keeps the passenger entertained, Vinks found that passengers are more concerned with the cleanliness of the aircraft. This can be because it is common to have a personal electronic device which passengers can use during their flight for entertainment. Luggage room is important because it will increase the legroom for passengers and is more important than toilet since they associate with legroom and cleanliness respectively and the former is more important. Lastly, air quality and noise is the lowest rank because Vinks found in his study that passengers notice these factors the least. However, long term exposure to bad air quality can cause passengers to be unwell which is why it is ranked higher than noise.

As there are so many DRs, the top five DRs will be examined further using a series of techniques because improving them will already significantly increase passenger comfort.

Technical Performance Measures

Technical performance measure breaks down the DR into more specific characteristics that have a quantitative measurement. This is useful as these metrics that can be used when comparing possible designs later on. The minus and plus signs stand for minimisation and maximisation of the characteristics respectively. X stands for optimising the characteristic.

Some of the engineering characteristics require an explanation. For legroom, Vinks found that decreasing the backseat pockets will increase the amount of legroom but since it was decided to be optimised here because the pockets still needs to be big enough to provide enough storage for magazines. Backrest thickness should be optimised because decreasing it will increase the amount of seat space but it still needs to be thick enough to support the passenger's weight. Seat pitch should be optimised rather than maximised because too much space will result in less seats available hence less passengers on board. Bright space was found to contribute to cleanliness in Vink's paper. The amount of fingerprints on a window is used to measure its cleanliness because it is usually the main cause of making windows dirty. For back support, Jm^{-3} is used because this is the unit for toughness. A tough material will give the passenger more back support. The range of angles that the back support can be adjusted to shouldn't be maximised as a large angle will result in discomfort for the passenger behind. Space below seat also contributes to luggage room because passengers are allowed to put luggage under the seat.

More specifically, it is important to optimise the overhead and under the seat's storage space so the customer can maximise the amount of space to themselves. Increasing overhead storage space will mean that passengers can have more legroom from the space under the chair. However, it needs to be optimised because a large overhead storage space can cause the height of the cabin can be significantly reduced, causing discomfort for passengers when standing up in their seat.

Table 3 Technical Performance Measure

ID	Design Requirements/Attributes	Engineering Characteristics	Metrics (TPM)
DR01-01	More Legroom	X seat pitch	m (length)
		X backseat pockets	m^2 (area)
		X backrest thickness	m (thickness)
DR01-02	Cleanliness	X bright space	(luminosity)
		+clean windows	Fingerprints/m^2 (no. of fingerprints)
		-rubbish in cabin	Percentage of clean space per m^2 (rubbish density)
DR01-03	Comfortable Chair	+back support	Jm^{-3} (toughness)
		+headrest flexibility	Radians (rotation of headrest)
		X flexibility of back support	Radians (angle between backseat and seat base)
		+seat width	m (width)
		+back support height	m (length)
DR01-04	In-Flight Entertainment	X personal TV	Personal TV

		X entertainment database	Entertainment database
DR01-05	More Luggage Room	X overhead space	m^3 (volume)
		X space below seat	m^3 (volume)

System Attributes

From the FBD, it can be seen that there are many subsystems in an aircraft cabin. Therefore, the design requirements are examined further by identifying the attributes that should be improved and which subsystem they belong to. This identifies the subsystem that can affect the most attributes hence design requirements. The attributes made in the cascade are self-explanatory except A2.3.2 Amount of disposable cutleries and cups. It can reduce the amount of rubbish because often in flights, passengers are provided with water bottles, disposable cups or packet of cookies for refreshment. All of these become rubbish once they've been consumed. Therefore, a solution would be to give passengers a reusable cup or just hand out cookies using tissue paper so passengers won't feel that they have rubbish once they finish using it because things such as tissue paper is at least smaller and more useful to passenger than the wrapper.

Table 4 Attributes Cascade

Primary attribute	**Secondary attribute**	**Tertiary attribute**	**Related Subsystem**
A1.0 More Legroom	A1.1 Increase seat pitch	A1.1.1 Seat depth	Seat
		A1.1.2 Space between seat base and seat in front	Seat
A2.0 Cleanliness	A2.1 Bright space	A2.1.1 Colour of walls	Brightness
		A2.1.2 Amount of lighting	Brightness
	A2.2 Clean furniture	A2.2.1 Window clearness	Brightness
		A2.2.2 Amount of stains on furniture	Seat
	A2.3 Reduce amount of rubbish	A2.3.1 Number of bins	Flight Services
		A2.3.2 Amount of disposable cutlery and cups	Flight Services
A3.0 Comfortable Chair	A3.1 Good posture	A3.1.1 Back support	Seat
		A3.1.2 Headrest flexibility	Seat
		A3.1.3 Adjustable back angle	Seat
	A3.2 Spacious	A3.2.1 Seat width	Seat
		A3.2.2 Seat height	Seat
		A3.2.3 Adjustable back angle	Seat
A4.0 In-Flight Entertainment	A4.1 Good entertainment database	A4.1.1 Amount of different types of entertainment (movies, music, tv shows)	IFE

	A4.2 Personal TV	A4.2.1 Screen resolution	IFE
		A4.2.2 Adjustable brightness and contrast	IFE
	A4.3 Headphones	A4.3.1 Volume	IFE
		A4.3.2 Fitting	IFE
A5.0 Luggage Room	A5.1 Increase overhead space	A5.1.1 Width of overhead space	Storage
		A5.1.2 Depth of overhead space	Storage
	A5.2 Increase space below seat	A5.2.1 Width of seat	Seat/Storage
		A5.2.2 Length of seat base	Seat/Storage

Table 5 No. of attributes associated with a subsystem

Subsystem	**No. of attributes**
Seat	11
Brightness	3
Flight Services	2
IFE	5
Storage	4

From Table 5 it can be seen that the Seat subsystem affects almost half of the 23 attributes. This means that the design of the seat should be focussed since it can improve comfort significantly. This agrees with the pairwise analysis where a comfortable seat is the second most important requirement. Therefore, this is why the solution is an improvement on the seat.

Concept Generation

From looking at the analysis so far, it can be seen that ultimately, passengers want an improved personal space through the comfort of the seat and increased personal space. Making all the seats like first class where the passengers can completely lie down would be ideal but not economically viable for the company. Therefore, two designs including the chosen design are found that addresses the customer's requirement as well as having a similar seat density as the conventional seat design. The chosen design is not shown here as it is already presented. As a comparison, the conventional design is presented to show the improvements in the two designs clearer.

Conventional (Qantas A380)

Figure 6 *The Economy Class seat in Qantas's A380 (O'Sullivan, 2009)*

Qantas's economy class will be used as a reference of conventional design as it is used in the A380 which is the most recent aircraft. Its main features is it's got adjustable headrest, feet rest, 30^{o} reclination and adjustable personal TV. (SeatGuru, 2013)

Economy-FLEX

Similar to the StepSeat, the Economy-FLEX offers alternating top and bottom rows and fold-up seats. This allows passengers to recline at an angle more than 45 degrees as shown in Figure 7 and the bottom row passengers will have an easier access to their luggage. The top row's seats slide back in order to recline while the bottom row's seat slide forward (Jacob-Innovations, 2014a). Due to the stairs for the top row, there are only 3 seats at the top and 4 at the bottom.

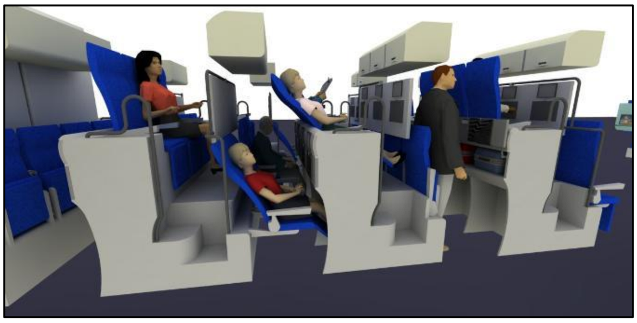


Figure 7 & 8 A Model of Economy-FLEX, An illustration of extra luggage storage for passengers sitting in the bottom rows *(Jacob-Innovations, 2014a)*

Design Validation

The attributes cascade shows that the change in the listed attributes will contribute to satisfying customer requirements. Therefore, tests should be done on the attributes of the design before it is chosen and implemented. An analytical model is presented to determine the optimal dimensions of the seat so it suits most of the population of passengers. A prototype testing is then presented so it can ensure the calculated dimensions is the best for customers. These tests are important in ensuring the design is resilient to the different perceptions of comfort for different passengers. As one of the tests asks for participant's feedback on the comfort of the design, the test results can also be used to convince the company to adopt the design.

A3.1.1 Back support, A3.1.3 & A3.2.3 adjustable back angle and A3.2.2 seat height (Analytical Models)- The following method gives a quick way of determining the suitability of different materials before a prototype is built.

1. Find the average human height and weight by using anthropometric data
2. Draw a free body diagram of the passenger at the most tilted angle
3. Calculate the force on each component of the seat
4. Calculate the tensile and compressive stress in each component
5. Compare the calculated value and see if it's less than 10% of the maximum tensile and compressive stress the material can withstand
6. If not, adjust the angle and height of seat and repeat steps 2-5 until suitable angle and height is found
7. If suitable angle is less than 110^{o}, the material is not suitable

As the anthropometric data of people from different racial backgrounds can be very different, this test should be applied to the varying data. The different results can be used to evaluate the suitability of different designs for various airlines. This is because a certain race may make up most of an airline's passengers. Nevertheless, since most airlines have a very versatile range of passengers, the anthropometric data for the world's population should be looked at as well.

A3.0 Comfortable chair and A1.0 more legroom (System Prototypes-Type II Testing)- From the system attributes, it is seen that the seat have a great effect on the passenger's comfort during the flight. As the production of aircrafts is expensive so a design will be used for 10 years at least, it is essential to perform a testing before any design is implemented and produced in large quantities. It was decided to test attributes A1.0 and A3.0 because both attributes will require the test subject to sit on a chair to rate their comfort. Therefore, it is more efficient to test them together. The test procedures are as follows:

1. Build a model of two rows of three chairs
2. Ask test subject to sit in the middle seat of the back row
3. Ask subject to rate the amount of legroom available (1 for insufficient, 5 for more than enough)
4. Ask subject to rate their comfort when the back angle is the smallest (1 for intolerable, 5 for very comfortable)
5. Ask subject to rate their comfort when the back angle is the largest (1 for intolerable, 5 for very comfortable)
6. Ask subject to rate the space available to them (1 for insufficient, 5 for more than enough)
7. Ask subject to rate overall comfort (1 for intolerable, 5 for very comfortable)

The design must be rated at least 3 for steps 3-7 in order to be considered further. The reason for step 2 is because legroom is influenced by the seat pitch which depends on the amount of space between the passenger's seat and the seat in front. Sitting in the middle also means that the passenger doesn't have the extra space from the aisle and therefore will rate the space provided solely by the design. Step 3 tests A1.0 while steps 4-7 tests A3.0. Though it seems that steps 4-5 have a focus on testing A3.1 but the comfort at different postures can also be affected the amount of space available. This is the same as step 6 where the focus seems to be on A3.2 but good posture is needed for a good amount of space. For example, the passenger will feel there is very little space if the back support can't be adjusted low enough. This test helps correlate the various dimensions of the seat to overall passenger comfort. Steps 3-6 provide feedback to whether the results found in the analytical model is effective. This allows another set of dimensions to be re-calculated and tested again using prototypes. However, the cost of producing seat prototypes will be expensive so this iteration will only be repeated twice or three times the most.

House of Quality

The first five DRs are further examined in a House of Quality (HoQ) because they are the most important factors that should be improved. By determining which engineering characteristic influences the most DRs, this will assist in better improving the passenger's comfort by focusing on the identified characteristics. As can be seen in the middle part of the HoQ in the next page, the engineering characteristics are rated against each DR. In the top section, it should be noted that large seat width and increase seat height all increase luggage space because the increase in space around the chair increases spaces for passengers to put their belongings hence more luggage space. For the ratings, good back support and backrest flexibility will give more legroom as the passenger will be more comfortable with sitting with their back closely against the backrest, allowing their legs to have a bit more room to move. Increasing seat pitch, overhead and under the seat space will also make the cabin look slightly cleaner as there is more space.

From this analysis, it can be seen that the space below the seat influences the DRs the most as it influences legroom and luggage space heavily. Seat pitch and backrest thickness are strongly related and affects many design requirements as well. This again highlights the need for a different seat layout to improve the room underneath the seat. However, to evaluate which seat layout is best, a weighted evaluation method is done on the right hand side of the HoQ.

Evaluation Matrix

The weighted evaluation matrix is used to assist in deciding on the best design. For legroom, it is clear that Economy-FLEX provides the most room. The layout of the seats affects the passenger's view of the cabin cleanliness because it affects the amount of lighting (which is one of the tertiary attributes of cleanliness) at the passenger's seat. As StepSeat and Conventional share a similar seat layout, passengers will feel the same about cleanliness. Economy-FLEX is best because the alternating height of the rows makes space feel more spacious and brighter. Step seat is decided to be more comfortable because its hard back provides more back support despite Economy-Flex provides a reclination angle of more than StepSeat's angle of 45^{o} (Jacob-Innovations, 2014a, Jacob-Innovations, 2014b). Economy-FLEX provides more luggage space because it has extra space for the bottom row as seen in Figure 7. For IFE, they all provide the same features so the same score was given.

From the evaluation matrix, it is found that the conventional, StepSeat and Economy-FLEX scored 246.6, 340, 460. Nevertheless, these scores are not accurate because they are based on the author's perception of comfort. For a more objective rating, the prototype testing outlined in the design validation section should be conducted on these three designs. Results from steps 3 and 7 can help rate the design requirements DR1-01 More Legroom and DR1-02 Comfortable Seat. It is difficult to rate the other design requirements based on the prototype testing but a CAD drawing can be made of the cabin with the seat design to measure the amount of luggage room and open space. The amount of open space can measure the cleaniliness of the cabin since more space usually give a better feeling of cleanliness.

Selection

Given the weighted score for each design requirement is around 20, Economy-FLEX's score is significantly higher than StepSeat's and conventional design's scores. Therefore, Economy-FLEX is clearly the most preferred design if the customer requirements are considered only. However, it contains a few factors that can deter airlines from adopting this design. First of all, it costs 20% more than the conventional design to produce (Jacob-Innovations, 2014a) and it can't carry as many passengers either. This problem is further worsen as the top row won't be accessible for old and disabled passengers. Furthermore, the stairs may pose as a safety hazard since sudden turbulence can cause passengers to fall. This is not unappealing to passenger but can cause a lot of problems to the company should an injury occurs. A passenger can sue the company if an injury occurs and this can damage the airline's reputation hence decreasing the number of passengers. StepSeat is much better where its production cost is similar to the conventional design and it can still carry the same amount of people. Its design also doesn't restrict the type of passengers. As StepSeat's score is still significantly higher than the conventional design, StepSeat is a better option since it will improve passenger comfort and is still viable for companies to adopt it.

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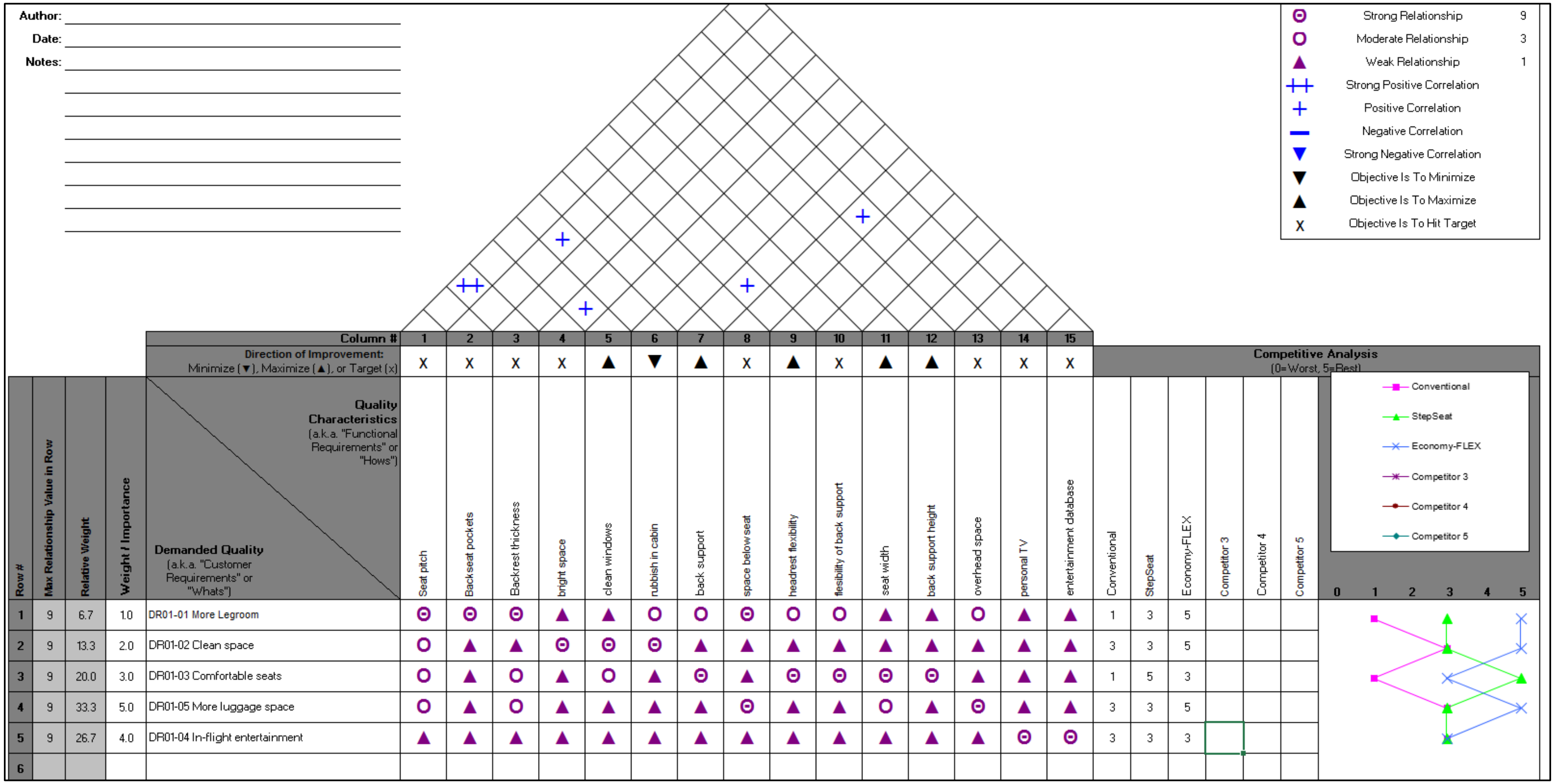

Figure 9 House of Quality

Conclusion

From conducting a systems engineering design process, it is found that improving the seat layout will increase the passenger's comfort the most. Even though the FBD shows that the seat is only a small part of the cabin system, functional analysis establishes that the passenger spends most of their travel time in the seat. The attributes cascade also proves that the system affects the most attributes related to the design requirements. It is further supported by Vink's paper where more legroom and comfortable seat are the top two design requirements that will improve customer comfort. Generating and evaluating the possible seat layout design concludes the StepSeat to be the best design. However, tests outlined in design validation should be conducted to improve the accuracy of the evaluation. The test can also be used to prove the effectiveness of the design. Along with the cost of the design, these can be used to convince airlines to adopt the design.

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