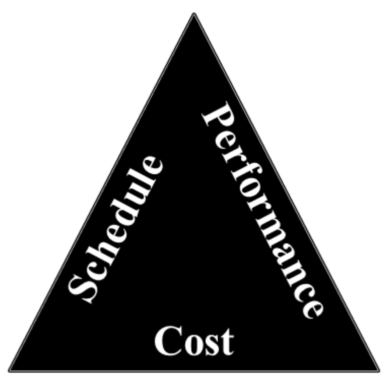
SURVEY OF TRADE STUDY METHODS FOR PRACTICAL DECISION-MAKING

Trade Studies & Decision Analysis

What is a Trade Study?

- Trade studies are decision-making activities used to identify the most acceptable technical solution among a set of proposed solutions. By nature, all decisions are subjective and involve risks. Trade studies provide an effective means for addressing this by documenting the decision-making process to enable traceability and repeatability.
- Potential solutions of a trade study are judged by their overall satisfaction of a series of desirable characteristics. These characteristics may conflict with one another or even be mutually exclusive.

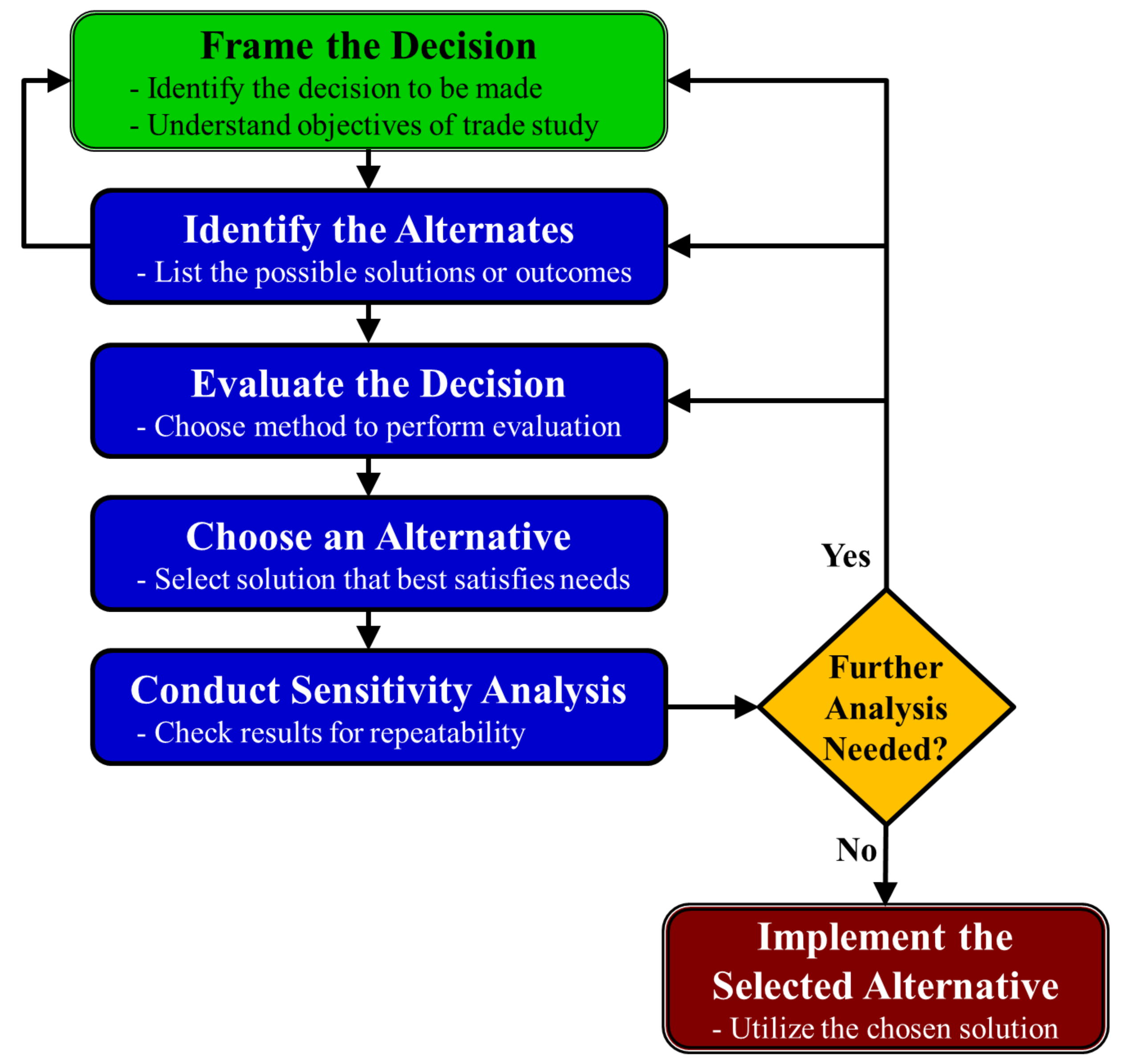


Why Use Decision Analysis Tools to Conduct Trade Studies?

To Assist Decision Makers in Situations Where:

- There is more than one possible course of action.
- Each outcome has a consequence that can be evaluated.
- Cost, schedule and performance variables must be weighed.

Decision Analysis Flow Chart



Methods Comparison

DECISION METHODS	CHARACTERISTICS OF METHODS		
	Time	Data	Accuracy
Pugh Method	Less Time	Less Data	Less Accurate
Analytic Hierarchy Process	More Time	More Data	More Accurate
Kepner-Tregoe	More Time	More Data	More Accurate

Which Decision Analysis Method is Preferred?

- There are numerous decision analysis techniques available to conduct trade studies. Selection of a method depends on factors such as the amount of time allotted to conduct a study, quantity of relevant data available and degree of accuracy desired in choosing a final solution.
- Here, we select three Multiple Criteria Decision Analysis (MCDA) techniques for comparison: Pugh, Analytic Hierarchy Process (AHP) and Kepner-Tregoe (KT).

Sample Application of Decision Analysis Methods

Analytic Hierarchy Process

PAIRWISE COMPARE	DECISION CRITERIA			
	Emissions	Fuel Cost	Range	Vehicle Cost
Emissions	1	1	5	5
Fuel Cost	1	1	5	5
Range	0.2	0.2	1	3
Vehicle Cost	0.2	0.2	0.33	1

CRITERIA MATRIX	Emissions	Fuel Cost	Range	Vehicle Cost		PREFERENCE VECTOR	
Propane	0.07	0.08	0.24	0.65		0.41	Emissions
Hybrid Electric	0.15	0.19	0.70	0.29	×	0.41	Fuel Cost
Electric	0.78	0.72	0.06	0.06		0.12	Range
						0.07	Vehicle Cost

MATRIX COMPUTATIONS	GREEN VEHICLE OPTIONS					
	Propane	Hybrid Electric	Electric			
Final Scores	**0.13**	**0.24**	**0.62**	=	1	Sum of Scores
SELECTED VEHICLE			✓			

Pugh Method

DECISION CRITERIA	GREEN VEHICLE OPTIONS		
	Propane	Hybrid Electric	Electric
Low CO_2 Emissions	S	S	+
Low Fuel Cost	S	S	+
Long Range	S	+	-
Low Vehicle Cost	S	S	-
Sum of Positives	**0**	**1**	**2**
Sum of Negatives	**0**	**0**	**2**
Sum of Sames	**4**	**3**	**0**
SELECTED VEHICLE		✓	

Kepner-Tregoe

DECISION CRITERIA		GREEN VEHICLE OPTIONS								
		Propane			Hybrid Electric			Electric		
Must Haves		Info		Y/N	Info		Y/N	Info		Y/N
Emissions < 120 CO_2 g/km		110		Yes	104		Yes	0		Yes
Capacity >= 4 adult passengers		5		Yes	5		Yes	4		Yes
Wants	Weight	Info	Value	Score	Info	Value	Score	Info	Value	Score
Emissions (CO_2 g/km)	0.3	110	0.83	0.25	104	1.33	0.40	0	10	3.00
Fuel Cost (US$/mi)	0.3	12.6	2.62	0.79	13.2	2.14	0.64	3.1	9.76	2.93
Range (miles)	0.2	448	4.35	0.87	896	9.95	1.99	100	0	0.00
Vehicle Cost (US$)	0.2	25,101	5.59	1.12	26,356	5.12	1.02	39,534	0.18	0.04
Relative Merit				**3.03**			**4.06**			**5.96**
Normalized Merit				0.23			0.31			0.46
Normalized Cost				0.28			0.29			0.43
Merit/Cost				**0.84**			**1.07**			**1.05**
SELECTED VEHICLE					✓					

Summary

- Three MCDA methods were applied to a green vehicle trade study. As a result, the electric vehicle scored highest as the most suitable AHP option. Alternatively, the Pugh and KT methods resulted in the hybrid electric as the optimal choice. This was not surprising as MCDA methods can produce different results when fed the same decision data.
- Our weighting preferences resulted in the electric vehicle as the AHP leader, but it had a low range of 100 miles and was not the best choice overall. We selected the hybrid electric as the overall winner as it best satisfied all our criteria.
- In some situations, a single MCDA technique is not sufficient. Riskier decisions may require a combination of MCDA techniques and higher stakeholder involvement to choose an optimal solution.

Paula J. Baker,[a] James T. Whalen[b]

[a]TASC, Inc., Chantilly, VA (Paula.J.Baker@ivv.nasa.gov)

[b]Stevens Institute of Technology, Hoboken, NJ (James.Whalen@stevens.edu)

NASA Independent Verification & Validation (IV&V) Facility

100 University Drive, Fairmont, WV

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References & Acknowledgements: 1. James T. Whalen, "SYS 660 Risk Management Course Material", Stevens Institute of Technology, Hoboken, NJ 2010. 2. Graham J. Bleakley, "A Systems Engineering Trade Study to Support Green Initiatives with Model-Driven Development", IBM Software Group, Somers, NY 2009. 3. Jennifer McBride, "Analytic Hierarchy Process", Operations Management 2003. 4. National Airspace Systems Engineering Manual, Federal Aviation Administration, Washington, DC 2006. 5. E. Triantaphyllou, S.H. Mann, "An Examination of the Effectiveness of Multi-Dimensional Decision-Making Methods", Amsterdam, The Netherlands 1989. 6. Edwin P. Chan (NIST). 7. Richard E. Kowalski (TASC, Inc).