Trade Study

1 Introduction

Trade studies are necessary when the system is complex and there is more than one design approach. It involves the comparison of alternatives. The approaches include:

- 1. Comparing advantages and disadvantages of several alternatives; can be qualitative.
- 2. Using a formal ranking system based on multiple criteria and a weighting system; 'more quantitative' approach.
- 3. Using back of the envelope calculations for multiple criteria and a weighting system; quantitative approach.

2 Pareto Frontiers

2.1 Introduction

Most engineering applications may be characterized as multi-criteria/multi-attribute problems. For this category of problems, optimum solutions cannot be obtained. The best one can wish for is to obtain the best compromised solution.



Figure 1: Pareto Frontier.

- 1. Sort the alternative from best to worst in one of the dimensions [X1]
- 2. The best alternative in X1 will be part of the pareto front call this A*
- 3. For each best to worst alternative in the X1 direction
 - a) Is this alternative batter than A* in another dimension [X2]?
 - b) If so, it is part of the Pareto front, and set it as new A* to compare to
 - c) You can stop when you reach best alternative in X2 dimension
 - d) If there are multiple alternatives with same X1 value, but different X2 values, only alternative with best X2 value out of these will be on the pareto front

Figure 2: Pareto Frontier Approaches.

2.2 Approach

3 Multi-Attribute Decision Making (MADM) Techniques

3.1 Decision Matrix (Additive Weighting)

Pros:

- 1. Very simple!
- 2. Can support criteria weighting which is very useful

Cons:

- 1. Qualitative data only
- 2. Careful when you mix "more is better" and "less is better" criteria, you can confuse your experts
- 3. Qualitative scales may not provide sufficient differentiation among alternatives

3.2 Pugh Evaluation Matrix

3.2.1 Introduction

This is a procedure to carry out concept formulation and evaluation in a progressive and disciplined manner. Pros:

Decision Matrix Example for Battery				Extend Old Battery Life	Buy New Batteries	Collect Experient Data With Alternative Experiment	
CRITERIA	Mandatory (Y=1/N=0)?	Weight	SCALE				
Mission Success (Get Experiment Data)	1	30	3 = Most Supportive 1 = Least Supportive	2	3	3	
Cost per Option	0	10	3 = Least Expensive 1 = Most Expensive	1	2	3	
Risk (Overall Option Risk)	0	15	3 = Least Risk 1 = Most Risk	2	1	2	
Schedule	0	10	3 = Shortest Schedule 1 = Longest Schedule	3	3 2		
Safety	1	15	3 = Most Safe 1 = Least Safe	2	1	2	
Uninterrupted Data Collection	0	20	3 = Most Supportive 1 = Least Supportive	3	1	2	
WEIGHTED TOTALS in %		100%	3	73%	60%	77%) (
$eight \cdot rac{score}{3}$ sim	ple additive w	eighti	ng			$\overline{\ }$	
э					Pref	ہ erred S	



- 1. Simple to evaluate
- 2. Easier for experts to compare "better or worse" than to assign a number on a scale

Cons:

- 1. Qualitative data only
- 2. Requires a datum point that must be well described
- 3. Cannot capture relative importance of metrics

3.2.2 Procedures

- 1. identify evaluation criteria
- 2. establish datum point (baseline) quantitatively/qualitatively
- 3. evaluate each alternative concept against the datum point: '+' implies better than, less than, less prone to, etc. '-' implies worse than, more expensive than, etc. 'S' implies same as datum
- 4. make an initial comparison to datum by summing the '+', '-', and 'S' for each alternative concept
- 5. assess individual concept score

Qualitative				Alternative Concept							
Quantative		Evaluation Criteria	1	2	3	4		n			
Example		\$/RPM	+	-	-	+					
	Airline Economics	Acquisition Price	+	-	+	S					
		Engine Price	-	+	-	-		+			
		DOC/trip	S	+	+	-		=			
	Manufacturer Economics	Sunk Cost	+	-	-	S					
		Break Even Unit	+	-	-	+		•			
	Environmental (noise)	EPNLdB SL _n	+	+	-	-		4			
		EPNLdB TO _n	-	+	-	-					
		EPNLdB FO _n	+	+	-	-		E			
	Reliability Maintainability	MTBF	+	+	-	+					
		MTTR	+	-	S	+		=			
		MMH/FH	S	S	+	S		-			
		Risk	+	S	-	-		я			
		$\Sigma+$	9	6	3	4		Q			
		Σ-	2	5	9	6					
		ΣS	2	2	1	3					

Figure 4: Pugh Evaluation Matrix.

3.3 TOPSIS

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is based on the concept that the chosen alternative should be the closest to the positive ideal solution and the farthest distance from the negative ideal solution. It also requires a decision matrix but uses given relative weights as the representation of the preference information.

Pros:

- 1. indisputable ranking obtained (i.e., math is consistent, repeatable, defensible)
- 2. SME not asked to think about maximizing vs minimizing
- 3. can handle mix of quantitative and qualitative data
- 4. takes into account relative importance of criteria

Cons:

- 1. solution highly dependent on criteria weight values, consider multiple what-if scenarios for robust selection
- 2. criteria have to have a monotonically increasing or decreasing utility
- 3. potential for false confidence on quantitative values (they still may include qualitative data)

3.4 Analytic Hierarchical Process (AHP)

AHP solves the decision making problem by reducing human decisions s into unit one-on-one for a single attribute decisions and combining them later with math. Its objective is to use the structured expert judgement to make decision and take advantage of expert knowledge to assess qualitative/quantitative information.

Pros:

- 1. Powerful and flexible, allows both qualitative and quantitative aspects to be considered
- 2. Reduces complex decisions to a series of one-on-one comparisons
- 3. Provides a clear rationale
- 4. Especially suitable for complex decisions with difficult to quantify elements and multiple layers

Cons:

- 1. Assumes elements, except for the bottom level, are independent.
- 2. Requires each alternative be compared with all others, which often causes an inconsistency problem.
- 3. Inconsistency becomes worse as the dimensionality increases.

4 Trade Study Considerations

4.1 Trade Study Selection

- 1. Is a trade study really necessary?
- 2. Can we use requirements, TRL, incompatibilities to eliminate alternatives?
- 3. Would the selection be obvious without an assessment?
- 4. Will the trade study decision affect an important requirement or narrow architecture space?

4.2 Importance of Information of each Alternative

- 1. Trade study analysis should use information that is relevant. Extraneous information can distract the decision maker.
- 2. Eliminate infeasible alternatives and non-discriminating criteria
- 3. Consider whether evaluation for each alternative and criteria is quantitative, qualitative or both

4.3 Priority of Criteria

- 1. Are all the criteria equally important to the decision or do we need to consider weighting?
- 2. Is there general agreement on the criteria priority or is a process for defining that priority necessary?

4.4 Assumptions

- 1. Trade studies are based on assumptions the team makes.
- 2. Changing assumptions within the trade study allows the team to perform a 'whatif' analysis.