

Trade Studies and Decision Making

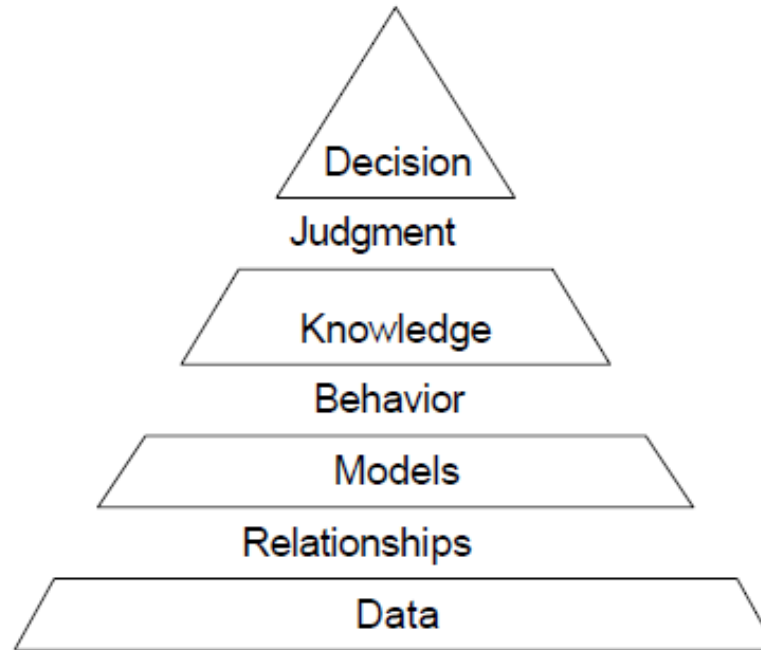
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Decision Making

- Choosing between possible solutions to a problem through gathering information and evaluating alternative solutions—a mechanism of making choices in the course of problem solving.
- Problem solving: generating and refining information punctuated by decision making
- A decision is a commitment to use resources

Decision Making Pyramid



Source: http://web.engr.oregonstate.edu/~ullmand/decision-making/Twelve%20Steps%20introduction_files/Twelve%20Steps%20introduction1.pdf

Decision Support System

In practice the needed information are:

- Inconsistent, incomplete, uncertain, and evolving
- Shared vision (conflicting customer requirements)

What to do next:

- Low cognitive load (do not overcomplicate)
- Rational strategy (basing strategy on evidence)
- Traceable trail (proper documentation)

Trade (off) Study

“A system engineering element that multidisciplinary teams use to identify the most balanced technical solutions among a set of proposed viable solutions.”

- Desirable and practical alternatives that meet cost and effectiveness measures are identified
- Most balanced technical solution (cost, schedule, quality, risk) from a set of proposed viable solutions
- These solutions must satisfy a series of measures or cost function
- A key tool to develop designs that meet stakeholder requirements in the most efficient way possible
- Trade studies prevents from committing too early to a design that may not be cost effective or meet all stakeholder requirements

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Trade Studies

- Conducted within and across disciplines at any phase of the lifecycle
- Any affected group should participate in the trade study (do not miss any important information)
- It is appropriate to develop a trade studies plan for each major problem for which alternatives are considered.

Trade Studies

- Weight factors are used to dictate how important the evaluation criteria are relative to each other.
- The choice of weight factors and normalization scale are extremely important to this process.
- Normalization scale creates a constant interval scale that allows us to set a numerical for each of the evaluation criteria (e.g. cost, mass, volume, power consumption legacy, ease of use).

Trade Studies Objectives

- Alternative design and implementation strategies (brainstorming different designs) based on architecture, performance, and cost
- Recommend commercial-off-the-shelf products (COTS) for purchase
- Recommend a supplier for services
- Document and justify a solution for a system requirement
- Reduce risk

Trade Studies

Requirement Types

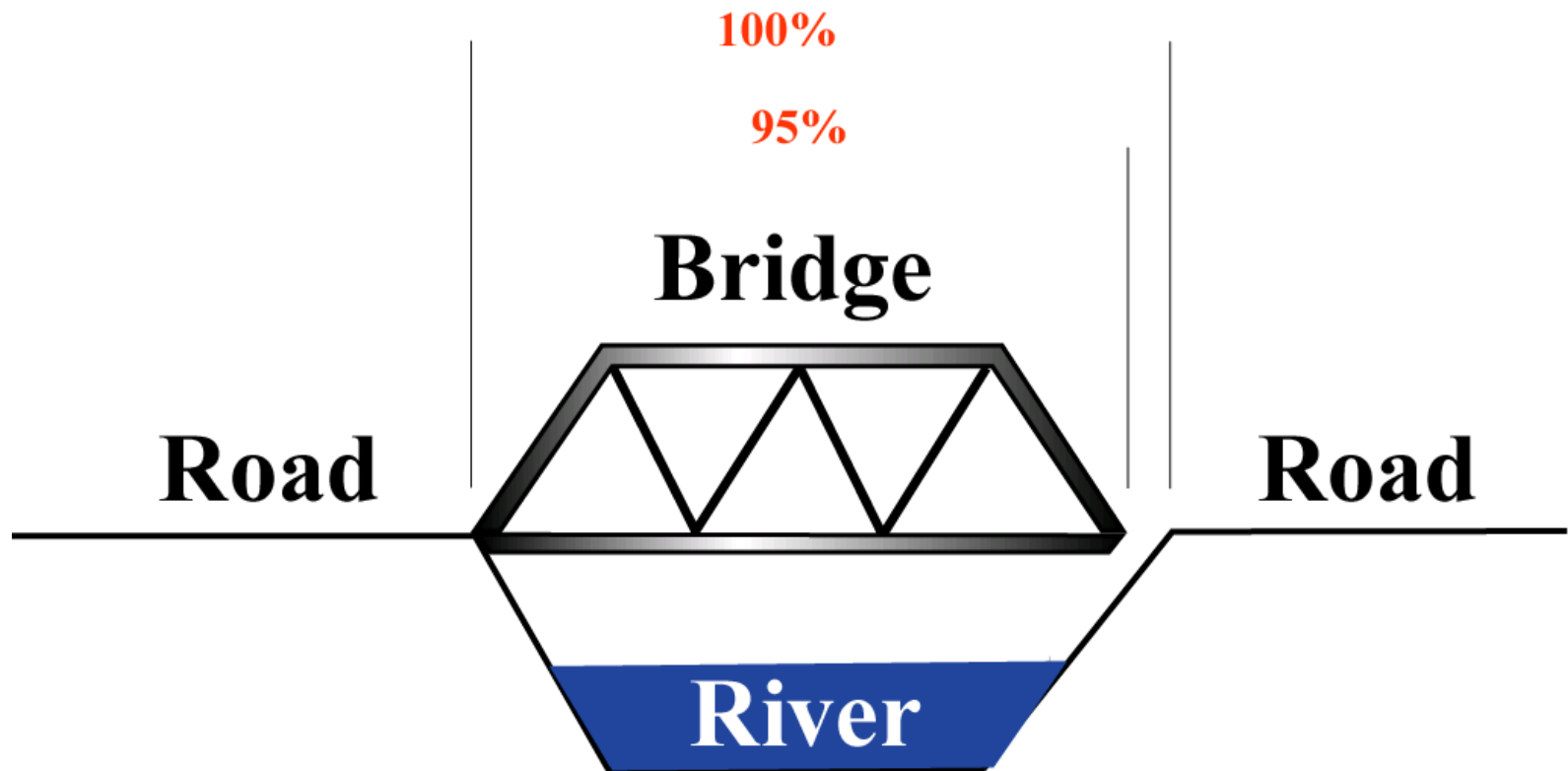
- Tradeoff vs. Mandatory
- Functional vs. Physical

Trade-off Bridge



Trade-off requirement: The bridge deck should be at the same level as the road surface (tolerance of $\pm 5\%$ would be acceptable)-*above mandatory can be trade off.*

Mandatory



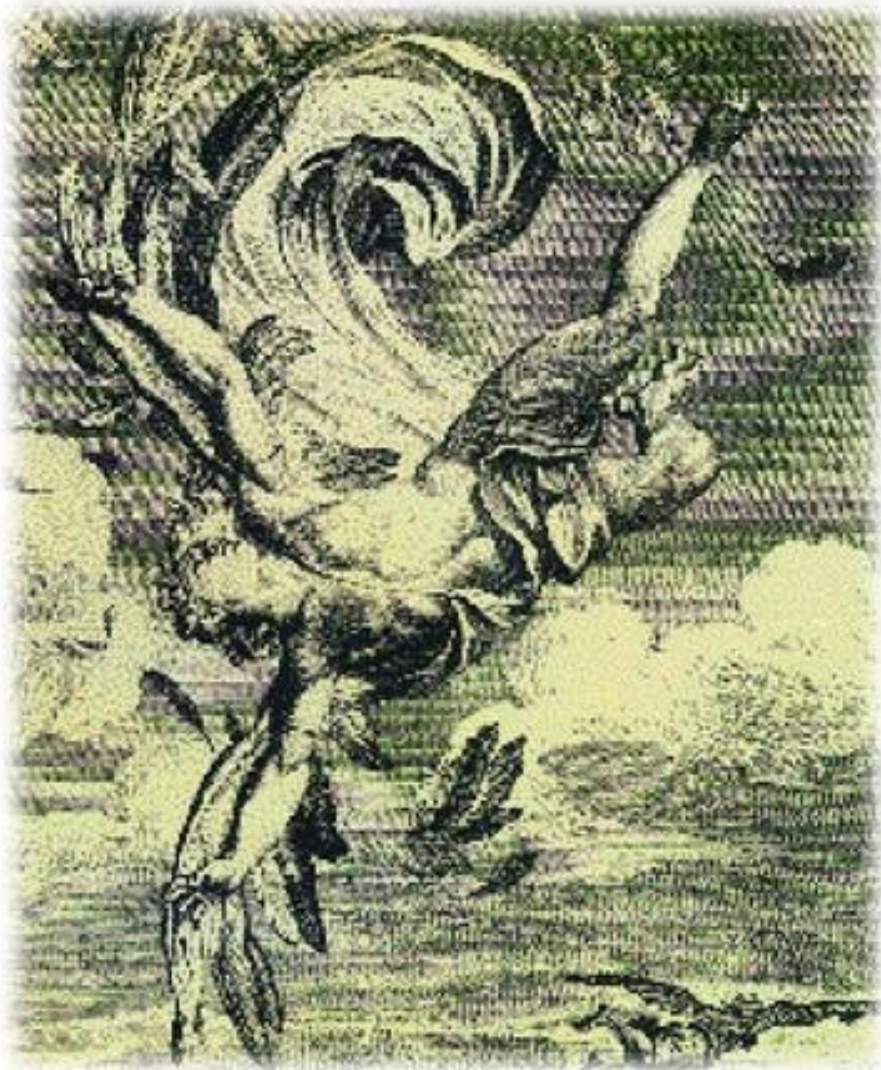
Mandatory requirement: The bridge deck shall stretch from bank to bank (95% is not acceptable)

Decomposition

- Physical: Decompose the product to its components and to develop product structure
- Functional: Resolving a functional relationship into its constituent parts

What do we need to fly?

Physical Decomposition

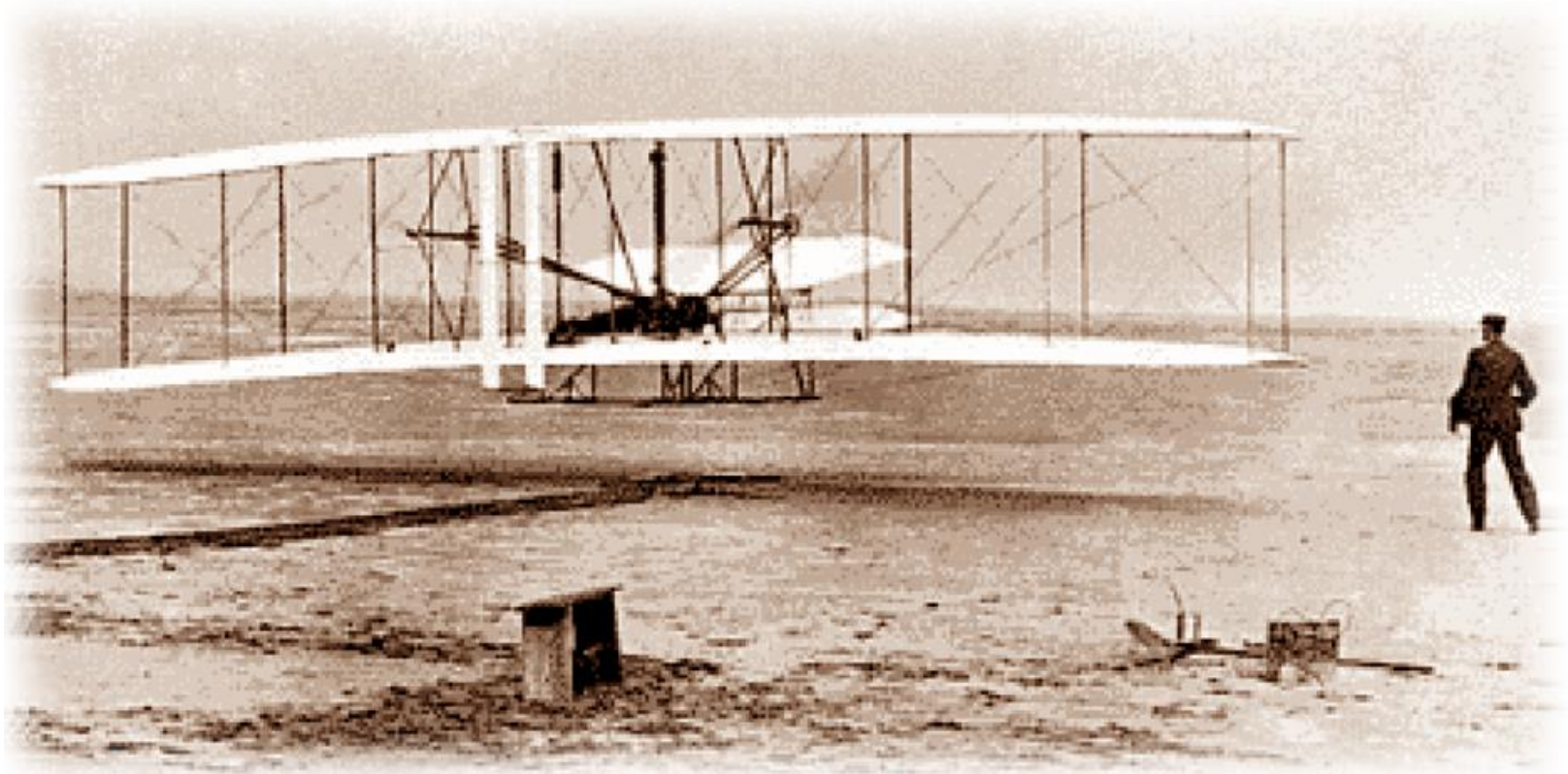


For centuries, humans have been unsuccessful in their attempts to fly because they used physical decomposition (brain, eyes, legs, and wings).

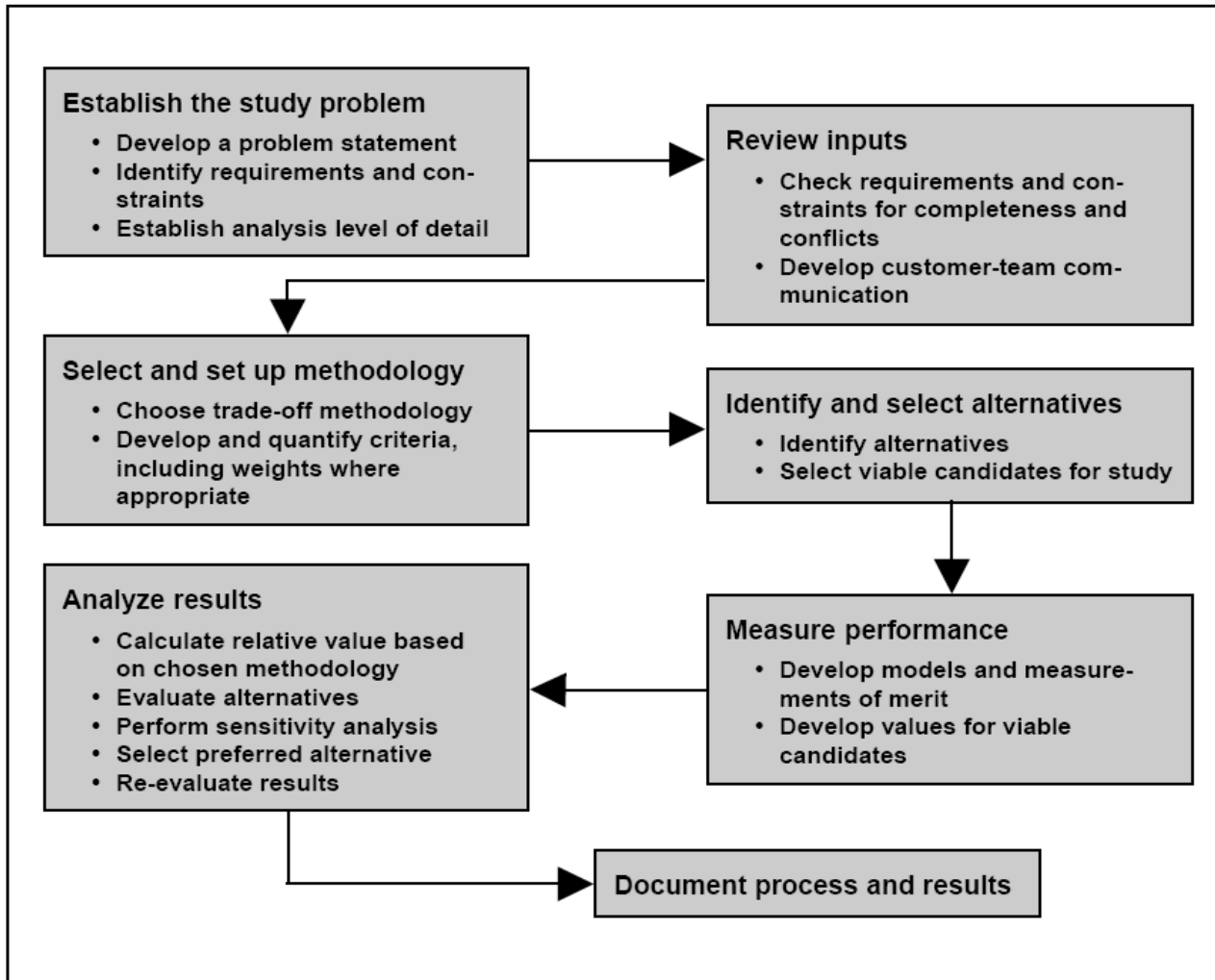
What do we need to fly?

Functional Decomposition

The Wright Brothers focused on three functions: control, horizontal thrust, and vertical lift.



Trade Studies



Trade Study Process

Steps to a trade study

1. Define the problem.
2. Define constraints on the on the solutions.
3. Find 3-5 solutions
4. Define evaluation criteria.
5. Define weight factors
6. Define normalization scale
7. Populate trade matrix
8. Rank the solutions

Task 1: Scope and Ground Rules

- Specific goals/requirements to be met
 - All viewpoints of stakeholders
 - Customers/stakeholders input is clearly understood and documented
- Define and analyze requirements (functional, performance, operational, programmatic)
- Define system goals and identify constraints
- Attainable Schedule and Major Milestones
 - Excursions from baseline concept should be defined
 - Boundaries (A study lacking boundaries easily grows far beyond the available resources)

Task 2: Define Evaluation Criteria and Weighting Factors

- Evaluation Criteria (*requires*):
 - Engineering Judgment
 - Interaction with Stakeholders
 - Measurable, if possible
 - Cost and Risk Included
- Weighting Factors
 - Requirements Analysis
 - Define and Record Method for Assigning Score
 - Prepare Scoring Matrix

Trade Studies

Scoring Matrix: Assign a column for each evaluation criterion and a row for each alternative

Decision Factors Alternatives	Decision Factor 1		Decision Factor 2		...	Decision Factor n		Total Weighted Score
	Weight = 3		Weight = 1.5		...	Weight = 2.5		
	Score	Weighted Score	Score	Weighted Score	...	Score	Weighted Score	
Alternative 1	7	21	4	6	...	8	20	47
Alternative 2	8	24	10	15	...	10	25	64
!	!	!	!	!	...	!	!	!
Alternative n	10	30	5	7.5	...	12	30	67.5
Alternative n+1	!	!	!	!	...	!	!	!

Common Trade Study Evaluation Criteria

- Development cost
- Lifecycle cost
- Requirements compliance
 - Functional
 - Performance
 - Operational
 - Programmatic
- Technical risk (Maturity)
 1. Reliability, Maintainability, Availability
 2. System Safety
 3. Quality
 4. Human Factors
 5. Electromagnetic Environmental Effects
 6. Hazardous Materials
- Budget risk
- Schedule risk
- Operational complexity
- Vendor assessment
- System maturity
- Development support tools
- Test support tools
- Development team familiarity with candidate hardware and software
- Quality of logistics support

Task 3: Select Alternative Solutions

Criteria	Alternative 1	Alternative 2	---	Alternative N
Cost <ul style="list-style-type: none"> ▪ Initial ▪ Recurring 	High low	Medium Low	---	Low Low
Performance	Low	High	---	New Design
Reliability Maintainability Availability	Medium	High	---	Medium
Risk <ul style="list-style-type: none"> ▪ Cost ▪ Technical 	Low (20%) Low (25%)	Low (10%) Low (20%)	---	Low (10%) Medium (35%)

Task 4: Down-select Alternatives

- High risk candidates
- Questionable feasibility
- High lifecycle cost

Task 5: Evaluate Alternatives

- Detailed evaluation of all approved viable alternatives
- Baseline reference method
 - +/-
 - S/U
- Relative rank method: *evaluates each alternative against the selected criteria.*
- Cost assessment method-*implementation and operational costs, fixed and variable costs.*

Task 6: Sensitivity Analysis

- Solutions have nearly equal score
 - Differences meaningful?
 - Would minor variations in the raw scores and weight affect the selection
- Weights
 - If determined by compromise → range of reasonable values
- Outcomes
 - Optimal choice (meets critical requirements)
 - Acceptable cluster (a number of choices)
 - No fully acceptable choices (none of them satisfy mandatory requirements)

Task 7: Review Result / Conclusion

- Trade Study Report
- Design and Manufacture

Thank you for your attention!