Massachusetts Institute of Technology

# Quantitative Methods in Systems Engineering
*Key Takeaways*

## WEEK 1: MAKING EARLY TRADEOFF DECISIONS

**Early Decisions**
Early decisions are decisions made early in the lifecycle, and "pre-design" decisions are made throughout the lifecycle.

- Early decision methods depend on limited information and lower fidelity models.
- Structured methods supported by models are important to making correct decisions.

**Tradeoff Analysis**
Tradeoff Analysis is a decision-making activity involving one or more types of analysis for the purpose of selecting from alternative solutions on the basis of benefits to the overall system and its stakeholders. Example methods:

- Decision matrix method
- Trade study method
- Tradespace exploration method

**Measurement Scales**
Engineering analysis often involves the use of measurements to indicate the degree to which attributes or objectives are achieved by various alternatives. Scale of measurements can be grouped into four types: nominal, ordinal, interval, and ratio. Each scale has specific properties.

**Use of Models in Tradeoff Analysis**

- Models are highly useful in trade-offs for complex systems with uncertainties
- Focusing on key system attributes illuminates behavior and relationships apart from less important system characteristics
- Reveal critical system issues by "stripping away" properties that are not immediately concerns with the issue under consideration
- All types of models can be useful in trade-off analysis

**Model Types**
Schematic models

- Solidify concepts and understand context
- Means for communicating to others and impetus for specifying terminology

Math models

- Means to understand relationships and dependencies
- Model functionality, performance, behavior

"Physical" models

- Realistic representations to aid validation
- May be computer-based or virtual mock-up

**Decision Matrix Methods**

- Compare concepts against decision criteria, which are unweighted or weighted
- Simple, intuitive method to use with audiences of varying technical backgrounds

- May be unweighted or weighted
- Can be used by an individual; most useful with small teams
- Well-suited to early discussions to narrow the range of concepts
- A relative tradeoff analysis, not easily transformed to absolute trades

**Basics of the Trade Study Process**

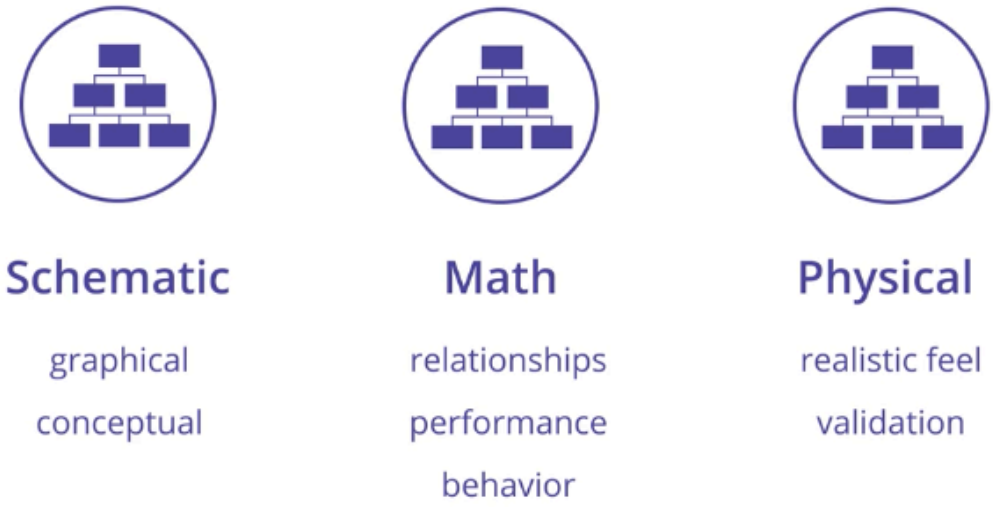
1) Define the objectives of the trade study
2) Review inputs, constraints, and assumptions
3) Choose evaluation criteria (Figures of Merit) and their relative importance
4) Identify and select the alternatives
5) Assess performance of each option for each criteria, including sensitivity analysis
6) Compare the results and choose an option
7) Document the trade study process and its results

**Trade Studies and Tradespace Exploration**

- Trade studies are useful with a relatively small number of alternatives
- Tradespace exploration allows for the comparison of a very large number of alternatives, and exploring the entire design space
- Trade studies can be used before or after tradespace exploration

## Key Images

Week 1: Making Early Tradeoff Decisions > Framing Early Decisions



# UNWEIGHTED DECISION MATRIX

| | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 | Option 6 |
|---|---|---|---|---|---|---|
| *Criteria 1* | 0 | -1 | 0 | 0 | +1 | -1 |
| *Criteria 2* | 0 | +1 | -1 | -1 | +1 | +1 |
| *Criteria 3* | 0 | -1 | -1 | 0 | -1 | +1 |
| *Criteria 4* | 0 | +1 | -1 | 0 | -1 | -1 |
| *Criteria 5* | 0 | -1 | +1 | +1 | +1 | +1 |
| *Criteria 6* | 0 | +1 | 0 | 0 | 0 | 0 |
| *Criteria 7* | 0 | -1 | -1 | -1 | 0 | -1 |
| *Criteria 8* | 0 | +1 | +1 | +1 | 0 | -1 |
| Better (+1) | -- | 4 | 2 | 2 | 3 | 3 |
| Same (0) | -- | 0 | 2 | 4 | 3 | 1 |
| Worse (-1) | -- | 4 | 4 | 2 | 2 | 4 |