The Use Of A Decision Makers Culture To Help Inform The Preferences Used Within A Generalized Utility Function

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***Abstract* — This paper provides the background rationale for and description of a conceptual Decision Influence Model (DIM) using utility functions taking into account the effect of culture on decision outcomes. This work was developed based on an assessment of the wider influences upon decision making within the Air Transport System (ATS). A novel approach in the use and development of utility functions is expressed, via the use of the Decision Makers (DM) culture.**

The usefulness of the approach, when validated, is the potential to generate useful utility functions, as a decision aid, from industry generic decision attributes within the context of an airlines decision to purchase aircraft, which are 'tailored' via the DM's culture. This paper is an introduction to the concept, outline of an approach and demonstration of possible outcomes. A description of the developed DIM and its application is provided.

Keywords—Air Transport System, culture, utility functions, decision modelling, DIM

I. INTRODUCTION

The Agile Wing Integration research project is aimed at developing rapid and world-beating wing design for aircraft, as well as helping to shape future air transport operating systems (1). Aircraft design practices employed in the aerospace industry have historically focused on designing and evaluating new technologies, operations, and products based on satisfying metrics supplied from direct customer requirements. In this regard, existing evaluation processes often look at the direct monetary effects to an OEM or airline/operator of any new concept, and do not consider important indirect and intangible effects e.g. customer loyalty, innovation perception etc.

Within this project, funded by Innovate UK, there is the aim of investigating the underpinning of stakeholder strategies and market drivers for future air transport systems (1). Within this scope an integrated approach to modeling the key stakeholders and the influences on decisions of aircraft acquisition is being developed.

The problem identified within the research is the lack of further customer understanding for an OEM and the need to expand this understanding via the incorporation of wider influencing factors such as socio-technical considerations.

There are a number of different approaches being employed to tackle the task of understanding future purchasing patterns of airlines. One approach is to understand the culture of the decision maker and how that may affect the decision outcomes. This is the focus of the author's research. The research question is how do the cultural traits of the DM (airline) affect decision outcomes within the aircraft acquisition process?

The specific focus of this paper is the utilization of utility functions as a decision-making model and how cultural traits of the Decision Maker (DM) could be implemented within these functions. The aim of the paper is a proof of concept for the initial development of the Decision Influence Model (DIM) functionality that, using utility functions, is able to demonstrate the impact that cultural traits have on decision utility values focusing on an airlines decision to purchase. Through the AWI project and the help of the industrial partner Airbus, a pre-purchase process (PPP) for key decision milestones in aircraft acquisition was established. Using the PPP, three main decision milestones were selected to build the decision model around and assess decision outcomes against; this shall be outlined in more detail later within the paper.

The paper structure is as follows, Section 2 outlines the assumptions that underpin the method and approach and Section 3 provides details on what shall constitute the assessment criteria for this proof of concept. Section 4 contains definitions of utility theory and outlines the how they are applied with an example application and outcomes. Section 5 provides an overview of the main decision makers within the ATS and what constitutes decision modelling. Section 5 also introduces the perspective of culture and some applications within past projects and studies.

Section 6 describes the application process of the utility functions to the context of the PPP; key aspects covered are decision attributes, generation of the utility function and DIM model output. Sections 7 and 8 discuss the conclusion and future work respectfully.

The following shall be demonstrated within this paper; identification and setting of a generic PPP for commercial aircraft acquisition, elicitation of the key decisions within that PPP, selection of the generic utility attributes for an airline in the context of aircraft acquisition at a corporate level, development of a utility function from those attributes and identifying, assessing and implementation of a key cultural trait of the DM within that utility function.

II. Assumptions

This section states the key assumptions that have been made whilst developing the DIM and if these hold for the model, the use and output of the DIM for each DM shall deliver the expected understanding outlined in the paper.

- Cultural traits of the DM (airline) do affect the outcome, based upon work done by Hofstede (2), Harding and Siemieniuch (3), (4) and de Mooij (5); and the research is assessing the extent of these effects.
- The national culture of the airlines headquarters is the airlines culture, because that is the origin of the key decision makers and organizational processes for that airline; based on the example airline organization used (6).
- The PPP framework developed is sufficient for all airlines, the only changes for each airline are the point of entry within the process and rate of progression through it; based on understanding gathered through interviews with marketing and sales personnel within an OEM.
- The use of the economic and population growth data and projections provides sufficiently accurate data to use as the scenario data; a scenario will refer to a period where external conditions are assumed to remain constant (7).

III. Assessment Criteria for Proof of Concept

This model has undergone initial prototyping and the development of the core functionality. This section shall provide an outline of the criteria by which the core functionality shall be assessed. The assessment will contribute to the proof of concept for the development of the initial version of the model.

The assessment factors have been derived from the operational requirement for the model from the research which has been driven by the project; taking account of required functionality, model integration (inputs/outputs) and usability. The key factors that must be demonstrated by the model are:

- Development of utility functions in Matlab Software, within the context of the airlines decision to purchase aircraft.
- Implementation of scenario data i.e. economic and population growth forecasts in the Matlab program.
- The application of cultural values to the scenario data within the utility functions as a weighting.
- The effect of the cultural values via a comparison of a DIM output where no cultural values are applied.
- The model has the capacity for application to different DM's and contexts based on the user input variables used.

The first three points stated are the main functions of the DIM and the fourth is the key assessment of the model output required. The final key factor within the proof of concept relates to the need for the model to be adaptable within the environment it shall be applied to; this is a desired capability for the end model and as such it may not be able to fully demonstrable within this paper.

IV. Utility Theory

A. *Definitions*

A definition of utility theory is the mapping of 'preferences for an attribute into a normalized value-under-uncertainty function, known as utility'; and a preference is the 'perceived value (return) under uncertainty' (8). Utility theory provides a mechanism to bridge the language barrier between experts of different backgrounds and differing needs e.g. scientists, engineers, managers, etc.

Stated earlier the type of decision making model used is the cognitive rational model which focuses on risk and utility (pay off) for the consumer, thus utility theory maps well to this type of decision modelling; The difficulty within the context of aircraft acquisition are the number of facets which influence decision and are inherent in the decision problems. Some of these facets include:

- Financial
- Performance (Organizational and Operational)
- Political
- Regulatory
- Demand

Within Section 4 it outlines how the facets can be, and in this case some are, used as the attributes within the utility functions.

B. *Application*

The preference for each attribute is typically generated through an interview with the DM using the lottery equivalent probability (LEP) method (9). The utility values can be derived by determining the point at which the DM is indifferent towards the lottery options offered.

The DM must take into account variables that range from economic to political, regulatory and reputational. Due to the complexities involved in each decision involving a number of attributes with varying preference it is vital to understand how the DM trades the various attributes.

The use of multi-attribute utility functions (MAUT) (8) has the potential to be able to handle these variables and provide a common platform to evaluate the outcomes. The way in which MAUT does this is by combining single attribute utility functions into a single function via quantifying how a DM values attributes relative to one another. From (8) if the assumptions associated with MAUT hold then the following is a general multi-attribute utility function:

$$KU(X) + 1 = \prod_{i=1}^{N} [Kk_i U_i(X_i) + 1]$$

where K is the solution to

$$K + 1 = \prod_{i=1}^{N} [Kk_i + 1]$$

$$\sum_{i}^{N} k_i < 1, \qquad K > 0$$

$$\sum_{i}^{N} k_i > 1, \qquad -1 < K < 0$$

$$\sum_{i}^{N} k_i = 1, \qquad K = 0$$

K = multi-attribute utility normalization constant
k_i = multi-attribute utility scaling factor for attribute i
N = number of attributes
$U(X)$ = multi-attribute utility function
$U_i(X_i)$ = single attribute utility function i
X = set of multiple attributes $1, \ldots, N$
X_i = single attribute i

Attributes used within MAUT can be quantitative/hard and qualitative/soft with virtually any unit. The key is that the preferences for different attributes are developed under a well-defined context which permits the concurrent evaluation of attributes due to the normalized scale used (10).

C. Example

Looking at the use of this method within the context of aerospace and specifically aircraft design, work has been carried out looking at how aircraft design can benefit from trade space studies with respect to evolving designs in (7). This example applies the utility theory to the physical design of aircraft concepts. The study looked at mapping several design concepts of various characteristics to a number of future scenario types to assess which would prove to be the best design choice to implement based on the design concept utility.

The following figure, **Error! Reference source not found.**, provides an illustration of the aircraft design concepts evaluated, including current designs to be able to compare the future concepts against current aircraft utility. From the figure it can be seen that six aircraft designs were evaluated within this study.

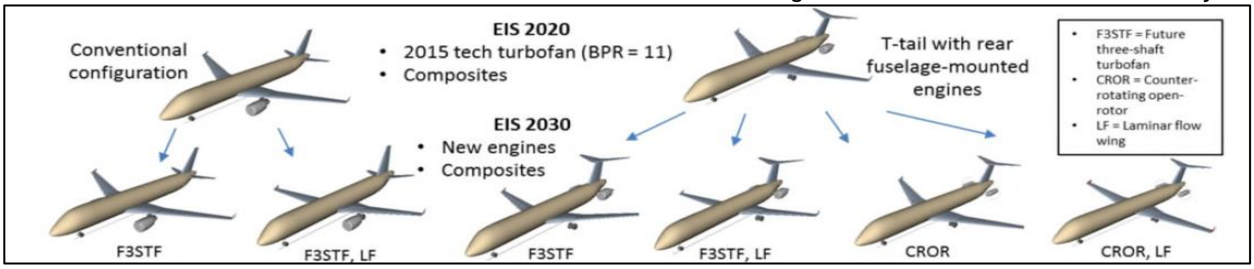

Figure 1: Aircraft design options assessed within the Tradespace (7)

Each of the above aircraft options, in **Error! Reference source not found.**, has been assessed using the following utility function (7):

$$u = w_F S_F + w_N S_N + w_E S_E + w_{FL} S_{FL}$$

The utility function utilizes the use of a System Effectiveness Ranking (SER) (11) and weightings to derive the utility value for the various physical attributes for each aircraft design option. An example SER for fuel-burn (Sf) taken from (7) is below:

$$S_F = \begin{cases} 0;\ \text{if } F > F_R \\ \dfrac{F_R - F}{(1 - K_F)F_R};\text{if } F \le F_R \text{ and } F > K_F F_R \\ 1; \text{if } F \le K_F F_R \end{cases}$$

Besides fuel burn this study used noise, emissions and field length as the other attributes by which the utility function was generated. A SER was produced for each of the attributes which can be found in (7) along with the weightings applied.

The utility values generated were mapped against a cost model which delivered the cost for each design option based upon a set of Design-of-Experiment (DoE) parameters (7) and led to the generation of Figure 2.

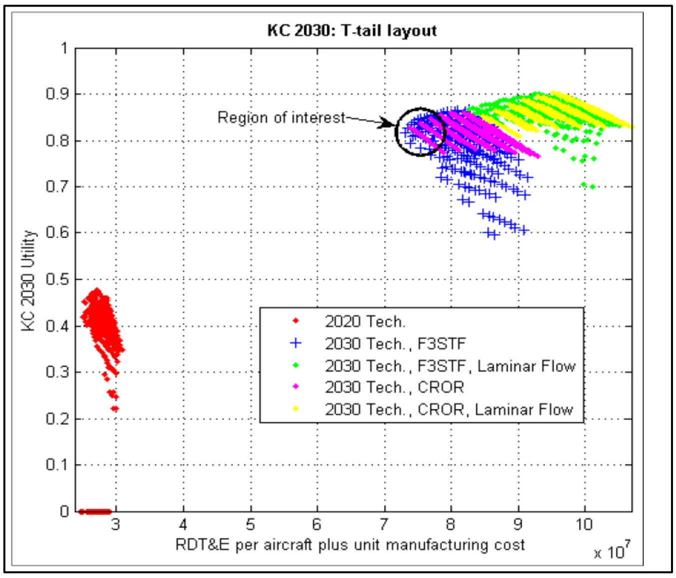

Figure 2: Example of Aircraft Utility Tradespace Model (7)

The work carried out in (8), (10) and (7) shows successful application of the theory of utility to the concept design phase for physical, quantitative attributes; based on the definition of utility theory used the method allows for qualitative or soft attribute (10) parameters to be defined and implemented as well.

Taking these factors into account there is merit to apply utility theory to the modelling of decisions within the context of future acquisition of aircraft; under unknown and incomplete scenarios where the parameters are less predictable and relate to a more qualitative modelling environment.

V. Decision Makers and Modelling

A. Decision Makers

Similarly to the stakeholder classification used within (8), the air transport system has a similar stakeholder/DM structure and interaction. Figure 3 provides a very simple view of the key stakeholders at three differing levels of decision hierarchy. Level 0 are external stakeholders with little stake in decision making but have influence via policies and regulations within which the decisions have to be made.
Level 1 are primary decision making stakeholders that comprise the core service and product suppliers within the ATS. Level 2 are users of the ATS, yet drive the decisions relating to service use and supply the demand by which the commercial aviation sector is driven.

This classification of stakeholders is used to provide a simple definition of the DM's taken into account within the research scope. For this paper's purposes, within Figure 3 the airline has been selected as the DM and the decision modelling shall operate within the context of assessing the options to decisions prior and leading up to contractual interaction between the firm (OEM) and the Customer (airline).

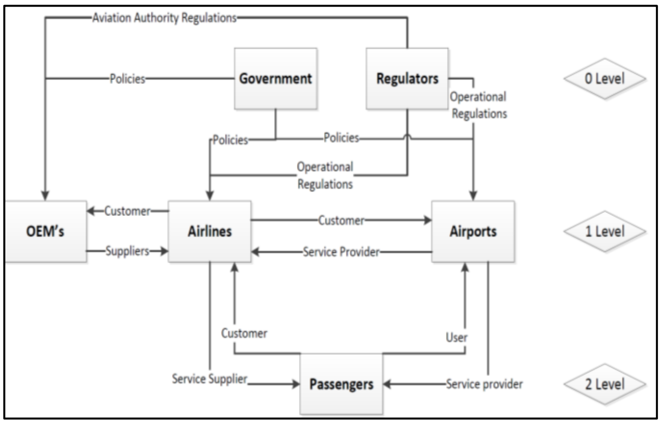

Figure 3: Decision makers and roles

B. Decision Modelling

The desired outcome of any model of decision-making is to deliver a level of understanding of how the DM is likely to 'behave'; behave in this instance refers to the likely choice the DM will make. A class of decision making models is known as "cognitive-rational" due to the models focus on the key variables of risk and utility (12). It is this class of decision making models that this paper shall be focusing on.

Within the operational scope of 'cognitive-rational' models, decision models can be referred to as 'additive utility models' (12). Within (12) it outlines three basic strategies that can be adopted when using additive utility models:

- Minimise Perceived Risk (Expected loss)
- Maximise Perceived Return (Expected gain)
- Maximise Net Perceived Return (Net Expected gain)

This paper adopts the third strategy, maximising net perceived return, as the strategy for the DM. The reason for selecting this strategy is that both positive and negative expectations of the DM are taken into account; it is intuitively a superior strategy. The strategy is used to direct the preferences used within the utility functions.

This strategy shall be used for all DM's modelled, allowing the application of the cultural traits to be the main variable; this provides easier assessment of how culture affects the utility values. The future research shall employ different decision strategies based upon the DM's that shall be modelled.

C. Culture

Initial investigation into literature on culture and the implications of it led to Hofstede's perspectives on culture, Figure 4 (2). The work carried out by Hofstede and his team on national culture and measures of cultural traits were used within a number studies; one which evaluated cultural factors and potential effects of them on military operations (3).

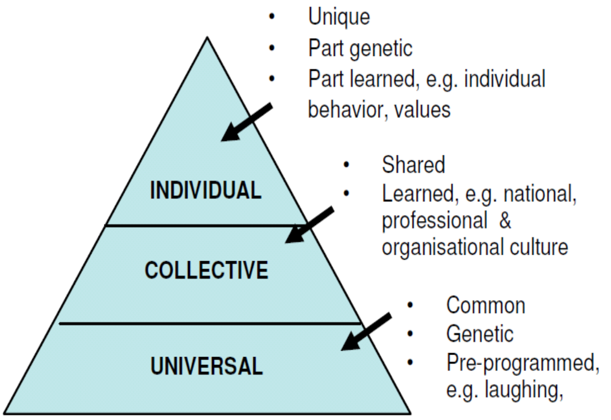

Figure 4: Hofstede's perspectives on culture

A further study assessed potential team performance taking into account the task and the team selected for the task which resulted in the Team Culture Tool (TCT) (4). The understanding from the sources stated led to the refinement of the types and values of the cultural traits selected for possible application within the utility functions.

The selected cultural traits are (13):

- Power distance (PDI) - the degree to which the less powerful members of a society accept and expect that power is distributed unequally
- Uncertainty avoidance (UAI) - the degree to which the members of a society feel uncomfortable with uncertainty and ambiguity.

The cultural trait values are shown in Table 1 obtained from Hofstede's national culture tool (2). Airline A has been selected as a UK based airline and Airline B is a United States based airline. Within the ongoing research these values shall be refined to reflect the organizational culture of the airline as well.

Customers	PDI	UAI
Airline A	0.35	0.35
Airline B	0.4	0.46

Table 1: DM Cultural Traits

The selection of the two types of cultural traits was the result of domain expert discussions with C. Siemieniuch and a study carried out by Merritt (1998) (14). How these are deemed to affect decisions is, PDI has an effect on decision structure and potentially decision lead time required by the DM and UAI directly affects the DM's preferences due to the relation of UAI and risk aversion which is elaborated on in the coming sections.

The work reported herein focuses on UAI; PDI is not included at present but will be introduced into the research at a later date. The reason for this that the paper is focusing on one decision within the decision process and thus the effect of PDI on decision structure is irrelevant for this paper. When the whole decision process is modelled later in the research the PDI trait shall have an influencing factor. The results are thus still relevant and the focus is around how UAI can be implemented within the utility function preferences.

VI. Utility Theory Applied to PPP Context

A. *Decision process - PPP*

As stated in the previous chapter the decision making process that is in focus is the PPP for the acquisition of an aircraft order from an airline to an OEM. The airlines chosen are a leading European and US Low Cost Carrier (LCC)'s. Figure 5 provides a generic simplified overview of the airline fleet planning process and the key decisions involved within the process. The decision that shall be used as an example to model is the 'Modify fleet?' question within the planning process.

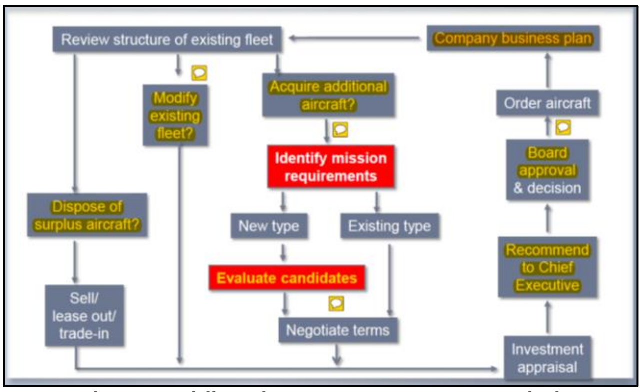

Figure 5: Airline Fleet Assessment Process (15)

Figure 6 illustrates the PPP from the OEM viewpoint, highlighting decision milestones; the PPP model has been developed within the research by the author as the framework for the decision modelling. The focus is on the first milestone – the Request for Proposal (RFP). This corresponds to the 'Modify Fleet?' and 'Acquire additional Aircraft?' decisions within the airlines decision process shown in Figure 5.

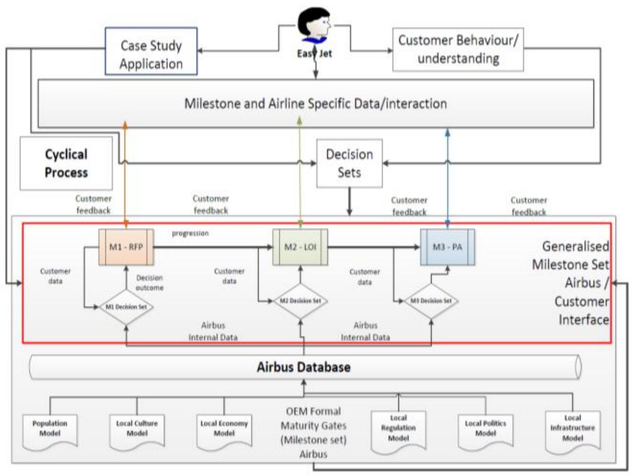

Figure 6: PPP developed together with Airbus

There are two output options for this decision, shown in Figure 7, and the model output is a utility v cost graph of the options which may inform the choices made by the DM. The output options were developed in the research via the understanding from

(15) such as Figure 5 and OEM understanding when generating the PPP.

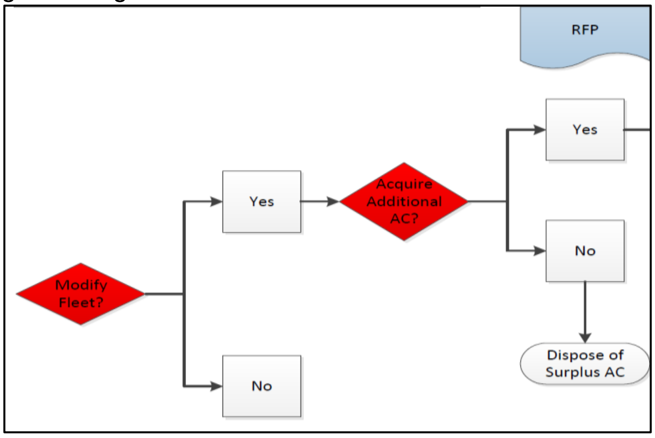

Figure 7: Decision Tree for the RFP milestone

B. Decision Outcome Attributes

The chosen LCC's from Europe and the US were used to develop the generalized attributes that were used to determine the utility function. An assessment of an example annual report from 2015 (6) was carried out. The document was assessed to derive key business drivers, performance indicators and key strategy objectives. From this work five attributes were selected which equated to the key strategic objectives the example airline has and subsequently to key performance indicators (KPI's).

These five attributes provide an initial 'generic' attribute set that shall be used for all airlines modelled. The reason for this is the focus of the AWI project research is the short to medium haul market and mainly LCC's and the chosen LCC's position within the airline industry as leading LCC's which operate short to medium hauls flights provides a foundation as to how most LCC's shall operate.

Further development of these attributes later in the research shall be to assess a select number of airlines and create a comprehensive attribute set across the airlines providing more validation for the attributes used to generate the utility functions.

Figure 8 gives an illustration of the five attributes and the interlinking aspect for all of safety; in such a safety critical industry this is a dictating factor in all decisions. The performance figures in (6) were used for each of the attributes to help establish a general preference profile for each attribute; based upon the figures in the report and assuming a linear trend for the intended growth of each of the KPI's.

A utility interview with this example DM was not possible and so the author acted as the DM using the annual report and working the example airlines objectives and using logical assumptions to produce the attribute preferences for this study.

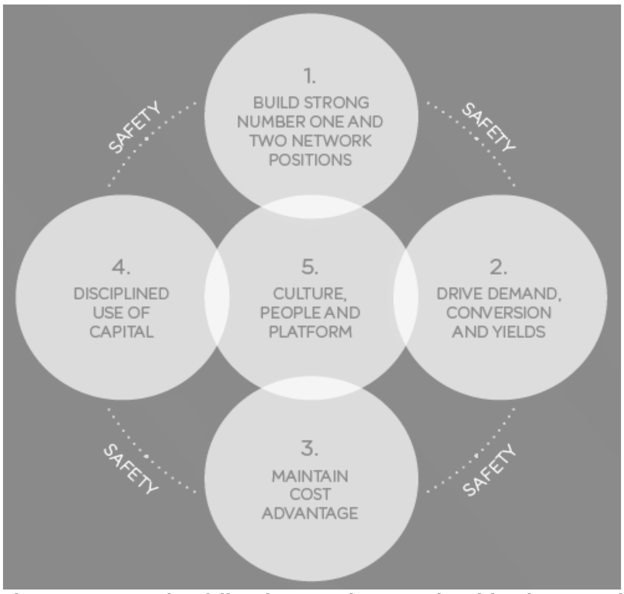

Figure 8: Example Airline (EasyJet) Strategic Objectives used as Attributes (6)

This is where the application of the cultural traits for the DM comes in. The cultural traits are inherent to the DM, unlike the five decision outcome attributes which relate to the decision outcome options available to the DM. By forming more generic preferences for the five decision outcome attributes based on industry typical behavior, one can assess how the differing airlines and their respective cultures alter and shape the eventual utility values that are produced.

C. Utility Function Generated

The simple additive utility function ((8), (7)) could be used to combine the attribute utility functions and generate the utility values and is calculated using the following (adapted from (11)):

$$U = W_B S_{BSNP} + W_D S_{DCY} + W_M S_{MCA} + W_{Du} S_{DUC} + W_C S_{CPP}$$

The following, outlines how the respective effectiveness rankings (SER's) are formed. Drawing from the theory outlined within section II, the approach of generating a SER for the five attributes set for the example DM and then applying weightings was carried out. Some assumptions that were made in order to generate the generic preferences are the following:

- The airlines (DM) want to keep improving on their KPI's compared to the previous year's performance.
- The five years of KPI (6) data for the attributes constitutes the current/present performance of the airline.
- The five attributes chosen are sufficient enough to effectively express an airlines utility function for the decision being modelled.

The following sub-sections provide a summarized overview of the details for each attribute.

1) Building Strong No. 1 & 2 Network Positions

The KPI measurement for this attribute is the number of airports at which the example airline holds number one or two positions (with regards to market share) in the top 100 airports out of which it operates, by catchment area and GDP. Values for this measurement have been obtained from data in (6).

$$S_{BSNP} = \begin{cases} 0; \text{ if NP} < \text{ mNP} \\ \dfrac{NP - mNP}{(K_{BSNP} * mNP)}; \text{ if mNP} \leq \text{NP and NP} < \text{NPb} \\ 1; \text{ if NP } \geq \text{ NPb} \end{cases}$$

S_{BSNP} can be interpreted as airlines effectiveness in maintaining/growing their network position depending on the outcomes that are possible. NP is the value for the network position i.e. the number of airports operated at where the airline is No. 1 or 2. The value mNP is the mean value of the five years and is derived from the KPI measured within (6).

The reason for using the average is to provide a more comprehensive figure for the current/present value as it gives a KPI value based on five years of data and thus the benchmark on how future performance for the attribute is evaluated.

NPb is derived from the mNP value and the addition of the standard deviation of the KPI figures in (6) as shown below.

$$NP_b = {}_mNP + {}_{sd}NP$$

2) Drive Demand, Conversion and Yield

The KPI for this attribute was taken as the revenue per seat performance of the airline.

$$S_{DCY} = \begin{cases} 0; \text{ if RS} < \text{ mRS} \\ \dfrac{RS - mRS}{(K_{DCY} * mRS)}; \text{ if mRS} \leq \text{RS and RS} < \text{RSb} \\ 1; \text{ if RS } \geq \text{ RSb} \end{cases}$$

S_{DCY} refers to the effectiveness ranking of the airlines revenue per seat annually. RS refers back to the revenue per seat form the KPI metric. Similarly to the other attributes the mRS value is calculated via the mean of the revenue figures over the past five years.

As with the previous attribute the value RSb is the mean plus the standard deviation of the KPI figures in (6), which is shown below.

$$RS_b = {}_mRS + {}_{sd}RS$$

3) Maintain Cost Advantage

The KPI for this attribute is derived from the cost per seat figures from the performance metric.

$$S_{MCA} = \begin{cases} 0; \text{ if CS} < \text{ mC} \\ \dfrac{mC - CS}{(K_{MCA} * mC)}; \text{ if mC} \leq \text{CS and CS} < \text{CSb} \\ 1: \text{ if CS } \geq \text{ CSb} \end{cases}$$

S_{MCA} refers to the effectiveness ranking for a cost factor. CS refers to the cost per seat value and again the mC is the mean of the figures for the past five years. CSb is calculated as shown below.

$$CS_b = {}_mC + {}_{sd}C$$

4) Disciplined use of Capital

The KPI for this attribute is derived from the ROCE (%) i.e. normalized operating profit after tax divided by average adjusted capital employed.

$$S_{DUC} = \begin{cases} 0; \text{ if DUC} < \text{ mDUC} \\ \dfrac{DUC - mDUC}{(K_{DUC} * mDUC)}; \text{ if mDUC} \leq \text{DUC and DUC} < \text{DUCb} \\ 1; \text{ if DUC } \geq \text{ DUCb} \end{cases}$$

This attribute has three metrics used to evaluate performance but the ROCE was chosen as it related to the other attributes on the theme of operating profit i.e. cost and revenue. The DUC refers to the ROCE % and mDUC and DUCb are calculated in the same manner as the other attributes. This is the one attribute where it may be possible in future development of this approach to review and potentially remove due to its complexity in calculation and variance with company changes.

5) Culture, People and Platform

The metric for this KPI from the annual report had only two years populated with figures and thus it was decided to use the overall customer satisfaction metric under the DCY KPI. The figures are from a customer service survey (6) and provide an evaluation of the airline by the customers and how the culture, staff and service has performed from a customer perspective.

$$S_{CPP} = \begin{cases} 0; \text{ if } CPP < \text{ m}CPP \\ \dfrac{CPP - mCPP}{(K_{CPP} * mCPP)}; \text{ if m}CPP \leq CPP \text{ and } CPP < CPP\text{b} \\ 1; \text{ if } CPP \geq \ CPP\text{b} \end{cases}$$

S_{CPP} refers to the effectiveness of the airline with regards to culture and people based on the KPI survey figures. The CPP represents the satisfaction rating and the mCPP is the mean; CPPb is calculated from the sum below.

$$CPP_b = {}_mCPP + {}_{sd}CPP$$

The weightings applied to the five attributes have been kept the same, all set to 1, for this initial proof of functionality; implying that each attribute carries the same influence on the final utility value for the DM. Further study shall refine these weightings aiming to reflect the DM as it is unlikely that the attributes shall have the same weightings.

D. Culture Trait Weighting

The cultural traits were applied through a product relationship with the scenario data and used as a weighting applied to the SERs. The scenario data was established through the AWI project to cover the key external environment aspects that impact the ATS. In brief these are economic, population growth (equates to projected demand), political and regulatory aspects.

Through the Global Market Forecast (16), data from the United Nations on world population projections

(17) and the IMF World Economic Outlook (18), the economic and demand data could easily be extracted. The political and regulatory data could not be easily established and for this paper within the model a normalised range was used for these aspects.

Using the population growth and economic data, three scenario types were derived based on rates of growth, these are high, medium and low rates. The number of scenarios currently used relate to the scenario types via the number of different scenarios that could be generated with two aspects with three variations each, thus nine scenarios were established.

Due to not currently having data sets for the political and regulatory aspects, these as stated above were defined on a normalised scale and generated via a random number generator within excel. These will be updated at a later stage in the research with defined data sets, but for this paper are sufficient as the focus is how cultural traits may be applied and thus the generated data set allows for this.

The following equation shows the cultural trait applied to the scenario data to produce the scenario 'perception' weighting.

$$Sc_{cw} = \frac{\sum((Ei, PGi, Pi, Ri) * (1 - Ct))}{4}$$

$SDi_{cw} = Culturally\ Weighted\ Scenario\ Data$
$E_i = Economic\ data\ fro\ scenario\ i$
$PG_i = Population\ Growth\ data\ for\ scenario\ i$
$P_i = Political\ data\ for\ scenario\ i$
$R_i = Regulatory\ data\ for\ scenario\ i$
$Ct \ \ = Cultural\ Trait$

The four in the denominator relates to the number of scenario aspects used in each scenario. The reason for this was to produce a singular averaged weighting for simplicity. In future this relationship shall be investigated further as the cultural trait shall most likely have a different weighting to each scenario aspect for the example DM and not a blanket weighting across them all.

E. Cost

The evaluation of cost against utility for this initial research has been calculated from the overall cost figures from the example airline (6) and projected for five years to match the scenario data years forecast, as a linear increase in costs based on the percentage increase of the highlighted 2014/2015 values shown in Figure 9 below.

	2015			
	£ million	£ per seat	pence per ASK	£ million
Total revenue	4,686	62.48	5.59	4,527
Costs excluding fuel	(2,801)	(37.35)	(3.34)	(2,695)
Fuel	(1,199)	(15.98)	(1.43)	(1,251)

Figure 9: Example Airline Financial Overview

Cost values for the 'No' option was just the linear increase in costs generated from the financial overview; based on the percentage increase established via the values in Figure 9. The 'Yes' option cost values added in the cost of future ordered aircraft , 36 aircraft by 2021 (30 A320neo's and 6 current generation A320's) stated in (6) to the values for projected 'As Is' growth i.e. the No cost values.

F. DIM Output

To demonstrate the DIM output and show the functionality of the model there are two outputs that shall be discussed. Firstly, Figure 10, which is the model output illustrating the generic utility values with no DM culture applied in comparison to applying Airline A's UAI cultural trait. As shown in Figure 10 both sets of values show a similar trend as expected but the generic utility output has exceeded the normalised maximum range of 1; this is due to the weighting values being set to 1 and thus the resulting addition of all the SER's within the utility function exceeding the expected normalised range. A second level of normalisation would address this.

The output demonstrates the logical implications of a DM with a level of UAI and its impact i.e. the utility is reduced due to the uncertainty that is inherent in the decision output options for a DM, in this case Airline A. As stated previously in the paper there is a relationship between uncertainty and risk and there is risk in either decision option available to the DM; thus the UAI has an effect upon the resulting utility value for each decision option when applied. Figure 10 illustrates the DIM's ability to apply cultural traits within the utility function generated and shows the implications of the application which is a key function required.

The work is a simplified illustration of this relationship and there are a number of key factors that will influence the associated risk for the decision options such as degree of accuracy of the data used, functions implemented and weightings of the attributes within the utility function. These are factors that shall be investigated in the continued research but for this paper the functionality of the DIM is the focus, which has been shown via the outputs and previous sections of the paper.

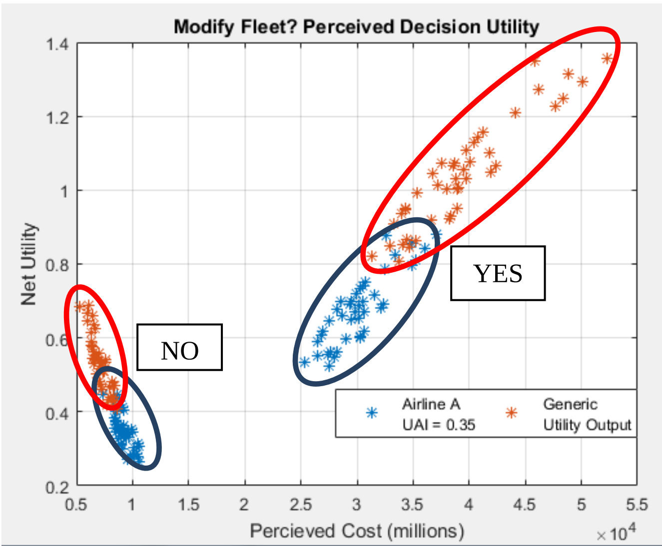

Figure 10: Utility model output: No Culture applied v UAI for Airline A Applied.

Shown in Figure 11, is the model output illustrating for DM's Airline A and Airline B. The values for each Airline are similar hence the utility function output for the two DM's are similar in trend and overlapping utility. Figure 11 demonstrates that the model can implement the application of UAI for different DM's which is a key function required. The user of the DIM can input the DM of their choice and assess the perceived decision utility for them.

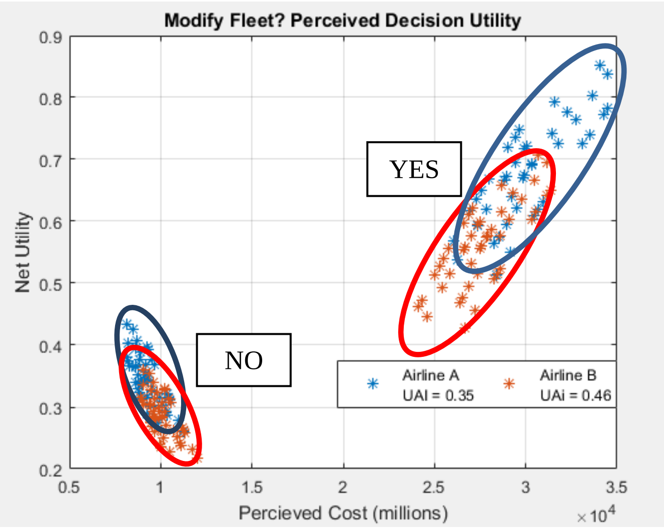

Figure 11: DIM Output Using Example Airlines A and B

VII. Conclusion

Factoring wider influences into decision modelling has a significant effect on the information and understanding that can be gathered about the DM and their likely behavior. This paper has demonstrated the functions of the DIM and how these may relate to aiding decision making within the context of the PPP. The application of a DM's cultural traits has been shown to be possible within a utility function with a logical relationship between the applied cultural trait and the utility output shown.

Cultural traits of the DM have an effect on the potential decision outcomes that a decision model can generate when applied. Although the model produced requires further work and some key validation stages, the key functions of the DIM have been demonstrated and some broad relationships can be seen. The main relationship being the effect of the cultural trait, uncertainty avoidance, within a DM has been shown to affect the output of the utility function developed.

The relationship provides incentive for further research into the application of the cultural traits, with a focus on verifying key functions within the DIM and assessment on the limitations of the relationship between the culture of the DM and tailoring of the generic attribute preferences. This paper has described a conceptual method where cultural traits can be applied within utility functions to support a DIM.

VIII. Future Work

Future work shall be the application of this method to the full sequence of decision phases within the aircraft procurement cycle (PPP); also refinements and improvements to the data used instead of using place holder data. The utility function U shall be amended to account for cross-term benefits for the attributes i.e. the weightings for each attribute shall be analyzed via further literature study as well as expert elicitation and evaluation and amended to more accurately relate to the DM's priorities. The use of fuzzy logic could be implemented to generate a cost parameter that relates to the DM's view of inter-attribute cost due to the variance and soft nature of the attributes currently being used.

Within the DIM functions specifically, further work will relate to allowing the user of the model to be able to set a number of key variables to enable the user to tailor the model to a required decision and context. Exemplar function variables include input data tolerances, UAI and PDI relationship ranges with the scenario data and preference ranges for the attributes.

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