Massachusetts Institute of Technology

Quantitative Methods in Systems Engineering
Key Takeaways

WEEK 2: VALUE-ORIENTED DECISION MAKING

Framing Decision Making and Trade-offs

Intro to core concepts: Value is benefit at cost that a stakeholder cares about, addressing three concepts: 1) degree of satisfaction (i.e. benefit); 2) resources used (i.e. cost); 3) degree of importance (i.e. priority); using attributes as multiple decision criteria, cost versus benefit framing decision opportunities, exploring many potential alternatives in a tradespace.

Examples of multiple criteria decisions: Cell phone (*user*: UI, battery life, ruggedization, camera, screen quality, etc.; *manufacturer*: production cost, manufacturing time, availability of suppliers, changes to existing production facility, etc.)

Value-Focused Thinking and Value-Driven Design

Value vs. alternatives focused thinking: Alternatives-focused thinking identifies potential solutions for the problem upfront and then compares alternatives to select the one that best solves the given problem. Value-focused thinking starts with the problem, trying to formulate it a more solution-neutral manner, identifying how to maximize the value derived from the system. Using (preferably solution-neutral) values as a focus, it encourages creative problem solving and opens the solution space.

Traceability and communication support: One of the key benefits of engaging with stakeholders early and using value-focused thinking is that it increases the likelihood of success at decision time.

Developing Value Models

Overview of value models: Design-value loop perspective, evaluative models as performance and cost models, value models

Alternative single and multi-attribute value models: Some examples of single attribute approaches are Net Present Value and Single Attribute Utility; examples of multi-attribute approaches are Lexicographic, Pugh, QFD-like, Modified Decision Matrix, Multi-Attribute Utility (MAU).

Example application of value models: Buying a car had different rankings of four alternatives via Lexicographic, Pugh, QFD-like, Modified Decision Matrix, and Multi-Attribute Utility methods. Each method has a different level of effort required and different degree of confidence in its results. It is important to understand the advantages and limitations of each method before using them.

Operationalizing Value Models

Operationalizing value with attributes: An attribute is a decision maker-perceived metric of how well the decision maker's perceived objective is met; decision makers are a type of stakeholder who has influence or control over driving the needs and setting the goals for the system.

Axioms of utility theory: Normative theories are useful even when known to be descriptively invalid, as they can be used prescriptively to help improve decision making if decision makers want the axioms to hold. The axioms of utility theory are: relative preference, transitivity, monotonicity, existence, and substitution.

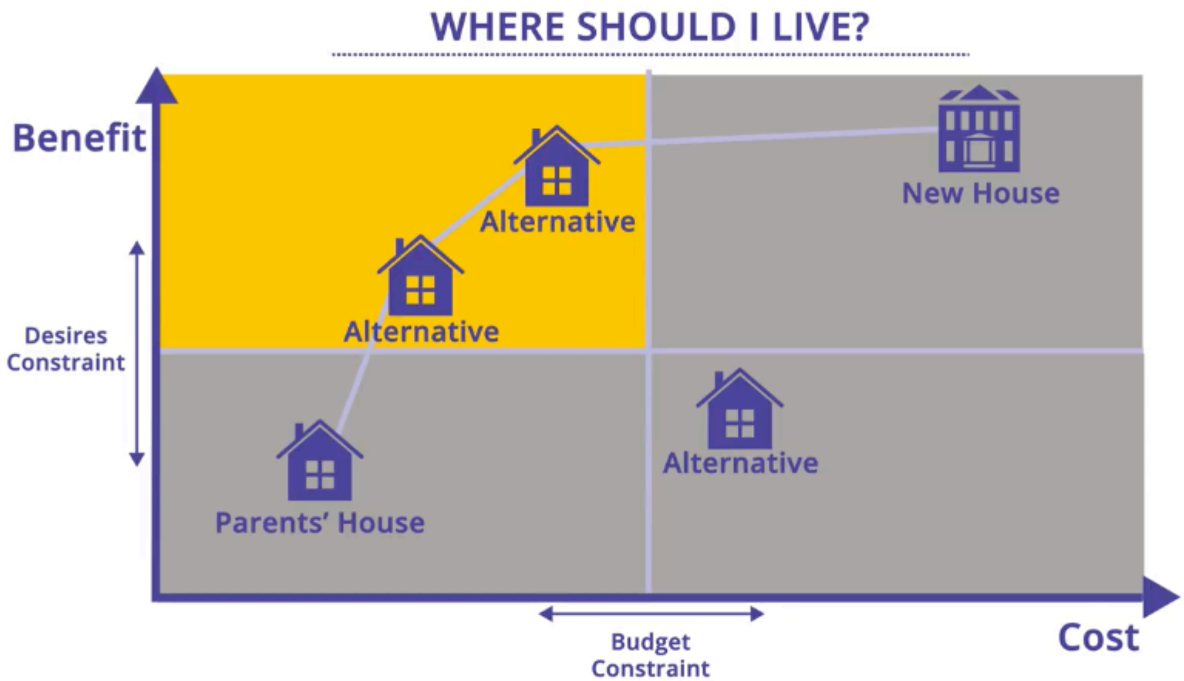
Considerations for utility elicitation: Decision makers must have preference over the attributes, and the characteristics of the set include: completeness, comprehensiveness, importance, measurability, non-redundancy, and independence. Human cognitive limitations lead to recognition that only about five attributes can be considered simultaneously. Likewise, people tend to think about changes in levels, be loss averse, risk seeking in loss domain, and risk averse in the gain domain, and tend to subjectively interpret probabilities. When interviewing people, it is important to put them at ease and frame questions in the proper context. Typically, utility information is elicited in three rounds: 1) identification of attributes and their rankings; 2) confirmation of attributes and elicitation of single attribute utility functions and multi-attribute utility weights; 3) validation of the elicited information.

Considerations for multiple decision makers: Technically, it is unsound to aggregate utility across decision makers since no absolute universal scale exists to convert across their individual scales. In hierarchical organizations, use of supra-decision makers may be possible, with subordinates' MAU (Multi-Attribute Utility) as attributes for the higher-level decision maker. Best practice is to keep decision maker utilities separate and leverage computational or negotiation-based techniques to find win-win solutions for all parties.

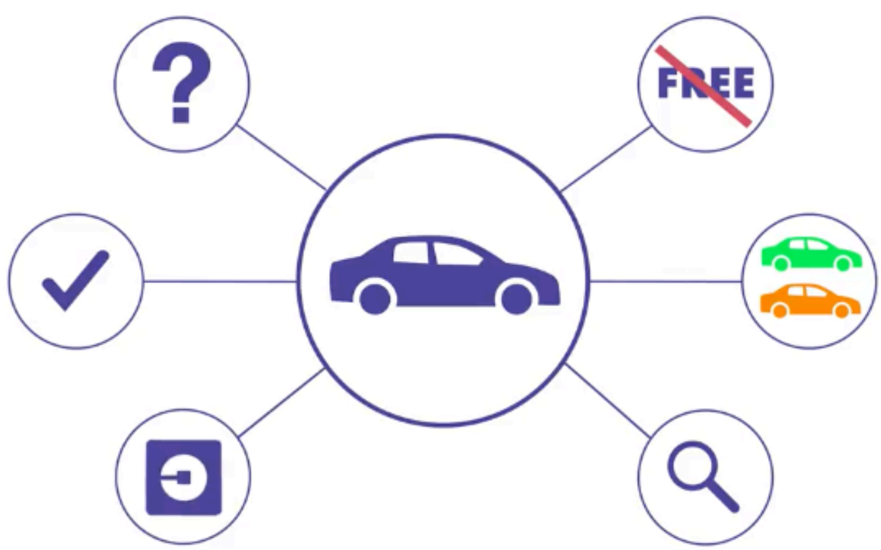
Value hierarchies: When there are more than 3-5 attributes, we can often simplify the problem via decomposition and abstraction using a hierarchy. Parents are decomposed into children, with no more than 3-5 children for a given parent. Weights can be assigned to each node (locally) and via aggregation functions; global weights can be determined. When all children independently contribute value, linear weighted sums can be used and all weights for children of a given parent must add to one.

Key Figures

Week 2: Value-Oriented Decision Making > Framing Decision Making and Tradeoffs



Week 2: Value-Oriented Decision Making >Value-Focused Thinking and Value-Driven Design

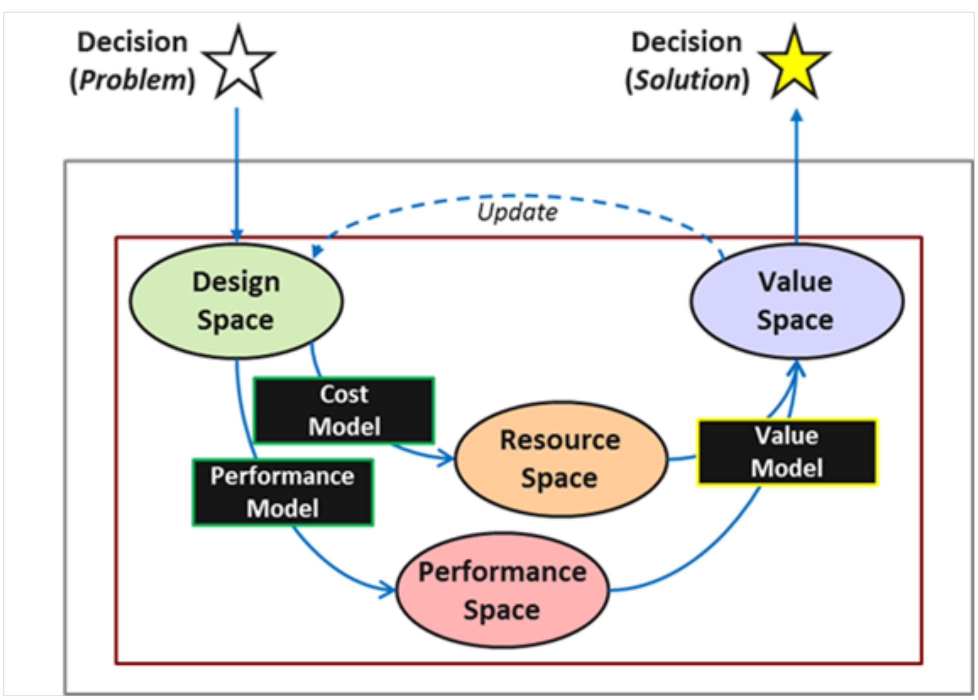


Week 2: Value-Oriented Decision Making > Operationalizing Value Models

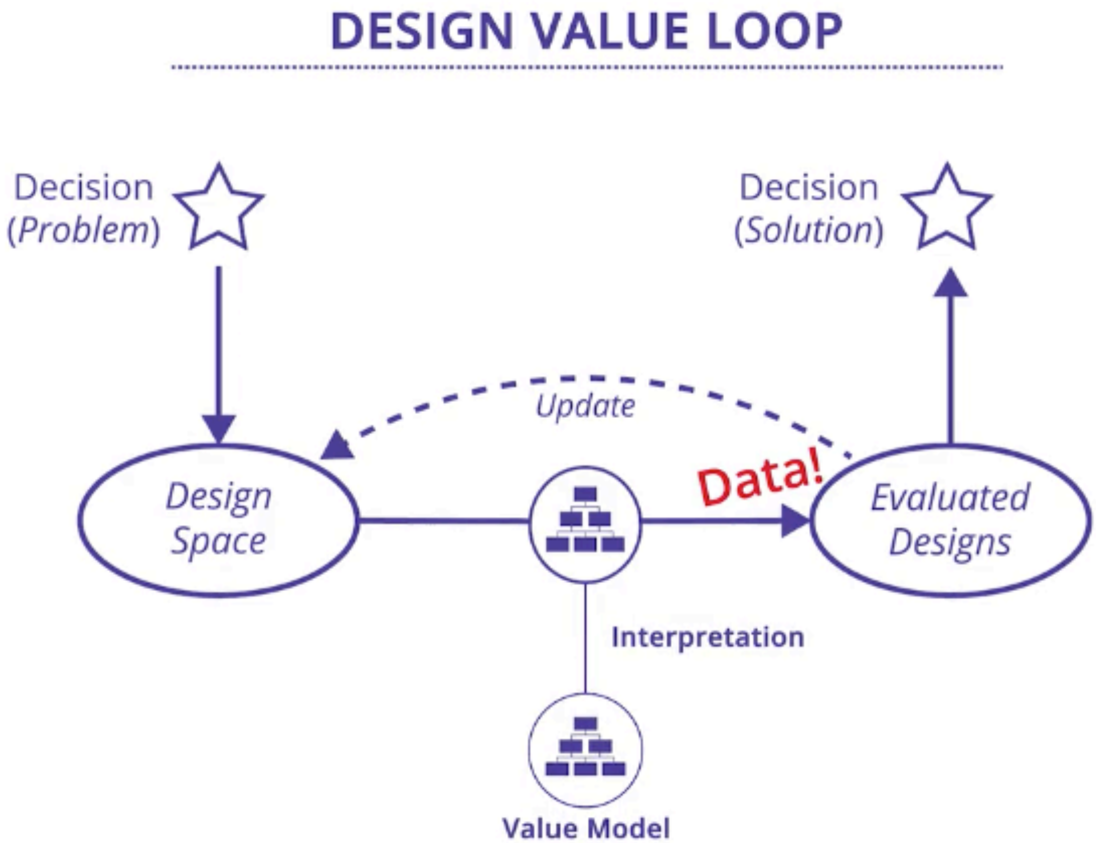
ATTRIBUTES FOR SATELLITE RADAR SYSTEM

	Attribute Name	units	range (U=0 to U=1)
Tracking	Minimum Target RCS	dB	12 --> 0
	Min. discernable velocity	m/s	40 --> 1
	Number of target boxes	#	0 --> 10
	Target acquisition time	min	3000 --> 30
	Target track life	min	0 --> 30
	Tracking latency	min	60 --> 1
Imaging	Resolution	m	100 --> .01
	Targets per pass	#	0 --> 50
	Field of regard	km^2	100 --> 1000000
	Daily revisit frequency	#	0 --> 8
	Imaging latency	min	1440 --> 10
Program	Baseline cost	$B	100 --> 5
	Deviation from cost	%	200 --> 0
	Baseline schedule	years	20 --> 3
	Deviation from schedule	years	5 --> 0

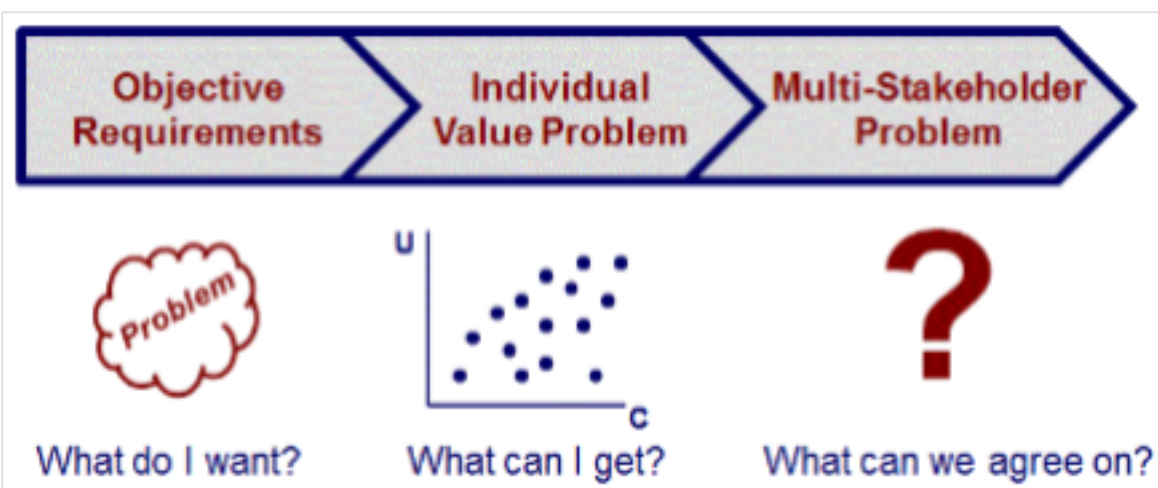
Week 2: Value-Oriented Decision Making >Developing Value Models (35 min) Overview of Value Models



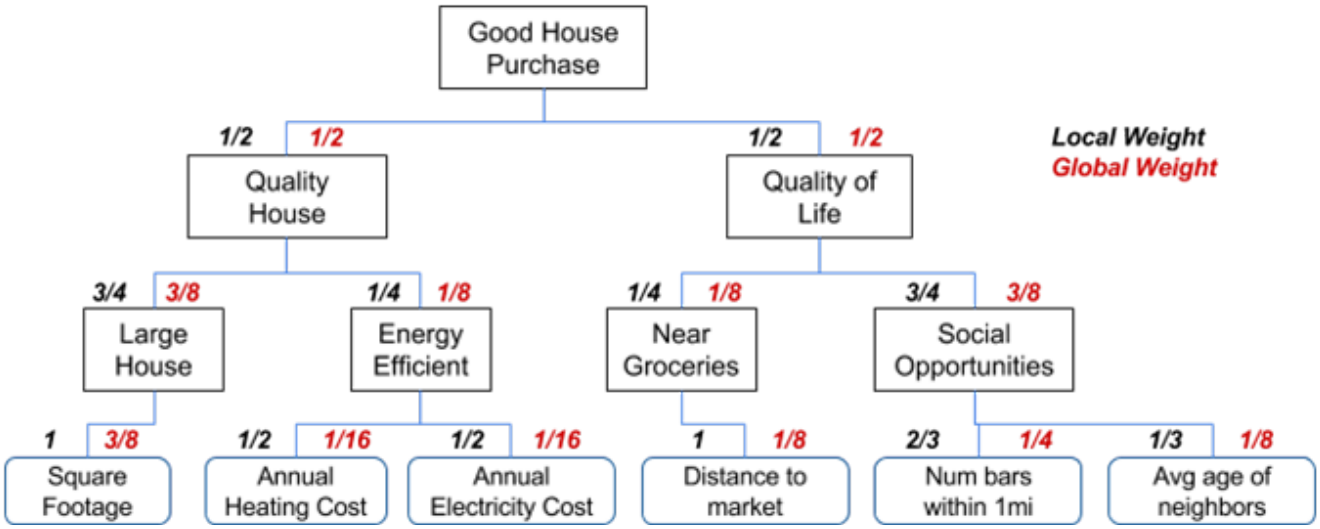
Week 2: Value-Oriented Decision Making > Developing Value Models



Course Week 2: Value-Oriented Decision Making > Operationalizing Value Models > Considerations for Multiple Decision Makers



Course Week 2: Value-Oriented Decision Making > Operationalizing Value Models > Value Hierarchies


Good House Purchase
1/2
1/2
Quality House
1/2
1/2
Quality of Life
Local Weight
Global Weight
3/4
3/8
Large House
1/4
1/8
Energy Efficient
1/4
1/8
Near Groceries
3/4
3/8
Social Opportunities
1
3/8
Square Footage
1/2
1/16
Annual Heating Cost
1/2
1/16
Annual Electricity Cost
1
1/8
Distance to market
2/3
1/4
Num bars within 1mi
1/3
1/8
Avg age of neighbors

