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Topic

Contract Negotiation in a Multi-objective Scenario using the Concept of Dynamic Shared Negotiation-Spaces and Soft vs. Hard Affordability Limits

Abstract

In today's business environment, a shift in the competitiveness paradigm "Business that Manufacture" is becoming essential. It covers the whole bandwidth from designing for performance to designing for affordability and finally delivering a cost effective product with added value that the Buyer is willing to pay for. Making the decision as to whether it is most cost effective to procure or to manufacture for reasons of affordability requires analysis of alternatives to achieve a convincing compromised solution that satisfies Seller and Buyer. Historical data verification or tacit experiences of Seller and Buyer tend to be the norm but often decision makers miss the choice of the best possible solution. Decision making for affordability is a critical and a difficult process due to the many known and unknown factors and anticipated associated risks. The wrong choices between alternatives can lead to an unprecedented over run to budgeted costs and therefore a reduced profit to the business.

Given the complexity of the problem that is recognised at the acquisition stage there is a definite appeal for "getting your money's worth". In this scenario, the "Satisfycing" concept of Compromise Theory is a useful approach to achieve satisfied value for money for the product that would be capable of the required functionality requested by the Buyer.

Negotiating in the region of the Pareto Front is the anticipated goal of any optimal and objective negotiation. The following paper focuses on optimal objective negotiations for affordability in the region of Pareto Front where the anticipated real affordability limits of the Seller and Buyer can be decisive, taking subjective "soft" real-world aspirations into account. "Soft" affordability limits depend on personal aspiration of the benefit of a negotiated deal thus influencing the outcome of a negotiation significantly. Affordability imposes "hard" objective limits, restricting the range of the negotiation space. However, in reality, in negotiations these hard limits may not be perfectly known. Soft, i.e. subjective limits are used instead. Negotiations test, challenge and influence these soft limits. Negotiations also take place because certain solutions more desirable than others. Changing and reducing the objectives to those relevant to both partners is a natural behaviour during negotiations. The use of a "dynamic shared negotiation space" with shared objectives makes negotiations a lot more effective. Effective negotiations try to find this shared negotiation space and the best compromise solutions within this space while compromising on the contradicting soft limits of each partner.
An easy-to-use technique to find value oriented non-dominated compromise solutions for affordability in a shared negotiation space will be demonstrated by using a scalarisation method based on the TOPSIS technique (Technique for Order Preference by Similarity). The efficiency of this technique will be demonstrated via a real world negotiation case study from the aerospace industry.

Contract Negotiation in a Multi-objective Scenario using the Concept of Dynamic Shared Negotiation-Spaces and Soft vs Hard Affordability Limits

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Decision to acquire a programme for an organisation largely depends on exploring related multiple objectives and assessing the business through a framework that affects the objectives. Primarily the objectives are considered through the framework of technology, competence, capability and complexity of the programme. A range of objectives from designing for performance to designing for affordability, producibility, quality and finally delivering a cost effective product with added value that a Buyer is willing to pay for could be Criteria of that framework (Kirby and Marvis 2000).

In the transaction between buyer and seller, it is the programme's value that the Buyer pays for. Affordability lies in the definition that it has programme price Criterion that is proportional to Buyer's willingness to pay. Providing superior value on affordability becomes an inherent component of the competitive business and this could be defined as the satisfied desire of the Buyer and Seller (manufacturer). In multiple-objectives scenario the concept of "optimality" is gradually being replaced by the fuzzy concept of compromise, satisficing and negotiation for the programme acquisition so to widen the issues of value and affordability.

The value of a programme is often referred with the utility value of attributes that would relate to the functionality and usefulness of the Criteria associated with the programme. Use of price and profit as a measure of desirability is often considered a goal. In a multiple objective scenario multi-attribute, multi-Criteria or multiple dimension objectives are used to describe the decision situation. In Multi Criteria Decision (MCD) each decision is represented by a real vector with a number of components called Criteria and an ordered set of numbers of Criteria or attributes those would correspond to relevant characteristics of each consequence of a decision.

Profit and Price Criteria, for example are surrogate for a number of complex attributes. Attributes of profit such as earning per share, stock price, market share etc., whereas price will be influenced by a number of different value judgements in terms of "goal" or "aspiration levels" for each Criterion affecting the outcomes of design to fulfil a number of objectives, such as cost of technology, volume produced, performance, finance, marketing and functionality of the product etc. The Decision Maker (DM) sets up Criteria directly on attainment of objectives and then Multi Dimension Analysis (MDA) is invoked with the aspired Criteria to describe the trade space in which the decision maker's information is appropriately captured. The outcome of the final phase in a trade space would be the consistent negotiated requirements that would lie within a compromised zone showing the difference between aspired affordable price and initial offer. By means of aspiration Criterion vectors the DM steers the solution procedure that enables him/her to experiment with new ideas to probe and pin-point the final compromised solution. This solution forms a greatly reduced non-dominated compromised set that would contain alternatives which are close to ideal,[1] .The Ideal Component is based on the axiom of choice that are determined by means of distance. These are useful process in multi-objective decision. However the outcome is not

[1] (In a given family of products the most cost effective configuration is termed as the Ideal Component configured to suit the application of the most cost effective production process and use the most cost effective material types and forms because it has Ideal properties. The configuration of the Ideal Component is dynamic in terms of time and economics, change of technology, improved materials, equipments available and so on)

always apparent (Xiaochuan (2004) but possibility to solve the problem of Seller and Buyer negotiated compromised solution would be to achieve "soft affordable limit" on a range of early target price based on high level of work break down structure and price with adequate risk averse targets, and experiment with new ideas then allow adjustments later to "real affordability limit" (Apgar 2008).

In the early stages of a product acquisition solutions are achieved by iterative approximation and they may not always be optimal in a strict mathematical sense but "good enough" in the context of satisfied negotiated acquisition. In this context the 'Satisfycing model' proposed by (Simon 1976,1996), (Wang and Zionts 2005,2006). is less of a decision rule than a search rule and it is appropriate for Multi Objective (MO) scenario.. The model is an interactive aspiration level model, where stakeholders' notional aspiration levels are set to be relaxed or tightened. Aspirations of the Seller and Buyer are instrumental, such that it requires a comparison of positive and negative attributes of each alternate design individually and obtain feed back as to their reasonableness and ultimately ranking will result to a compromise. Compromised decision in a negotiation process thus, when applied with MO framework for early target price it has definite appeal namely "getting your money's worth". Compromising the aspirations of Seller and Buyer through the interactive information is achievable for "soft affordability" rather than optimisation concept.

2. Interactive Decision Making for Affordability through Multiple-Criteria

2.1 Negotiation and compromise in multi-Criterion scenarios

In MO decision Seller and Buyer look for rational of understanding of the programme and compromise (Zeleney 1982) amongst all desired aspirations and objectives to achieve an affordable life cycle cost and attempt to seek improved performance, effectiveness, reducing risk in a "Trade space". Affordability of the programme is then negotiating, compromising and determining what the programme content and scheduling will fit in within the available cost constraint that is desirable for both the Seller and Buyer.

The process of negotiation is the natural discourse of give and take between Seller and Buyer. It provides interaction between Seller and Buyer whilst acquiring information to deal with conflicts or tensions and seek decisions of mutual benefits and eventually leads to a compromise which is close to an ideal (i.e. basic configuration) for the Seller and Buyer (Opricovic and Tzeng 2004).

The Win, Win model in a negotiation provides a general framework for identifying and resolving requirements conflicts and often there are trade-offs among the win condition that need to be balanced. Multiple Criteria preference analysis provides a means to balance these trade-offs and the framework for discussion lead to resolution. Resolution is not necessarily a conflict situation but compromise is evident. In a conflict a compromise is made within the framework of relaxing or keeping one constraint tight and giving in to another and slacking while picking compromise solutions that come from the corresponding Pareto optimal set.

The approach to evaluate the negotiation lies in a process of mapping multiple Criteria on to a constructed scale by applying multi-attribute utility theory framework (Seppala and Hamalamen 2001). During negotiations affordability imposes discrete limits to both Seller and Buyer. It imposes hard limits, restricts the range of negotiated aspiration overlying the objectives and makes certain solutions more desirable. While they might be perfectly valid best compromise solutions, in this process when aspirations of the negotiating Seller and Buyer meet, the solutions become feasible, i.e. they are affordable and satisfy all other possible restrictions. The solutions are then close to optimal with respect to the objectives of each party and a compromise solution thus can be found.

2.2 Process of sharing non-dominated solutions on the Pareto front during negotiations

Two conflicting objectives functions (e.g. Price and Performance) are the least shared requirement in the negotiation. Further objectives might not be shared with respect to the individual, e.g. Cost, schedule and external objectives namely market conditions, legislative issues etc. An optimal solution has to be a compromise of all objectives including the individual objectives which other negotiation partner cannot see. This, therefore, makes negotiation complex and dynamic.

In a multi-objective negotiation, scalarisation (Ehrgott 2000) or dominance techniques are commonly applied. The latter are more advanced than the first because they do not need any a priori knowledge of the preferences of each partner such as e.g. availability of resources or aspirations change. Using the dominance principle a set of non-dominated solutions can be identified from a set of solutions. Non-dominated solutions are not dominated by any other solutions from a given set. Considering the set of all possible solutions, the set of non-dominated solutions form the so called pareto set (Miettinen 2002) or bargaining solutions, Zeleny (1982). The points from the Pareto set are called Pareto optimal. The corresponding set to the Pareto set is called the Pareto Front. The Pareto Front lies in the objective space. Points in the Pareto set represent the parameters of an optimal solution while points in the Pareto Front give the corresponding objective values. They represent the set of compromise solutions which cannot be further improved with respect to the dominance principle. Each Pareto optimal solution corresponds to a point in the objective space defined by the values of the objective functions. Assigning a value greater than budgeted margin forfeits the sprit of aspiration and soft negotiation pursues which often results in high price and cost.

Figure 1 illustrates the idea of shared objective spaces. A possible setting of features of an object will be called a solution. The quality measure of a solution will be called objective function. Each negotiating partner has his/her individual Pareto Front and objective space. Generally only one decision space and only one decision maker is considered but for modelling competing decision maker scenario it is necessary to introduce the new concept of “shared objective spaces and shared Pareto fronts”.

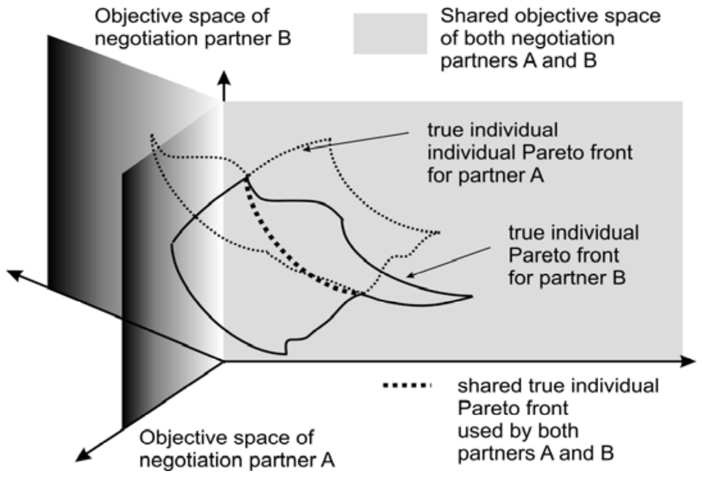

Figure 1: Concept of shared objective spaces for optimal decision making for negotiations

The concept of sharing parts of the objective space between two Seller and Buyer is a novel approach. Here, the shared subspace in the objective space is used between the negotiating Seller and Buyer and it will be called negotiation space. If the quality functions of both negotiating partners are the same – e.g. because they have decided on sharing full information about the evaluation of solutions – the Pareto fronts of each partner will match and they can negotiate a solution along the shared Pareto front. This way it can be guaranteed that each partner picks a solution that is an optimal compromise concerning all of his/her own objectives. Aspiration, affordability and current circumstances and the likelihood to have to repeat other negotiations with the same party again at a later time will certainly affect the final decision on a single shared solution

2.3 Affordability negotiation in the region of Pareto front

Anticipation of real affordability limits (i.e. hard limits) in negotiations between Seller and Buyer can be decisive on the other hand underestimating the affordability limit may lead to inefficient deals. Nevertheless affordability may change over time and may also not necessarily be completely objective. Soft affordability limits depend on personal aspiration of the benefit of a deal and thus influence the outcome of a negotiation significantly. In the following, the term 'real affordability limit' is used for objectives with strictly nonnegotiable hard limit while 'soft affordability limits' solutions within these limits are called satisficing solutions (Pongpeng and Liston 2003) and those limits are overestimating the real affordability limits. The mathematical counterpart of hard affordability limits are called constraints while soft affordability limits can be modelled using e.g. desirability functions or penalty functions (Harrington1965; Menzura E and Coello Coello,2006).

3 Compromise approach to Affordability

3.1 Technique to find value oriented non-dominated compromise solutions

One classical technique of finding best compromises is to seek improvements focussing on Criteria which are perceived to be the most important since they subsequently focus on alternatives. This process is also known as lexicographic multi-objective optimisation (Ehrgott 2000), and it is an iterative procedure which finds trade-off solutions quickly using extraction of short listed Criteria (Belton and Stewart 2002, Simon 1976) described this process a descriptive model of heuristic, a result of bounded rationality. The main feature of these methods is that each Criterion need to be associated with an attribute defined on a measurable scale and the decision maker is required to express value judgement in terms of "goals" or "aspiration levels" to each Criterion defined in terms of "desirable levels" of performance for the corresponding attribute values. In this process the decision makers have to have very good idea of their goals, a priori; therefore the above mentioned methods are called a priori techniques. Other techniques such as population based technique a set of solutions are used to find a set of best compromise solutions in one single run rather than finding a single point on the Pareto front like with the classical methods. Other methods suggested (Cvetkovic and Parmee 1999, Branke and Deb 2004) focus on specific areas on Pareto front given a priori expert knowledge.

3.2 Identifying compromise solutions in a shared negotiation space

All the above mentioned methods are generally not used for negotiation. They do not incorporate the concept of a negotiation space. Generally a negotiation process starts with an initial "basic design configuration". This is typically an existing solution or a variant of a solution one partner is offering to another. The "ideal" solutions are generally configurations which are considered to be set optimality with regard to the application under consideration. Of course the perception of an ideal configuration strongly depends on individual preference and views.

In order to identify best compromise solutions in the shared negotiation space, the individual solutions found in the individual objective spaces have to be mapped into the shared objective space. Due to the fact that the shared objective space is an intersection of the individual objective spaces, the mapping is an identification of the components in the objective space that are shared by the negotiating partners.

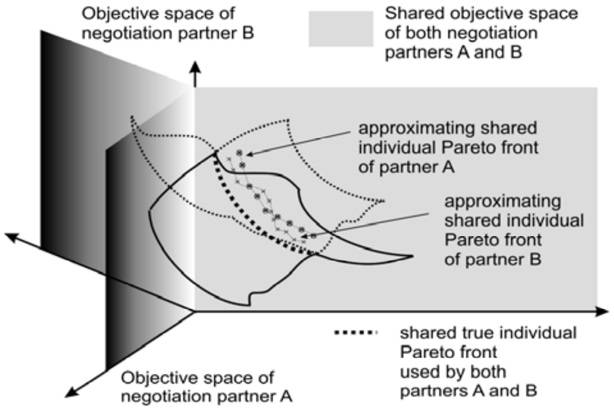

Figure 2: Sharing individual Pareto Fronts in the negotiation space (for a posteriori methods). Intersections of individual Pareto fronts with the shared negotiation space are used.

In the case of the application of a posteriori method only the components of the shared approximating individual Pareto Fronts have to be considers (see Figure 2).
An example of the intersection of two approximating Pareto fronts for partner A and B with a resulting plane being the shared objective space can be seen in Figure 3. The connecting lines between the points are formed using e.g. an attainment surface technique. Individual solutions are projected into the shared negotiation space.

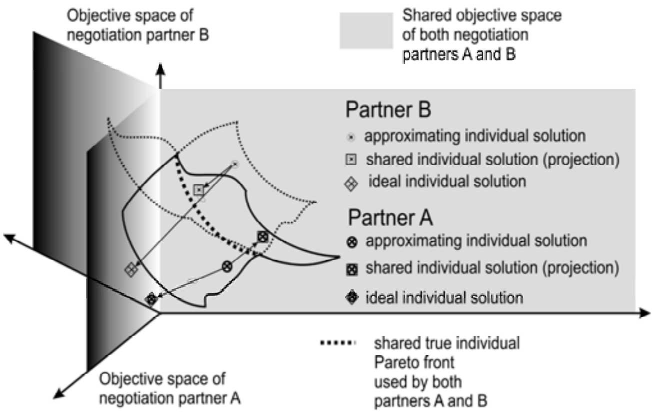

Figure 3: TOPSIS using the shared negotiation space.

A priori methods such as TOPSIS generate single points near the true individual Pareto Fronts. However, only the projections of the currents solutions into the shared negotiation space will be available to both Seller and Buyer during the negotiations. After several negotiation and optimisation steps the solutions in the shared negotiation space will eventually become Pareto optimal. However, they may deviate significantly from solutions that were generated by individual TOPSIS applications because the ideals of the negotiation partners generally do not align (see Figure 4) independently. In the following, for both the a posterior approach (such as MOEA) and the scalarisation approach (such as TOPSIS), the goal of an optimal negotiation is to find optimal compromise solutions that maximise the individual multiple aspirations and are not too far apart from each other. If the points found by each partner match satisfactorily the aspirations of the other negotiating partner, a win-win solution has been found. This can be the case e.g. at intersections of individual Pareto Fronts or if two projections of single point solutions are satisfactory near to one another. In the case where the solutions do not satisfy one or both partner, or if one can expect that the current solutions have not converged near the shared Pareto Front the individual configurations of the solutions of each partner have to be modified and re-evaluated. The process of changing configurations, re-evaluation and perhaps changing preferences continues until the Seller and Buyer are satisfied, a time limit is reached for the Seller and Buyer part without finding a satisfactory solution because certain individual limits have been reached. Typical constraints that cannot be crossed are hard affordability limits. The hitting of hard affordability limits may be the most typical cause where negotiations will stop or even fail.

3.3 The TOPSIS approach for a single decision maker

To find optimal compromise solutions one can follow the idea of approximating an aspired ideal solution as close as possible and to maximise the distance to a potential worst case scenario. The worst solution is often called “nadir solution” or “nadir point”. The ideal point on aspiration level is the Cartesian product of the best levels of all objectives and the nadir point, (Miettinen2002) is the Cartesian product of the worst level of all objectives (see Figure 4).

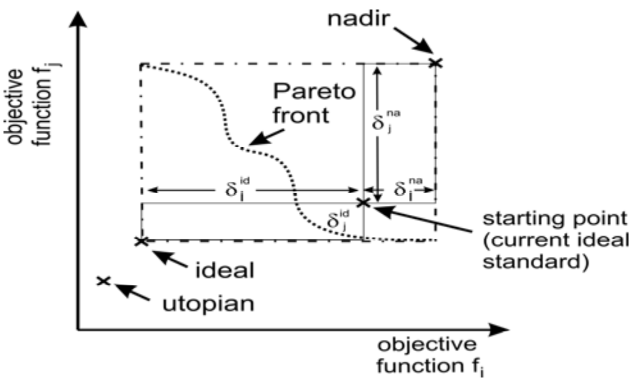

Figure 4. Nadir, ideal and utopian points and distances δ_j

One approach in finding an optimum compromise solution is to minimise the distance from a given ideal and to maximize the distance from the nadir. The distances between a solution $\vec{y}$ mapped to the objective space and a point f* in the objective space can be calculated using Minkowski's p-norms $L_p = (\sum_{i=1}^{m} w_i^p \left| f_i(\vec{x}) - f_i^* \right|^p)^{1/p}$, ..(1), with 1≤p≤∞ and w_i^p weights scaling the Criteria f_i. i=1,..,m. The dimension of the objective space is m having a m-Criteria, multi-objective problem. The distances $\delta^{id} := \left\| f(\vec{x}) - f^{ideal} \right\|^p$ …(2) and $\delta^{na} := \left\| f(\vec{x}) - f^{nadir} \right\|^p$ …(3) are the non-negative weighted p-norms determining the degree to which a solution $f(\vec{x})$ falls short from the goal and deviates from the nadir, respectively. The Tschebycheff norm (or L_∞-norm) is used to minimise the maximum weighted deviation in a given goal and in many ways this is closer to the spirit to the “Satisficing” concept. Use of the Tschebycheff norm has the further advantage that one avoids the disadvantages of e.g. the weighted sum approach which can only be applied to problems with convex Pareto fronts. The Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), first developed by Hwang and Yoon (1981) makes use of the L_∞-norm (Deng and Yeh2000). TOPSIS makes use of relative distances $D^{id} = \delta^{na} / (\delta^{id} + \delta^{na})$ …(4).The relative distances D^{id} are evaluated for each available solution $\vec{y}$ and sorted in increasing order. The solution with the smallest D^{id} is considered to be closest to the ideal and will be used in the following negotiation.

3.4 Implementation of the negotiation space concept in TOPSIS

A solution $\vec{y}_a$' of partner A, which is used for negotiation in the shared objective space Figure 3, i.e. the negotiation space, can be calculated as a projection of the solution $\vec{y}$ from the individual objective space f_1 x f_2 x ..x f_{m_a} into the negotiation space $\vec{y}_a$' ∈ f_{a1} x f_{a2} x ..x $f_{m_{ak}}$, with $\{a_1,..,m_{ak}\} \subseteq \{1,..,m_a\}$. In case of a two dimensional negotiation sub-space the vectors f_j, f_k span the two-objective function space f_j x f_k.. The same operations are applied to the solution $\vec{y}_b$' ∈ f_1 x f_2 x ..x f_{m_b} of partner B and the other partners $\vec{y}_b' = (\vec{f}_j, \vec{f}_k)^T$. Notice that the same negotiation space is shared by partner A and B.

4 A case study from an Aerospace organisation; Acquisition of programme; Aero-structure component engine Inlet Cowl

A scenario is set for the acquisition of product–programme of an engine Inlet Cowl. An Inlet Cowl (see Figure 5) is one of the major parts of an aircraft engine nacelle. Buyer Requirement (BR) for the Inlet Cowl is to maintain the right amount of upstream volume of air through the Inlet Cowl relative to the required thrust, provide acoustic treatment for noise reduction within cost and weight constraints imposed by the installed engines specification. The Seller/manufacturer has to maintain specified BR in terms of weight and size of the inlet Cowl at the point of delivery.

In this study we have identified six evaluation Criteria those are to be considered with in a negotiation space and they would affect contract price. Same Criteria for six programmes in an aerospace industry are examined to validate the aspiration based model applying TOPSIS approach in a shared decision space. Evaluation Criteria of a programme are Functional (F), Technological (T), Business (B), Environmental (E), Marketing (M) and Safety (S). These Criteria are benefit criteria to negotiate contract price objective. Although six Criteria are interdependent but four Criteria F, T, B, M are considered more important for the Seller Objective (SO) to negotiate on contract price and other two Criteria E and S are considered more important to the Buyer Objective (BO) to negotiate on the contract Price. For ease of calculation and to show SO, CO and Price to cost ratio as an objective in a negotiation space following assumption is made.

Since programme is a firmed fixed price contract and Price is a function of Cost therefore estimated life cycle cost of the programme is of most importance to the Seller rather than to the Buyer. Seller would cost the programme, based on how successfully the organisation would be profitable over a period of time and for how many sets of engine nacelles are sold. In negotiation responsibility for good assessment of cost is on to the Seller and this is often an iterative process until negotiation to contract price is complete. Contracted fixed price to cost ratio therefore is considered as an objective to reflect the programme success ratio.
The need of BR is translated from Inlet Cowl specifications and they are translated to major attributes those affect the evaluation Criteria. Attributes are grouped to reflect the Criteria. Assigned available parametric value to each attribute are according to the DM opinion for each programme. Values to attributes are assigned with respect to each Criteria and an ideal programme that has similar Criteria. Criteria F, T, B, M are added to SO and E and S are added to BO.
Primarily the Criteria should also conform to technical and functional requirements such as geometry, weight and design of the Inlet Cowl air-wash area in order to maintain intake volume of incoming air to the fan face at high pressure so to support desired engine thrust; (Andrew 1991).

Figure 5 Inlet Cowl of an engine nacelle

By using the available attribute data for each programme and converting them into utility values the Price/Cost ratio termed as success performance ratio of each programme with respect to each Criterion was calculated.

4.1 Proposed method applied to demonstrate TOPSIS for Affordable design

Seven Inlet cowls of the presently manufacturing program are considered for which design configurations are different but each has similar producibility. Some are produced with a combination of composite and metal and some are produced completely from metal
In the following analysis Pareto front points for SO, BO partial utility values and resulting Price/Cost ratio as an objective are plotted with in a shared objective space to identify which programmes can be compromised for affordability and then individual solution are applied to TOPSIS to show which programme has been more satisfactorily negotiated for best affordable value that has been generating demonstrable profit margin.

4.2 Multi-attribute partial utility cost value function

In order to compute affordability, a success matrix containing value for each attribute with regard to each evaluation Criterion for each programme was developed by Seller, Decision Maker (DM). Table 1 shows an example of a matrix for a programme with estimated attribute values against each Criterion. Success matrix for each programme is denoted by; $a_i, i=1,..,n$, where n=6 for each Criterion. Criteria C_j $j=1,2..,m$, where $m = 6$, are shown vertically and attribute values are shown horizontally. Criteria are; F, B, E, M S. For the analysis proportion of generated affordable unit cost C £/lb values are allocated by the DM to each Criterion to sum up to affordable unit cost.

Success ratio derived from the matrix for each programme is linked to each Criterion and it is affected by Seller and Buyers negotiated Price. Utility values derived for each Criterion reflect the nature of conflicting Criteria and enables to incorporate the inter-dependence of Criteria. Success of the reliable generated cost would reflect the fixed price. Note: In Table 1, attribute values allocated reflect the characteristics of the criterion eg; If fan blade of the engine does not come off then its attribute value is 1 and similarly attribute value for widen Buyer base and product base for business Criteria is 1.
The value of attribute within each success matrix are normalised so that they have similar dimensions. The normalised success ratio matrix shows relative success of each programme In the proposed case study partial values of the Criterion are evaluated from each Criterion allocated cost values and utility values. The simplest and most widely used form of value function is the additive form $V(a)=\sum_{j=1}^{m} w_j v_j(a)$. It is applied to obtain Criterion utility values in the assumption that the relevant preferential independence axioms hold. The additive

form $V(a)$ is the overall value of alternative a, and $v_j(a)$ is the value score reflecting alternative a's success on Criterion j and w_j is the weight assigned to reflect the importance of Criterion j. The above function can be reformulated in the form $U(a)=\sum_{j=1}^{m} u_j(a)$, where the partial value functions are scaled in proportion to their importance weights (Belton and Stewart (2002).

	Att	Att	Att	Att	Att	Att	Att	C
F	Low weight	Aerodynamic considerations	Thermal considerations	Durability	Low maintena requirem	High quality	Fan blade containmen	14
	0.82	0.88	0.92	0.73	0.68	0.74	0.98	
T	Reduction in cabin noise	Reduction in specific fuel consumption (SFC)	Advanced materials selection	Greater instrumentation potential	More use of electronics	Better than "Brand X"		13
	0.55	0.44	0.62	0.77	0.63	0.82		
B	Defined risk	High margin	Use of intellectual property	Follow-on business	Widened Buyer base	Widened product base	Favourable terms of business	3
	0.9	0.95	0.41	0.99	1	1	0.65	
E	Reduction in community noise	Reduction in SFC	Reduction in CO2 emissions	Recycle compatibility	Low maintena requirem			26
	0.55	0.44	0.44	0.75	0.68			
M	Low cost	Reduction in SFC	Reduction in CO2 emissions	Durability	Low maintena requirem	High quality	Aesthetics	6
	0.70	0.44	0.44	0.73	0.68	0.74	0.95	
S	Passenger safety	Structural integrity	Ease of evacuation	Fire resistance	Fire detection	Fire extinguishing	Fan blade containmen	103
	0.98		N/A	0.92	0.92	0.92	0.98	

Table 1 Criteria, Attributes (Att) and allocated Cost values (C)

The rationale of importance of the partial values is noted by the Criterion/Objective weightings generated for each Criterion and they lie between the lower and upper bounds applying monotonic interval assessment of magnitude. Objective weights of Criteria is measured by the average intrinsic information generated by a given set of alternatives through each Criterion reflecting the nature of conflicting Criteria and enable the incorporation of inter dependent Criteria (Diakoulaki D et al 1995). Mean weight method is applied to get objective weighting on the assumption that all Criteria are of equal importance. The model thus constructed ensures the construction of the partial utility value function, and the assessment of weights when applied, it ensures alternate trade-offs. It is algebraically convenient to index utility (performances) and cost values applying utility theory and set the "least" desired with utility "0" and the "most" desired with utility "1" of say value v_j. We then define all programme Criterion utility values to a total Partial Utility Value (PUV) pu_{ij} as the value of $pu_i(a)$ for $a_i, i=1,..,n$ whose performance in terms of Criterion $j=1,2,..m$ is associated with the utility values of the categories p. For all the programmes, for measurable Criteria value function is then defined by u_{ij} for $j=1,2,..,m$ and for p=0,1,2,.. v_j. The scaled partial value $pu_j(a)$ can be represented in terms of a linear function of differences or weighted Euclidian distances $\delta^{id} := \left\| f(\vec{x}) - f^{ideal} \right\|^p$ and $\delta^{na} := \left\| f(\vec{x}) - f^{nadir} \right\|^p$ to the categories of Criteria for the selection of the "best" family of alternatives, here p is 1/2. Here we applied TOPSIS concept to calculate D^{id} .The process is subjective but negotiating to aspirations levels of best value is achieved iteratively to a compromise negotiated solution. Upon completion of each iterative stage as suggested, value of information is important and the scores would reflect the Criteria of an investment in the programme this would maximise the Buyer satisfaction with respect to more than one alternative.

4.3 TOPSIS applied to calculate relative distance for a single decision maker

The value judgements of DM are incorporated into the model in the form of "goals" or "aspiration levels". Prior to the application of TOPSIS where formulation of a decision matrix is a must, aspiration levels must be defined for the negotiation scenario so that by tightening and loosening of the aspiration levels feasible solutions can be identified. Interval aspiration level, (Wang and Ziontis 2006) is applied uniformly over the range of total pu_{ij} of each Criterion whilst considering best and worst for all objectives. The aspiration levels to each Criterion are defined in terms of "desirable levels" of performance for the corresponding criterion values. In this process the decision makers have to have very good ideas of their goals, a priori; therefore the above mentioned methods are called a priori techniques.

5 Data dissemination

Stages to Compute Partial utility value from success matrix utility cost value

1 Pre-process

1.1 Construct a performance matrix say $X = N \times m$ for each programme a and $A=(a_i, i=1,..,n)$ where n=6, and a_i are considered alternative. Here N are the attribute values for and $C= (Cj ,j=1,2,..m)$ m Criteria. Example is shown in Table 1 for a programme. Last column is estimated allocated cost /lb for each Criterion.

1.2 After normalisation and allocating portioned estimated cost values to attributes, decision matrix total utility $\sum U_{ij}$ representing performance of alternative is obtained. The information contained in the decision matrix is utility value for each Criterion Cj $(j=1,..m)$. Normalised decision matrix is the consequence of performance matrix where U_{ij} utility values of each Criteria for an alternative and where j=1,..,m and m=6

2 For ease of calculation and to show SO and CO and Price to cost ratio as an objective in a negotiation space as per assumption made from utility value of each Criterion and associated estimated cost values partial utility values pu_{ij} are calculated for each objective as shown in the Table2 and 3.

2.1 pu_{ij} are computed values for an alternative programme applying estimated allocated cost values allocating [1,0] highest and the lowest utility cost-values to the corresponding Criterion for each programme (1-6), Ordered set for objectives are $u_j(a)$, and one programme has the ideal values.

3 Plotting Pareto front diagram indicates which programmes are more affordable.

4 Identify f^{ideal} and f^{nadir} each Criterion j (Wang and Zionts 2006 appendix A).

4.1 Let $pu'_j(a)$ be an ordered set of $pu_j(a)$ such that it is descending if j is maximising and ascending if j is minimising, giving increasing best value to CO and SO.

4.2 Choose interval aspiration level A or uniformly interval level to consider the worst to best and best achievable levels for each Criterion. A is possible combinations of intermediate levels of all Criteria.

5 Formulate weights to reflect the importance attached to objectives as the aspiration level moves closer to the ideal. Calculate normalised weight on Criteria *j*, as $w_j = w_j' / \sum_{i=1}^{n} w_i'$ where $w_j' = (_{\varepsilon}(A_j - nadir_j)/(ideal_j - nadir_j) if (A_j - nadir_j) \neq 0$, otherwise, A_j is the intermediate aspiration level and A_j are the combination of aspiration levels.

6 Rank the alternatives

6.1 Obtain the distance decision matrix of the aspiration level for each alternative $D_i = w_j d_{ij}$ where $d_{ij} = (pu_{ij} - A_j)/(ideal_j - nadir_j)$

6.2 Calculate the distance of a programme to the ideal point δ^{id} and distance from the negative ideal δ^{nd}

6.3 Calculate relative closeness D^{id} of each design to the ideal point

6.4 Rank the alternatives based on the magnitude of closeness D^{id} if $D^{id} > D^{jd}$

5.1 Seller and Buyer Criterion partial utility values

C_m	2	3	4. pu_{ij} *i=1*
T	13.0	31.28	0.94
B	3.0	0.29	0.2.0
M	6.0	6.92	0.42
F	**14.0**	31.44(H)	1.0
			$\sum pu_{iJ} = SO_i$ 2.512

C_m	2	3	4. pu_{ij} *i=1*
S	0.80(H)	103.0	1.0
E	0.21	26.0	0.29
			$\sum pu_{iJ} = BO_i$ 1.294

Table.2 Seller Criterion total partial utility value   Table 3 Buyer Criteria total partial value

For Seller SO_i objective total Criteria *m* =4; T,B,M and F are computed utility cost values, utility values and partial utility values are in column 2-4 respectively inTable2. These values indicate satisficing principle. The highest utility value 31.436 is for F and partial value is 1 as shown in column 4 Sum of Partial utility value is pu_{iJ} =2.52 the Seller. Based on the similar principal for the Buyer BO_i in Table3 Columns 2-4 are cost effective factors attributed to the Criteria, S and E for Buyer total Partial utility value is 1.29.

Three objectives are shown for alternative programmes in Table 4. Values for PR_i are price to cost ratio and for other two objectives, have calculated partial utility values. Pareto front in a negotiation space Figure 6 shows programme 2 and 6 are Pareto set on which negotiation can be done. At this point given soft and hard affordability limits the programmes would eliminate border solution. To get a single solution TOPSIS is applied modifying objective weights while concentrating on these two programmes for a solution that can be identifies closest to the individuals

P		SO_{ij}, j=1..4	BO_{ij} j=1..2	Price/cost PR_i
1	M	2.511	1.33	1.37
2	M	**2.512**	1.39	1.32
3	C	2.639	**1.294**	1.62
4	C	2.617	1.296	1.75
5	C	2.533	1.189	1.75
6	M	2.318	1.136	1.35

Table 4 shows related objectives data on P, Programmes partial utility values and ratio

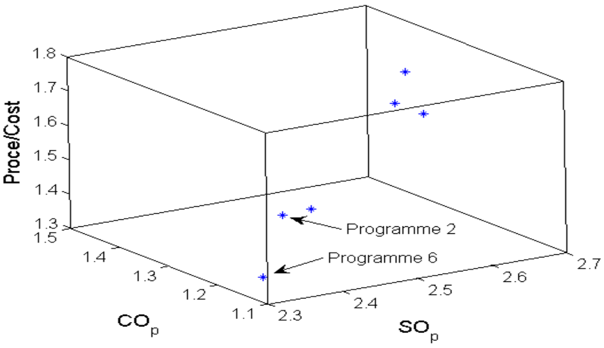

Fig 6 Pareto front consists of two points on P, programmes 2 and 6

6 TOPSIS: Computation of Affordability

In this section the partial utility values computed in the previous section 5 for the Seller and Buyer Criteria are applied to express a value judgement in terms of "goal" or "aspiration level" for each objective. The rationality of affordability is the compromise outcome from the Pareto front aspiration that lies in the framework of the TOPSIS. It is a tool for screening more than one alternative; eg, one or more readiness reviews. It generates to detail the programme that will meet less quantifiable issues and clear the way for final contract pricing.

6.1 Aspiration based affordability model on relative closeness of alternative to the ideal design

A decision matrix of alternatives and Criteria C_j is computed as per stages 4-6 shown in section 5. Formulate weights to reflect the importance attached to objectives as the aspiration level moves closer to the ideal. For an Ideal Inlet cowl, computed partial utility values for objective SO is 2.457and for objective BO it is 1.37. Iteration of a compromise solution is a feasible that is closest to the ideal. Weightings are applied to ensure comparable scaling for both objectives. The attainment of closeness to the ideal and assessment of the weighted mean contribute to the potential success of the decision. In this TOPSIS, the value of comparative closeness to the ideal point variant is obtained by computing δ^{id} , δ^{nd} and then ranking the preference order. The technique defines "relative closeness" by combining the proximity to the positive-ideal solution and the remoteness of the negative-ideal solution (Sen and Yang 1998).

6.2. Relative distance values between alternative programme and Ranking

Construct the objective weighted vector of Criteria then apply chosen normalised weighting w_j' for each alternative programme. The normalised weights are the comparative weights computed on the aspiration levels of combination of all objectives.

a_i		SO_{ij}		w_j' SO	d_{ij}	$w_j d_{ij}$ SO	BO_{ij}		w_j' BO	d_{ij} BO	$w_j d_{ij}$ BO
Id	*M*	***2.457(I)***					***1.370(I)***				
1	*M*	*2.511*	2.318	1.764	0.179	0.004	1.331	1.388	0.081	0.295	0.049
2	*M*	***2.512***	2.382	1.411	0.184	0.004	*1.388(N)*	1.338	**0.253**	0.538	0.090
3	*C*	*2.639(N)*	2.446	1.058	0.882	0.020	1.294	1.287	0.229	0.137	0.023
4	*C*	*2.617*	2.511	0.705	0.761	0.017	1.296	1.237	0.209	0.145	0.024
5	*C*	*2.533*	2.575	0.353	0.299	0.007	1.189	1.186	0.229	-0.312	-0.05
6	*M*	*2.318*	2.639	0.000	-0.88	-.020	1.136	1.136	0.236	-0.538	-0.09

Table 5: Computed cost and benefit values for Inlet Cowls alternatives on two objectives

They reflect the assumed degree of closeness between objectives that would benefit the aspirations and goals. The weightings assigned could lead to a "displacement" of ideal to achieve affordability at a desired ratio say 60-40. In Table 5 weightings are derived from the Table 4 and they are defined on a measurable scale.

The weighted normalised value for the Seller and the Buyer weighted $w_j d_{ij}$ are calculated for six programmes shown in Table 5, 1-6 are alternatives and Id is the ideal. In Table 6 Seller and Buyer shared percentage cost values for each program and comparative closeness to the ideal point variant δ^{id} and the distance δ^{nd} are to nadir point respectively. Relative distances values D^{id} are sorted in increasing order. Programme 2 alternative is manufactured primarily from metal and it is closest to the ideal in that the organisation may use this as a starting configuration as base cost values for variant δ^{id} , δ^{nd} . Distances D^{id} is for negotiation to affordability, since it also offers almost equal percentage of desired level 57-43 (60-40) to fulfil Sellers choice. The scenario between alternate 2 and alternate 6, is that the desired ratio is 50-50 but affordability price/cost ratio would be the guiding objective from soft to hard limit and alternate 2 would be a choice to compromise.

a_i	δ^{id}	Buyer %	δ^{nd}	Seller %	D^{id}	R
1	0.029	40.783	0.141	59.217	0.827	3
2	0.067	42.832	0.181	57.168	0.889	1
3	0.001	40.935	0.119	59.065	0.788	4
4	0.003	48.318	0.120	51.683	0.878	2
5	0.077	49.392	0.046	50.608	0.373	5
6	0.121	50.625	0.000	49.375	0.002	6
	M value	45		55		

Table 6 Buyer and Seller variants δ^{id} , δ^{nd} distance D^{id} R and ranking

7. Conclusion

The method presented is useful for negotiator and equally for cost engineers and designers to compromise a feasible programme that the Seller and Buyer would be satisfied with. The approach for resolving the choice however is not simple but it provides a systematic iterative approach applying multi criteria utility value methodology. The method provides decision makers aspirations and preferences to use them to map measurable changes on to variant configurations of programmes and generate alternate designed programme to explore. By making valid distinction between measures and utility indices the Criteria could be applied to facilitate and transfer the knowledge of important attribute drivers and important Criterion into higher fidelity of design that could resolve ambiguity and facilitate designers and negotiators to explore the trade space and offer better value for Seller and the Buyer. For example re-certification to upgrade the engine nacelle power plant could require installing more effective acoustic treatments or increase effective surface area in the Inlet. The process demonstrates a mechanism for shared negotiation space and expands understanding of Buyer's requirement and Seller's capability with product management issues. The process could be applied to examine potential changes in the values of attributes and Criteria those are of interest to the Seller and then compute the separation values between Objectives in order to meet Seller and Buyer aspirations. Pareto Front indicates a priori move from soft to hard affordability and then TOPSIS is applied. The computation provides a ranking of alternatives based on Tchebycheff distance measure constructed from the given levels of aspiration. Essentially application of Multi-Criteria decision in trade space exploration offers decision makers and negotiators to more closely to the required contract price and cost.

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Appendix 1 Definitions

Attribute: Attribute is a quantitative measure of performance associated with a particular criterion according to which an alternative is to be evaluated.. An attribute is used to measure performance in relation to an objective.

Parameters: They are the mapping of attributes into one design criterion.

Utility : Utility as measure, is a score of the total worth of a particular outcome. It reflects Decision Maker attitude towards a collection of attributes, such as Profit, Loss and risk. The computation of utility helps in selecting the best decision/trade offs alternative.

Criteria: This highlights a particular perspective to which decision alternative may be compared, usually representing interest concern or a point of view. In decision theory, Multi-Criterion decision analysis implies some degree of measurement of alternatives against specific criterion. It is usual to decompose criteria to a level of detail where multi-attribute theory could be applied.

Functional Criterion: For the Seller it is very important to what extent the product can fulfil buyer's requirement. e.g. As per technical specification

Technology Criterion: For the Seller it is very important to asses technology need for the product and asses how best the technology may be applied to design, manufacture and deliver the product.

Business Criterion: This is important for the Seller from the point of organisation profitability; when the programme is being acquisitioned. What is the commercial viability in terms of employment in the region as well for the organisation and what would be the business risk and degree of the risk.

Marketing Criterion: How well the Seller can market to the Buyer and end users, whether the product is saleable to other buyers.

Environment Criterion: This is more important to the Buyer and he would be more concerned about how effectively the noise, fuel consumption and other processes those the Seller is offering would effect the environment.

Safety Criterion: Buyer would be more concerned than the Seller on this Criterion. Buyer of the engine nacelles would judge how safe it is for other airlines to use the engine nacelle and how many aeronautical miles can be achieved safely with minimum inspection on ground.