SYSTEMS DESIGN

Science studies what is.

Engineering creates what has never been.

Scientists study how birds fly.

Engineers create ways that *WE* can fly.

Engineering creativity is expressed via *design*.

Design
- **creative, iterative, decision-making process**

System Design
- **purposeful combination of elements to create a system**

Creativity

19th Century Questions

- **What is creativity?**
- **Who has creativity?**
- **What are characteristics of creative people?**
- **Who should benefit from creativity?**
- **Can creativity be increased through conscious effort?**

Theoretical Approaches to Creativity:

- **Mystical**
  - spiritual process

- **Pragmatic**
  - methods and techniques (e. g., brainstorming)

- **Psychodynamic**
  - Freudian unconscious; studies of outstanding creators

- **Psychometric**
  - paper and pencil tests for "average" person

- **Cognitive**
  - mental processes and creativity (e. g., computer programs)

- **Social-Personality**
  - interactions of personality, motivation and environment

- **Confluence**
  - convergence of multiple components

Creative Process - Four Phases

Graham Wallas - *The Art of Thought*

- **Preparation**
  - *learning about the problem*
- **Incubation**
  - *exploring ideas about alternatives*
- **Illumination**
  - *identifying a feasible alternative*
- **Verification**
  - *confirming alternative viability*

Theoretical Approaches to Design:

Christopher Alexander:
(architecture)

**"The form is the solution to the problem,
the context defines the problem"**

Herbert Simon:
(cognitive psychology)

"Satisficing" - i.e., Sufficiently Satisfying

Design alternative is satisfactory if:
- **criteria exist that describe minimally acceptable alternatives**
- **the alternative meets or exceeds all criteria**

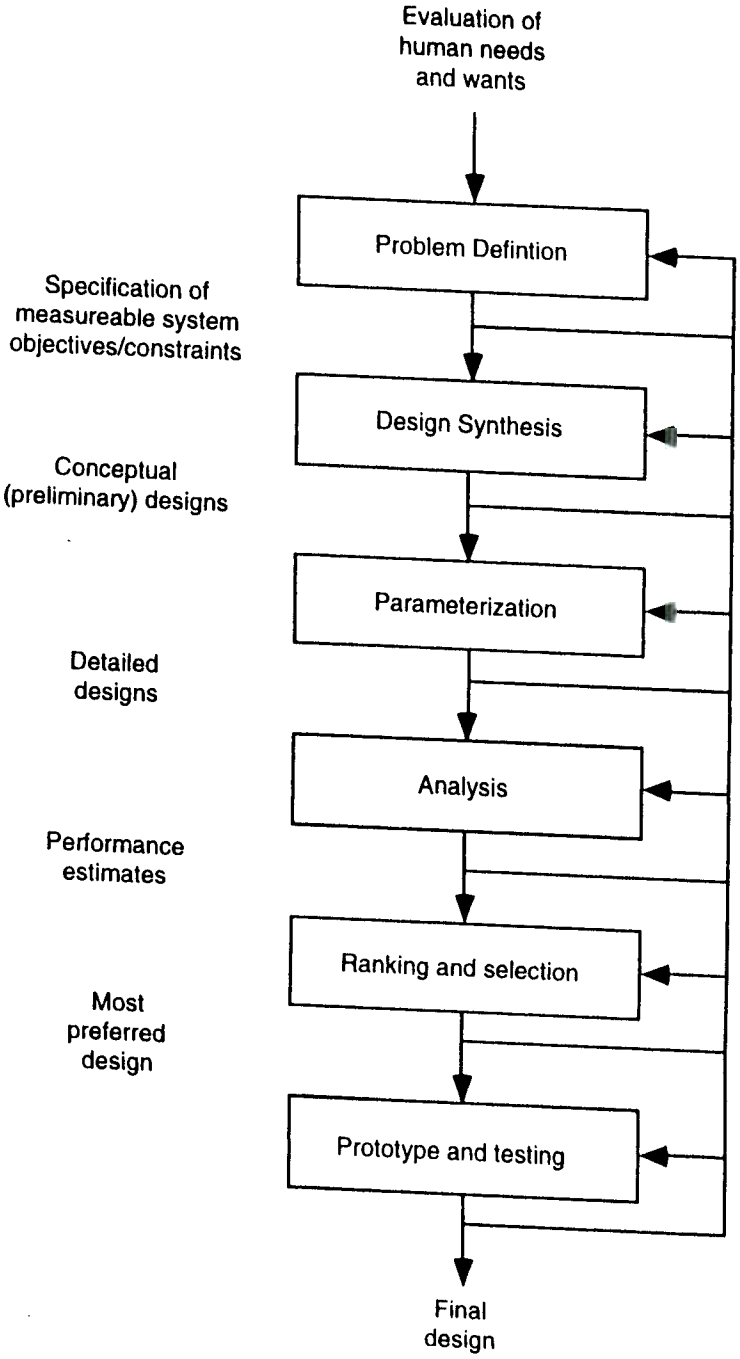
Thomas Moran and John Carrol:
(computer science)

Design Rationale
- **yields reasons and reasoning process for a given design**
- **provides an organizing principle for design**

Nam Suh:
(manufacturing and mechanical engineering)

- **Specification of too few functional requirements yields unacceptable solutions**
- **Specification of more functional requirements than necessary yields overdesign**

Design Process
(Figure 13.1, Page 456)

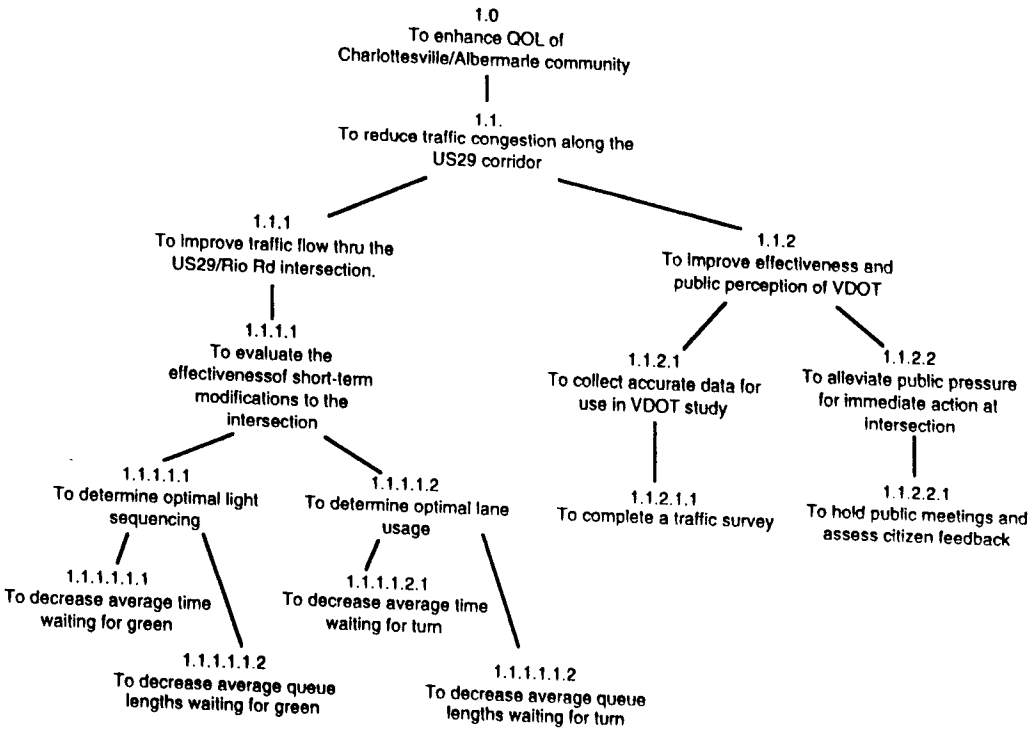


PROBLEM DEFINITION

(John E. Gibson, 1991)

1. Generalization
2. Descriptive Scenario
3. Normative Scenario
4. Axiological Component
   (axiology = study of values and value judgments)
5. Objectives Tree
6. Validate Goals and Objectives
7. Iterate

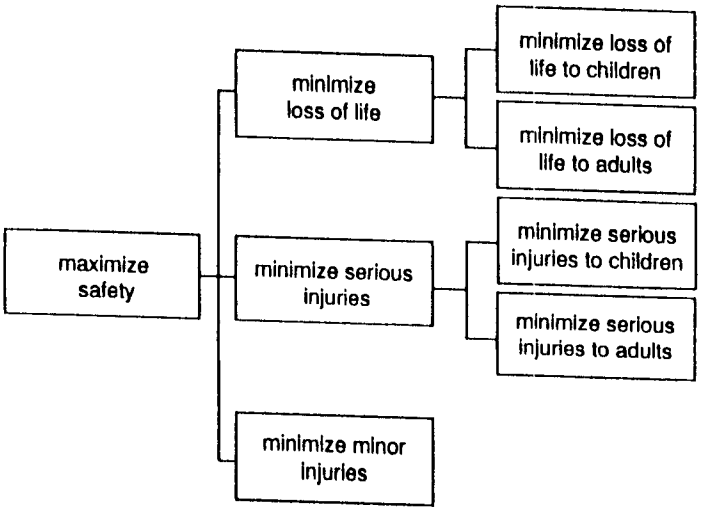
Example Objectives Tree
(Figure 13.3, Page 459)



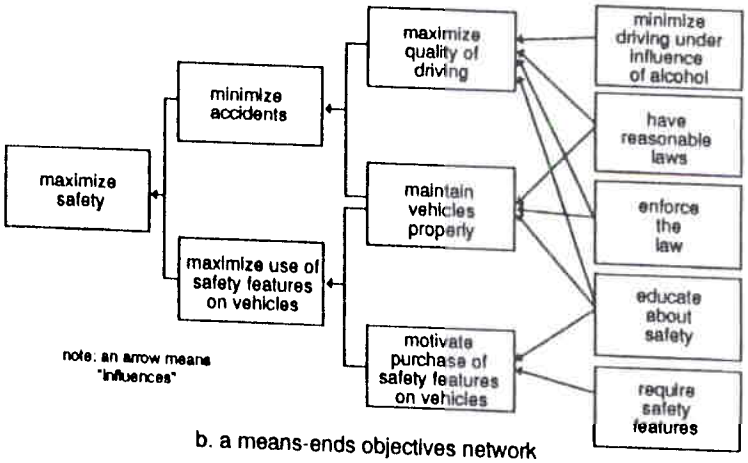
QOL = Quality of Life
VDOT = Virginia Department of Transportation

Example
Fundamental Objectives Hierarchy
Means Objectives Network

Objectives Structures for the Safety of Automobile Travel
from
Ralph L. Keeney, *Value-Focused Thinking: A Path to Creative Decisionmaking*



a. a fundamental objectives hierarchy



b. a means-ends objectives network

SYNTHESIS

Generating Feasible Alternatives

Pragmatic Approach to Creativity:

Methods and Techniques

(e. g., brainstorming, morphological analysis)

- James Adams, *Conceptual Blockbusting*
- Michael Michalko, *Thinkertoys*
- Roger von Oech, *A Whack on the Side of the Head*

Confluence Approach to Creativity:

Convergence of Multiple Components

Intrinsic motivation, domain knowledge and abilities, creativity skills

- Teresa Amabile, *Creativity in Context*
- Abraham Maslow; David McClelland

PARAMETERIZATION AND ANALYSIS
(Often referred to as simply Analysis)

Problem Solving !

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RANKING AND SELECTION

Optimization Methods; Decision Analysis

Example (on 13-12 and 13-13)
from
John S. Hammond, Ralph L. Keeney and Howard Raiffa
Smart Choices: A Practical Guide to Making Better Life Decisions

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PROTOTYPE AND TESTING

(Includes additional Analysis)

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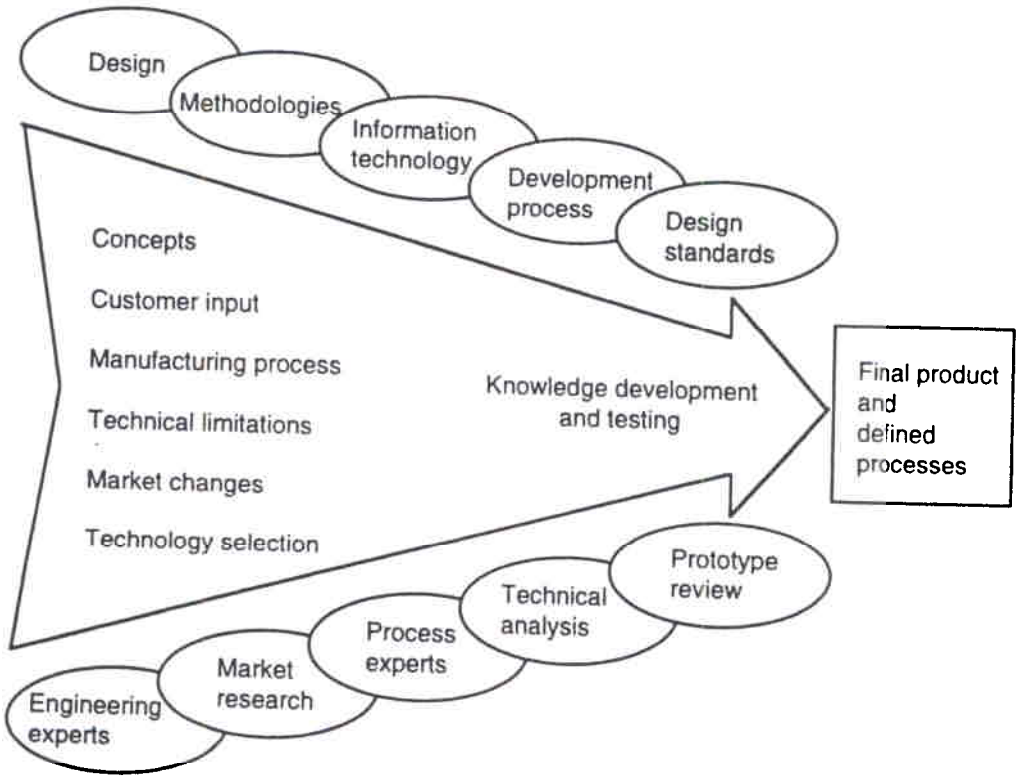
Consequences Table for the Mathers' New House

Objectives	Subobjectives	Alternatives				
		Amherst	*Eaton*	*School*	*Wade*	*West Boulevard*
Good location	**Commute time for Drew (one way)**	40 min. erratic	30 min. heavy	20 min.	15 min.	30 min.
	Commute time for Darlene	25 min. heavy	20 min. moderate	25 min. light	20 min.	15 min.
	Distance to school for John	Bus 10 min.	Bus 10 min.	Walk, 2 blocks	Walk, 5 min.	Walk, 4 blocks
	Distance to shops	Needs car, 5 min.	Needs car, 3 min.	Easy walk	Easy walk	Long walk
Quality of school	**% scoring above state norm**	90	65	55	95	70
	Basics (reading, math, science)	Very good	Passable	Poor	Very good	Good
	Music program	Good	Fine	None	Excellent	Just OK
	Athletic program	Superb	Poor	Very good	Good	Good
	High school quality	Very good	Good	Good	First-rate	Good
Quality of neighborhood	**Crime**	Some	Moderate	Low	Little	Mod. to high
	Traffic	Quiet street	Mod. rush hours	Moderate	Mod. rush hours	Mod. to high
	Playgrounds	Wonderful	So-so	Adequate	Pretty good	Poor
	Athletic facilities	Excellent	Adequate	Fine	Adequate	Good
	Kids close by	Some	Very few	Lots	Lots	Just a few
	Neighbors	New friends	Bothersome	Congenial	Compatible	Seem nice
Quality of house	**Bedrooms**	4, 2 small	4 small	3 small	3 large	3 average
	Bathrooms	Great	Adequate	Not good	Good	A problem
	Kitchen	A pleasure	Good	Good	Nice	Best part of house
	Family room	Adequate	Pitiful	Fine	Large, fireplace	Small
	Required maintenance	Good shape	Fine shape	Poor shape	Needs work	Mod.
	General aesthetics	Pleasant	Just OK	Poor	Pleasant	OK to good
Yard	**Size**	3,000 sq. ft.	5,000 sq. ft.	1,500 sq. ft.	4,000 sq. ft.	2,000 sq. ft.
	Garden (trees, shrubs)	Fine shape	Pedestrian	Awful	Needs work	Needs attention
	Suitability for dog	OK	Great	Not good	Good	Poor
	Suitability for kids	Perfect	Good	So-so	Fine	Poor to OK
Cost	**Asking price**	$225,000	$240,000	$175,000	$195,000	$180,000
	Real estate taxes	$3,500/year	$3,200/year	$2,200/year	$2,500/year	$2,300/year
	Other concerns	Low maintenance	—	High maintenance with renovation	Mod. maintenance	—
		Growth in equity				

Ranking the Alternatives for Each Main Objective for the Mathers' New House

Objectives	Alternatives				
	Amherst	*Eaton*	*School*	*Wade*	*West Boulevard*
Good location	5	4	2 (tie)	1	2 (tie)
Quality of school	2	4	5	1	3
Quality of neighborhood	1	4	2	3	5
Quality of house	1	3	5	2	4
Yard	1	3	5	2	4
Cost	5	4	1	3	2

Designing Well by Designing For
(Figure 13.8, Page 474)



Designing Well by Designing For

- **Concurrent Engineering**
- **Simultaneous Engineering**
- **Integrated Product Development**

- **DFM (manufacturing)**
- **DFA (assembly)**
- **DFF (fabrication)**
- **DFMA (manufacturing and assembly)**

- **DFX ~~**

  Design for:

  disassembly/disposability
  green/environmental
  maintainability/service evaluation
  inspection
  reliability
  life-cycle design

"Systems Design," by K. Preston White, Jr.
in *Handbook of Systems Engineering and Management*, A. P. Sage and W.B. Rouse, eds.

What should be gained from reading and studying this chapter?

(1) You should be able to define systems design and to describe an iterative design process.

(2) You should be able to describe some common difficulties encountered in the design process, and some approaches to ameliorating them.

(3) You should be able to identify and briefly describe a design tool.

(4) You should be able to describe at least one design theory.

(5) You should have the ability to convey a basic understanding of concurrent engineering, DFM, and DFX, as well as their relationships to one another and to systems design.

(6) You should be able to describe some common difficulties encountered in implementing concurrent engineering, DFM, and DFX concepts.

(7) You should be able to describe the applicability of concurrent engineering, DFM, and DFX concepts to your technical professional domain.