Multiple Criteria Decision Analysis for Industrial Engineering Methodology and Applications 1st edition Evans Solutions Manual

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Multiple Criteria Decision Analysis for Industrial Engineering: Methodologies and Applications

Chapter 2: Solutions to Exercises

2.1. Recall a situation where you encountered an ill-structured problem. Describe why this problem was ill-structured, as well as the solution approach you used. Did you start thinking of solutions right away or did you employ problem structuring techniques (even if you did not know them as such)? Based on the information gained in this chapter, describe how you might have approached the problem differently.

The answers here would depend upon the student's personal history. Examples of problems might include problems like (stated within the format of the "why-what's stopping" method): 1) How might I determine what to do after high school?, 2) How might I decide on what to do this summer?, 3) How might I decide where to go to college?, 4) How might I afford my expenses as a college student?, 5) How might I improve my grades?

2.2 Describe at least one ill-structured problem faced by each of the following organizations. What are the characteristics of this problem that makes it ill-structured?

a. The neighborhood/apartment complex in which you live.

b. The metropolitan area in which you live.

c. The academic department to which you belong.

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a. *Examples might include: parking and traffic issues, crime, and noise. With respect to the parking and traffic issues, it might not be clear who the stakeholders and decision makers are.*

b. *Examples for a metropolitan area might include problems related to crime, homelessness, traffic, jobs, etc.*

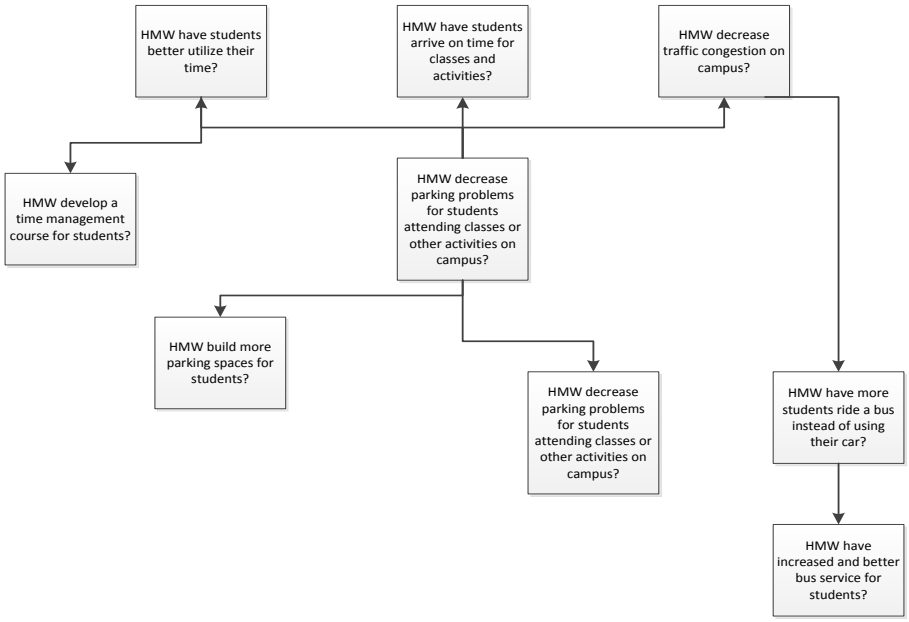
c. *Examples for an academic department of a university might include problems related to job opportunities for graduating students, hiring of an adequate number of faculty, recruitment of students, having a correct number and mix of courses each semester, starting a distance-based educational program, development of adequate classroom facilities, etc.*

Each of these problems would have one or more of the characterizing features associated with an ill-structured problem: existence of multiple DMs and stakeholders; multiple, conflicting performance measures; uncertainty/risk related to the outcomes associated with possible solutions; related problems associated with the original problem; good solutions not readily apparent.

2.3 Consider a problem faced by many students at a commuter university: "How might we decrease the parking problems for students attending classes or other activities on campus?" Using the "Why-What's Stopping" Technique, develop a problem map originating from this initial problem statement.

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Here is one example of a problem map. Note that this map could be expanded even further to allow for an even larger number of alternatives to examine.



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2.4 Consider the problem map associated with Figure 2.2. Develop several problem statements associated with answers to the question:

"What's stopping us from spending less money on reworking?"

Compare these newly generated problem statements to the ones already in Figure 2.2.

Answers to "what's stopping us from spending less money on reworking?" could be:

"How might we automate the rework process?",

"How might we make the personnel in the rework process work more efficiently?",

"How might we reschedule rework so that it works more efficiently with the rest of the facility?".

These would be just three of the answers. Additional answers could also be found.

2.5 Analyze the mission statements of three different organizations. Discuss how these statements reflect the values of these organizations.

For this exercise, it would probably be a good idea for students to select local organizations with which they would be familiar.

A good example of a mission statement is the one from Ford Motor Company: (see http://retailindustry.about.com/od/retailbestpractices/ig/Company-Mission-Statements/Ford-Motor-Mission-Statement.htm, accessed November 11, 2015):

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"ONE TEAM
People working together as a lean, global enterprise for automotive leadership, as measured by:

- *Customer, Employee, Dealer, Investor, Supplier, Union/Council, and Community Satisfaction*

ONE PLAN

- *Aggressively restructure to operate profitably at the current demand and changing model mix*
- *Accelerate development of new products our customers want and value*
- *Finance our plan and improve our balance sheet*
- *Work together effectively as one team*

ONE GOAL
An exciting viable Ford delivering profitable growth for all."

Note how all stakeholders and decision makers are mentioned at the outset. Note also the value placed on lean, leadership, teamwork, global perspectives, satisfying customers, and profitability among other values.

2.6 Suppose that a medical patient has a situation in which he or she can have an operation and thereby have a 90% chance of living for 10 years with a "quality of life" = .7; there is a 10% probability that he or she will die during or immediately after the operation. If he or she does not have the operation, then he or she can expect to live 5 years with a "quality of life"= .7. Assuming that the patient's criterion is to maximize the expected value of quality adjusted life years, compute the expected value of quality adjusted life years for each decision. Which decision should be taken under this criterion?

For the alternative: surgery, the expected value of quality adjusted life years is:

$$.9(.7(10)) + .1(0) = 6.3.$$

For the alternative: no surgery, the expected value of quality adjusted life years is:

$$1.(.7(5)) = 3.5.$$

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Hence, under this criterion, the optimal decision is the operation.

2.7 Identify the following attributes as being either natural or constructed in nature:

a. Prestige.

b. Cost.

c. Appearance.

d. Pain.

e. Reputation.

Typically, prestige, appearance, pain, and reputation would each be thought of as constructed attributes. Cost, typically measured in dollars, would be thought of as natural attributes.

2.8 Using a "top-down approach" for the development of a hierarchy of objectives and attributes is more appropriate for what type of problem (choose one):

a) A strategic problem.

b) A tactical problem.

A top down approach is more appropriate for a strategic problem.

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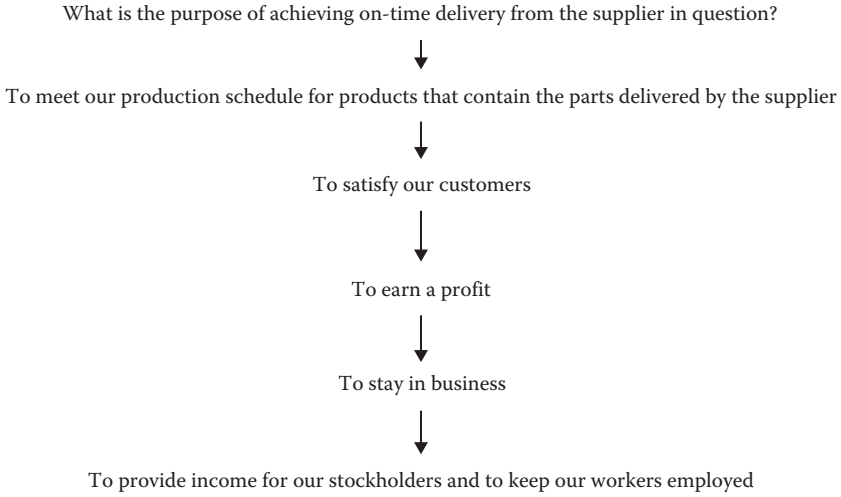


Figure 2.1
Purpose hierarchy associated with the problem of achieving on-time deliveries from a supplier.

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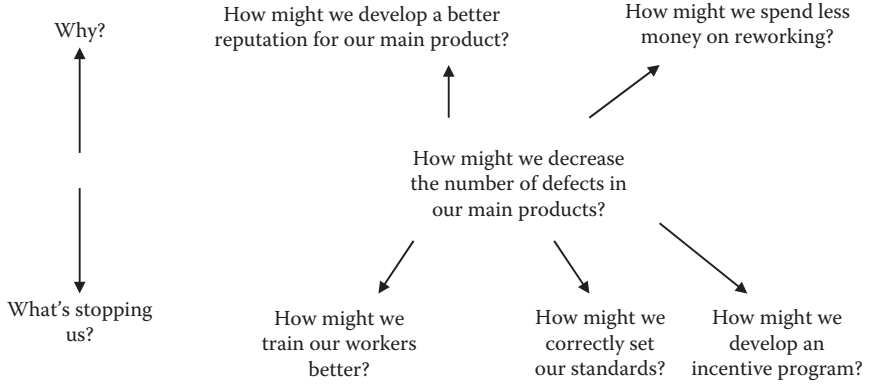


Figure 2.2
Part of a problem network resulting from applying the Why–What's Stopping technique.

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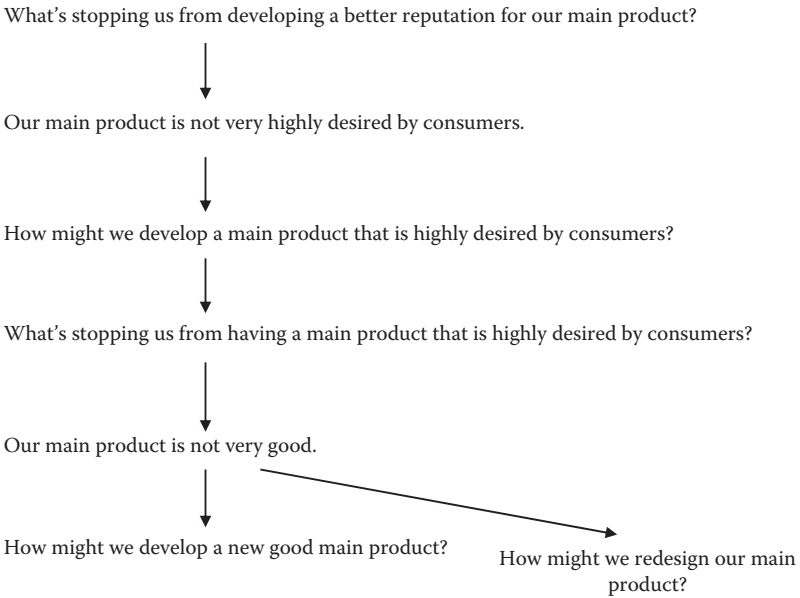


Figure 2.3
A partial problem network.

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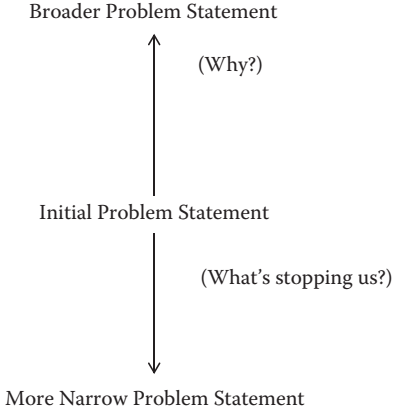


Figure 2.4
Network of problems resulting from the Why–What's Stopping technique.

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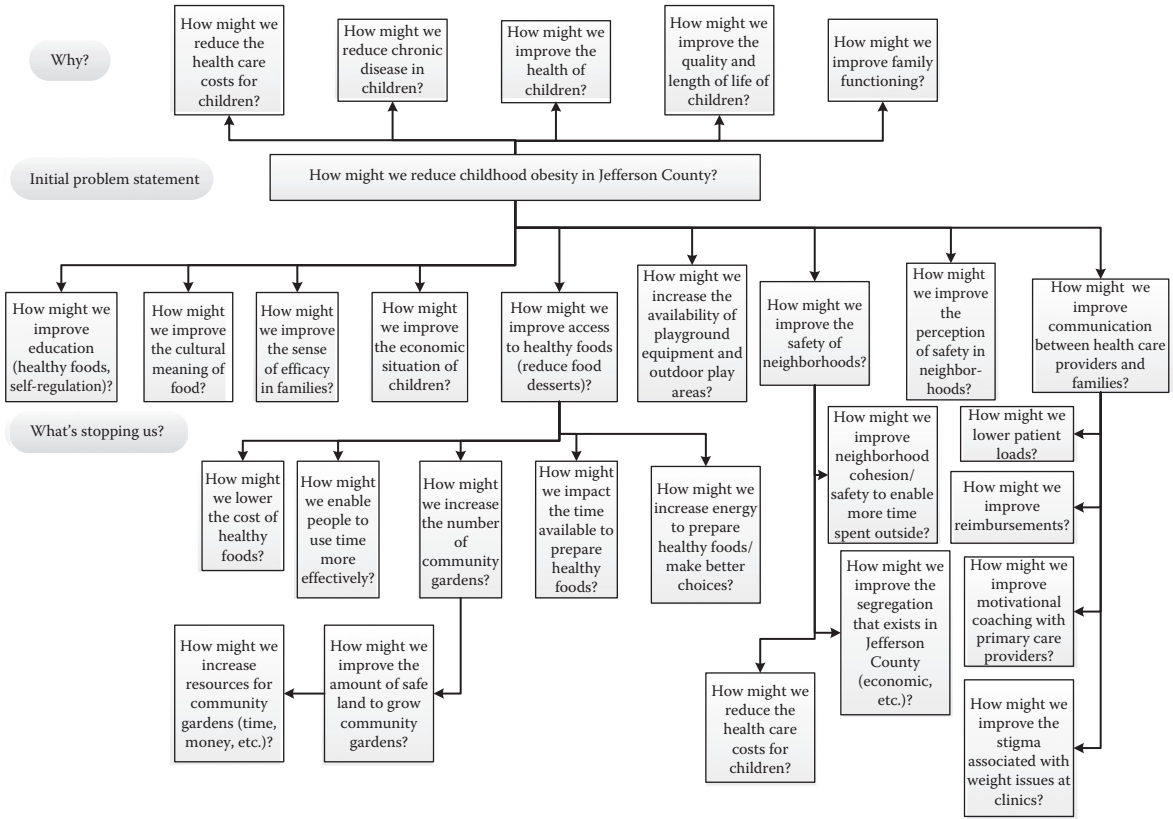


Figure 2.5
The WWS network as determined from interaction with staff of Healthy for Life Clinic.

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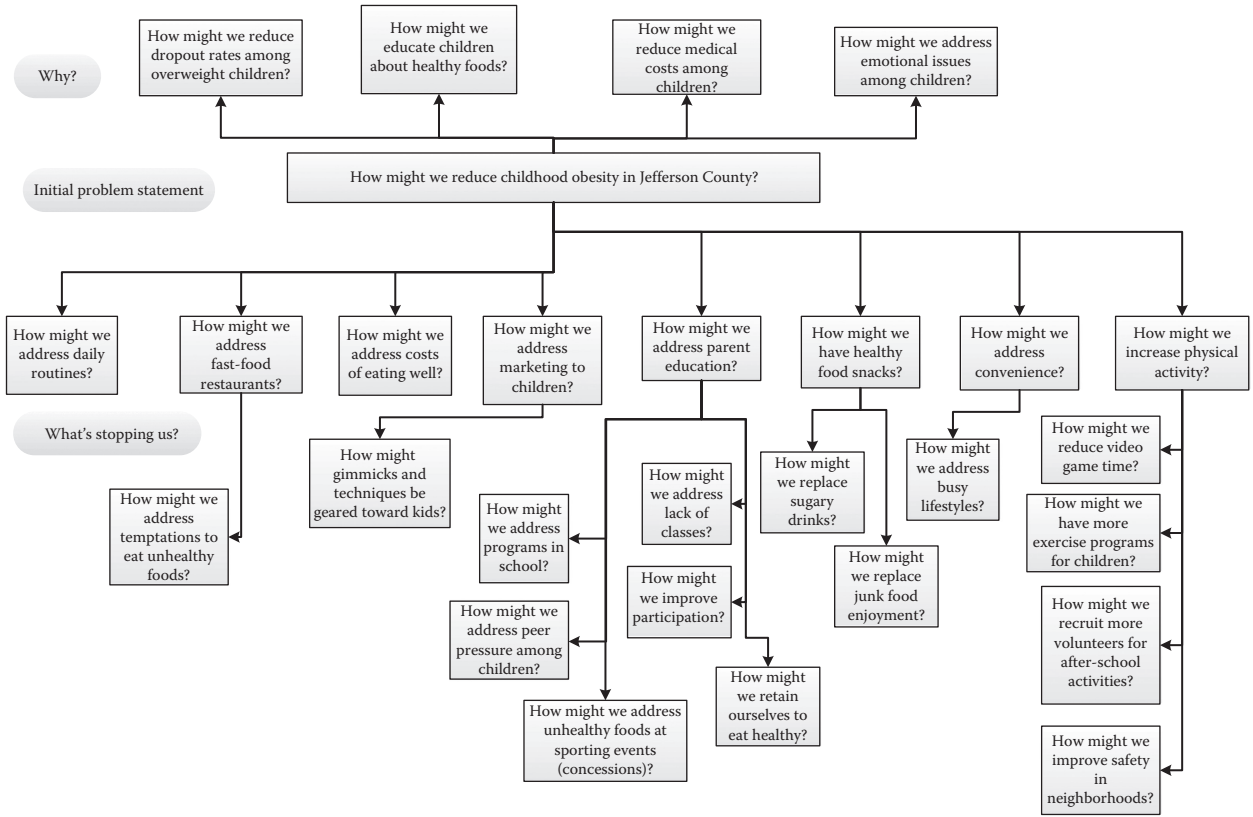
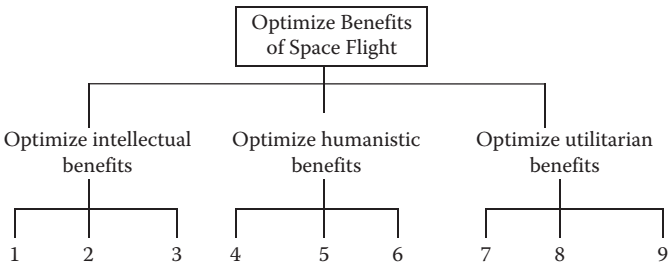


Figure 2.6
The WWS network as determined from interaction with parents of patients of Healthy for Life Clinic.

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Where the numbers denote the following subobjectives:

1. Optimize mapping morphology and mineralogy of the moon, planets, and asteroids.
2. Optimize benefits associated with research beyond the solar system.
3. Optimize benefits associated with improving our understanding of astronomy, biology, geology, and meteorology.
4. Optimize benefits associated with improving domestic/global communications.
5. Optimize benefits related to understanding/controlling of the earth's climate.
6. Optimize benefits associated with understanding of the earth's upper atmosphere.
7. Optimize benefits associated with the research and development of industrial processes.
8. Optimize benefits associated with providing services such as satellite repair, maintenance, and refueling.
9. Optimize benefits associated with mining of minerals and other resources.

Figure 2.7
Hierarchy of objectives associated with the benefits of space flight.

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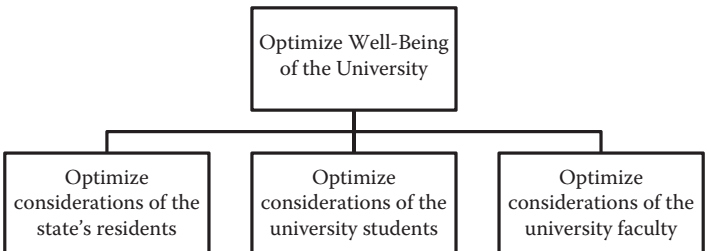


Figure 2.8
Partial hierarchy for considering strategic decisions at a public university.

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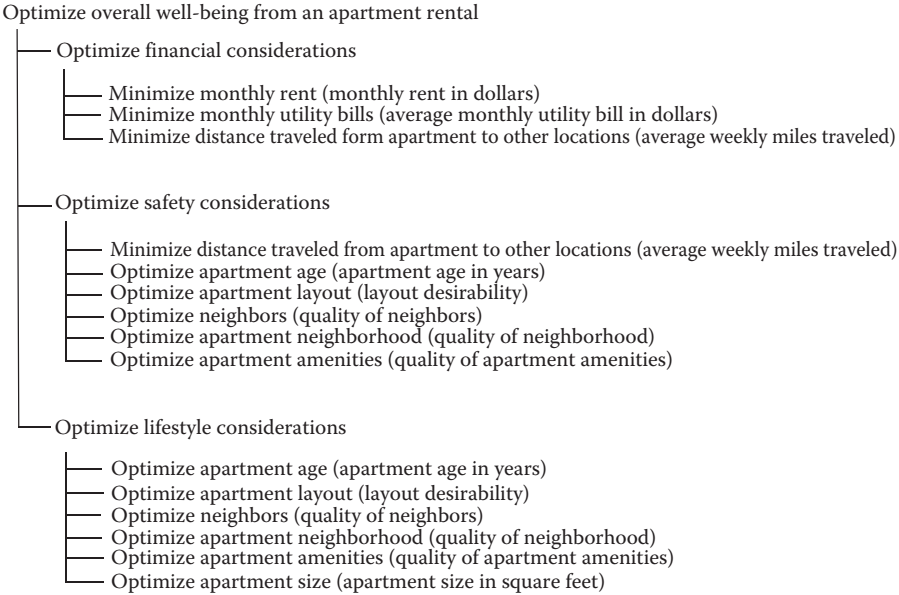


Figure 2.9
Hierarchy of fundamental objectives, means objectives, and attributes for an apartment rental decision.

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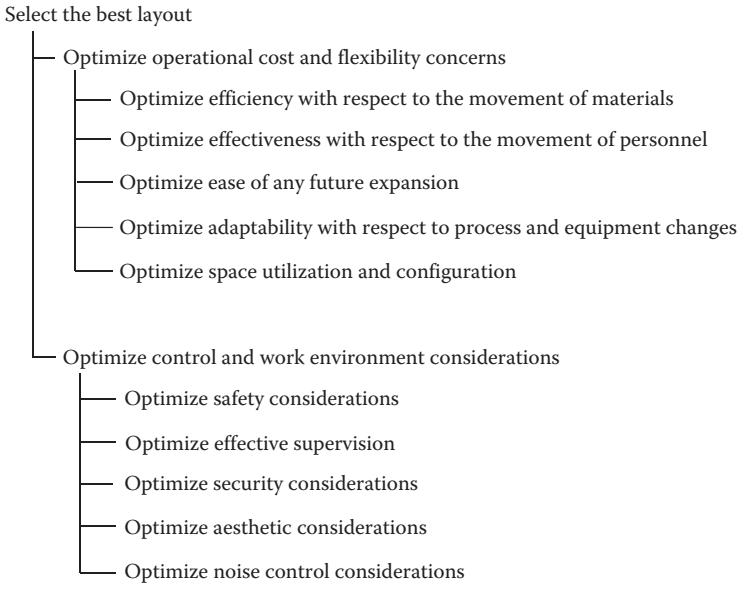


Figure 2.10
A hierarchy of objectives for layout design. (From Cambron, K. and Evans, G.W., *Comput. Ind. Eng.*, 20, 211, 1991.)

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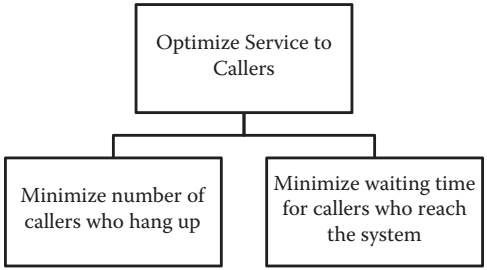


Figure 2.11
Sample portion of objective–attribute hierarchy for the determination of a staffing schedule for a call center.

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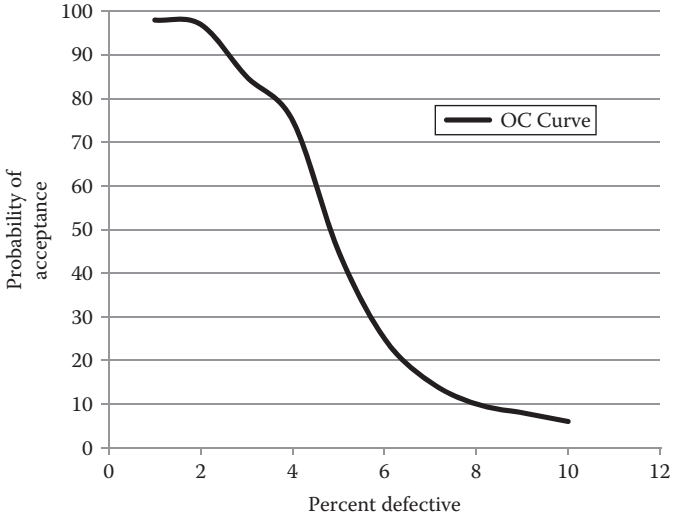


Figure 2.12
Operating characteristic curve for a particular sampling plan.

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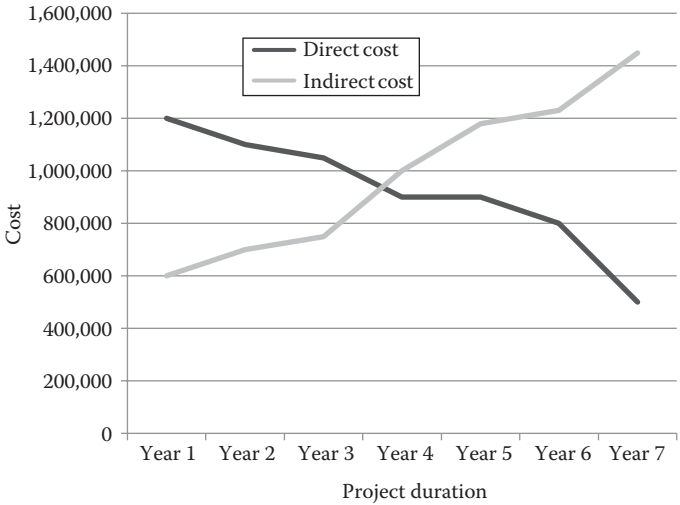


Figure 2.13
Relationships between project duration and direct/indirect costs of a project.

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MULTIPLE CRITERIA DECISION ANALYSIS FOR INDUSTRIAL ENGINEERING: METHODOLOGY AND APPLICATIONS

CHAPTER 2: PROBLEM STRUCTURING

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OUTLINE

- 2.1 Introduction
- 2.2 General Concepts
  - Definition and Types of Problems, Problem Structuring (PS): Importance and Definitions, Example PS Methods, Outputs of PS Methods
- 2.3 Breakthrough Thinking
- 2.4 Why-What's Stopping Technique
- 2.5 Additional Methods for Problem Structuring
- 2.6 Generating Objectives and Attributes for a Decision Situation
  - Terminology: Criteria, Values, Objectives, Goals, Constraints, and Attributes
  - Formation of a Hierarchy of Objectives and Attributes: Mission Statements, Techniques, Examples from the Literature
- 2.7 Important Attributes for Specific Categories of Decision Situations
  - Engineering Economics
  - Location and Layout Design
  - Quality Management
  - Project Management
  - Medical Decision Making and Health Care Management

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CHAPTER 2.1 INTRODUCTION

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INTRODUCTION

- Many initially encountered problems:
  - *are not set up for the application of classical DA techniques;*
  - *i.e., related problems, stakeholders and decision makers, alternative solutions, sources of uncertainty/risk, and relevant performance measures among other problem aspects, need to be identified*
- **Problem structuring (PS) methods** address these issues.
- Two categories of methods:
  - *Broader methods used for providing perspective on a problem*
    - *Why-What's Stopping technique*
    - *Breakthrough Thinking*
  - *More specific methods, used for generating the objectives and attributes (performance measures) for the decision situation, typically in the form of a hierarchy*

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EXAMPLE APPLICATIONS OF PS TECHNIQUES

- Policy analysis for the Home Office Prison Department of the United Kingdom (*Eden and Ackermann, 2004*),
- Reduction of electromagnetic field exposure from electric power lines (*Von Winterfeldt and Fasolo, 2009*),
- Organizational restructuring of the manufacturing function at Shell (*Checkland and Scholes, 1990*),
- Quantification of delay and disruption of a litigation process (*Ackermann, Eden, and Williams, 1997*), and
- Management of a housing co-op (*Thunhurst and Ritchie, 1992*).

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CHAPTER 2.2
GENERAL CONCEPTS

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GENERAL CONCEPTS

- Definitions of a **"problem"** (Evans, 1991):
  1) *a gap to be circumvented,*
  2) *a felt difficulty,*
  3) *a dissatisfaction with the current state of affairs,*
  4) *a **perception** of a variance between the present and some desired state of affairs,*
  5) *an undesirable situation.*

- Each definition connotes the concept of a **gap** between a **current** state of affairs and a **desired** state of affairs.

Note that the "State of affairs" implies a **set of performance measures.*

GENERAL CONCEPTS

- "Gaps" are
  - **Negative**: "drop" in performance.
    - *A machine has all of a sudden started producing many defective parts.*
  - **Positive**: Opportunity perceived.
    - *Land (Callahan, 1972), attributed his Polaroid camera invention to his ability to discover and define a problem in terms of an opportunity.*
  - **Unknown**: significant change in the base state of affairs
    - *New technology developed*

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GENERAL CONCEPTS

- Three types of problems (Simon, 1960):
  - **Well-structured** (course level):
    - *alternatives are obvious, objectives are clear; routine in nature*
  - **Semi-structured**
  - **Ill-structured** (real-life):
    - *little or no data and unclear performance measures*
    - *alternatives not readily apparent; complex in nature, non-routine, and difficult to define*
    - *the relevant DMs and stakeholders, are often not obvious*

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GENERAL CONCEPTS

- Examples of well-structured problems:

We must choose one of two possible vendors to supply a particular purchased part. We have all of the relevant data on both vendors (cost, quality, schedule performances, etc.) Which vendor should be chosen?

Our firm needs to locate a new manufacturing facility in one of four possible locations. All relevant data (e.g., transportation costs, taxes, incentives, potential pool of personnel) has been collected, and we know our criterion. Which location should be chosen?

- Examples of ill-structured problems:

Our employees seem dissatisfied. What, if anything, should we do about it?

Our company is losing market share. How can we change this trend?

The country's social security system will go broke within 25 years if nothing is done. Should we do something about this, and, if so, what?

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GENERAL CONCEPTS

- A project involving some application of decision analysis may have **failed**, not because of a lack of expertise or effort in solving the problem as defined, but because **the problem was not defined correctly in the first place**:

  - ***"There is an old saying that a problem well put is half-solved. This much is obvious. What is not so obvious is how to put a problem well."*** (Churchman, Ackoff, and Arnoff, 1957).

  - ***"70 percent of the value added of operations research is the correct framing and formulation of the problem."*** (Larson, 2004).

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GENERAL CONCEPTS

- Problem Structuring:
  - *A critical step in the problem solving process, especially for ill-structured problems.*
  - *Preliminary to the other steps of the problem solving process, such as data collection, interviews, development of simulation/other types of models, model experimentation, sensitivity analysis, etc.* (Pidd ,1989)

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DEFINITIONS OF PROBLEM STRUCTURING

- "The activity of identifying relevant variables in the problem situation, as well as establishing relationships between the variables" (*Pitz, Sachs, and Heeboth,1980*)
- A process "by which some initially presented conditions and requests become a set of issues for further research" (*Pidd ,1989*)
- "The problem of formulating the present set of conditions, symptoms, and causes and triggering events into a problem or set of problems sufficiently well specified so that the risk of using analytic procedures to solve the wrong problem has been minimized" (*Shwenk and Thomas,1983*)

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SYSTEMS OF PROBLEMS

- Every problem is actually part of a **network** of problems (a **problematique**, a **mess**)
- Understanding this network and the **relationships** between the problems in the network is an important part of the problem structuring process
- Use **hierarchies**, **networks**, and **matrices** to represent the relationships among problem elements

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OPTIMISTIC ATTITUDE AND DIVERGENT THINKING

- An **optimistic** attitude is important (opportunity).
- **Divergent** rather than **convergent** thinking.

CHARACTERISTICS OF ILL-STRUCTURED PROBLEMS ADDRESSED BY PS TECHNIQUES

- **Several** decision makers and stakeholders.
- **Multiple** (conflicting) performance measures.
- Large amounts of **uncertainty** (and related **risk**) associated with parameters and relationships of the problem.
- An entire **network** of problems to which the original ill-structured problem is related.
- Good **alternative solutions** to the problem not readily apparent.

PS METHODS

- **Participative** and **interactive.**
- **Decision Makers/Stakeholders (with different perspectives)**



Analyst

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EXAMPLE PS METHODS

- The Kepner and Tregoe Method (*Kepner and Tregoe, 1965*)
- Cause and Effect Diagrams (*Chapter 12 of Wilson, 1993*)
- Soft Systems Methodology (*Reisman and Oral, 2005*)
- Stairstepping (*Huge, 1990*)
- Brightman's Alternative Worldview Method (*Brightman, 1988*)
- Cognitive Mapping (*Eden, 2004*)
- Mind-Mapping (*Chapter 12 of Wilson, 1993*)
- The Five W's and H Technique (*Chapter 3 of VanGundy, 1988*).
- Dimensional Analysis (*Chapter 3 of VanGundy, 1988*).
- The Smith Framework (*Smith, 1989*).
- Breakthrough Thinking (*Nadler and Hibino, 1990*)
- The Why-What's Stopping Approach (*Basadur, Ellspermann, and Evans, 1994*)

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OUTPUTS ASSOCIATED WITH PROBLEM STRUCTURING METHODS

- A Network of Associated Problems
- A Set of Decision Makers and Stakeholders
- Good Alternative Solutions
- Relationships Between Important Variables
- Key Risks and Uncertainties
- A Hierarchy of Objectives and Attributes (Performance Measures)

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CHAPTER 2.3
BREAKTHROUGH THINKING

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BREAKTHROUGH THINKING

- See book by *Nadler and Hibino (1990)*.
- Its roots lie in the Purpose Design Approach of Nadler and Hibino.
- Used not only for problem structuring, but also for determining **problem solution** and **solution implementation**.

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BREAKTHROUGH THINKING

- Based on the Application of 7 core principles:
  - ***The Uniqueness Principle.***
  - ***The Purposes Principle.***
  - ***The Solution After Next (SAN) Principle.***
  - ***The Systems Principle.***
  - ***The Limited Information Collection Principle.***
  - ***The People Design Principle.***
  - ***The Betterment Timeline Principle.***

Breakthrough Thinking: **The Uniqueness Principle**

- Every problem is unique (running counter to the old adage: "do not reinvent the wheel").
- Problems which may appear to be the same at the outset will differ in terms of different time periods, different environments, and different sets of stakeholders, decision makers, available technologies for solution, etc.
- Turnkey solutions normally require substantial modifications.
- Example: building a simulation model of a distribution system for two different organizations
  1) *the decision makers have quite different technological backgrounds.*
  2) *data availabilities for the two organizations are different.*
  3) *simulation software packages owned by the two organizations are quite different.*

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BREAKTHROUGH THINKING: **THE PURPOSES PRINCIPLE**

- Prior to doing **anything**, one should have a **purpose** for doing it.

- Examples:
  - *What is the **purpose** of **solving this problem**?*
  - *What is the **purpose** of **collecting this data**?*
  - *What is the **purpose** for **this meeting**?*

BREAKTHROUGH THINKING: **THE PURPOSES PRINCIPLE**

- Four elements associated with a purpose:
  - ***function***,
  - ***values/goals***,
  - ***performance measures***, *and*
  - ***objectives.***

- One can develop a **purposes hierarchy** which allows **for varying perspectives**.

Note that a Purposes Hierarchy might allow for the **generation of alternative solutions not readily apparent from an isolated consideration of the initial problem only.*

BREAKTHROUGH THINKING: **THE PURPOSES PRINCIPLE**

- **Example Purposes Hierarchy:**

What is the purpose of achieving on-time delivery from the supplier in question?

↓

To meet our production schedule for products that contain the parts delivered by the supplier.

↓

To satisfy our customers

↓

To earn a profit

↓

To stay in business

↓

To provide income for our stockholders and to keep our workers employed.

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BREAKTHROUGH THINKING: **THE SOLUTION AFTER NEXT PRINCIPLE**

- ***Solution after Next* (SAN)** principle refers to the fact that often there is another problem that will occur after a solution to the initial problem is implemented, and that this problem should be foreseen and planned for.



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BREAKTHROUGH THINKING: **THE SOLUTION AFTER NEXT PRINCIPLE**

- Example:
  - **Problem**: *inefficient production system.*
  - **Solution**: *installation of a new computerized production control system.*
  - **New Problem**: *employees not trained in new production system.*
  - **Solution**: *training program for employees.*

BREAKTHROUGH THINKING: **THE SYSTEMS PRINCIPLE**

- Used to address the **unintended consequences** that often occur when a solution to a problem is implemented.

- Example (of unintended consequences):
  - ***FAA law*** *requiring that parents be required to purchase a separate ticket for their children under the age of two for airline flights (rather than holding child on lap).*
  - ***Intended consequence:*** *increased safety for infants.*
  - ***Unintended consequence:*** *many more parents would drive rather than fly due to the cost, and since driving is much less safe than flying, many more infants would be injured or killed (Machol, 1996).*

- Reason for not considering unintended consequence: consideration of only the **air transportation system**, and not its **interface** with the **personal auto transportation system**.

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BREAKTHROUGH THINKING: **THE SYSTEMS PRINCIPLE**

- **Systems matrix:**
  - *helpful in the consideration of the systems principle*
  - *allows one to show the relationships between two different categories of elements associated with a system*
  - *relates alternative solutions to performance measure values*

- **House of Quality** (*Bossert, 1991*) is an example of a systems matrix
  - *allow one to relate product characteristics to engineering characteristics, engineering characteristics to part characteristics, part characteristics to process plans, etc*

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BREAKTHROUGH THINKING: **THE SYSTEMS PRINCIPLE**

- Systems Matrix for FAA Law Implementation Decision

	Projected Annual Airline Travel Deaths	**Projected Annual Auto Travel Deaths**
Safety Law Implemented		
Safety Law Not Implemented		

BREAKTHROUGH THINKING: **THE LIMITED INFORMATION COLLECTION PRINCIPLE**

- A special case of the **Purposes Principle**.
- **Limited Information Collection Principle:** one should always have some **purpose** for collecting data, prior to the collection/gathering process.
- **Too much data** often obscures the problem structuring process.
- **False sense of security** when one uses a lot of data.
- Collect data with a clear understanding of its **underlying meaning** or of the **underlying processes**.

BREAKTHROUGH THINKING: **THE PEOPLE DESIGN PRINCIPLE**

- **Different perspectives** are usually extremely useful in the problem structuring process.
- Aids in **divergent thinking.**
- Allows for **buy in** by a large number of stakeholders in the solution implementation phase.

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BREAKTHROUGH THINKING: **THE BETTERMENT TIMELINE PRINCIPLE**

- A **schedule** should be developed for improving on a solution once it is implemented.
- Closely related to the **Solution After Next Principle.**
- Nicely complements the concept of **Continuous Improvement.**
- Requires the use of **Monitoring** and **Control Systems** (as in **Project Management**).

CHAPTER 2.4
THE WHY-WHAT'S STOPPING TECHNIQUE

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THE WHY-WHAT'S STOPPING TECHNIQUE

- Every problem exists within a **system** or **network** of problems (*Ackoff, 1981*).
- In order to be sure that the **"right"** problem is being addressed, one should be aware of this network of problems
- The network of problems is helpful in generating **alternatives** and **performance measures**, and in evaluating the effect of various alternatives on a system-wide basis.

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THE WHY-WHAT'S STOPPING TECHNIQUE

- Interactive, participatory technique involving a **facilitator** and a group of **decision makers and stakeholders**.
- **Input**: an initial problem statement.
- **Output**: a **network** of problem statements, with the more general problem statements at the top of the network, and the more specific problem statements (e.g., alternatives) at the bottom of the network.
- All problem statements begin with the phrase: **"How might we/I …"** (optimistic tone) – allows a viewpoint in which the problem is perceived as an opportunity.

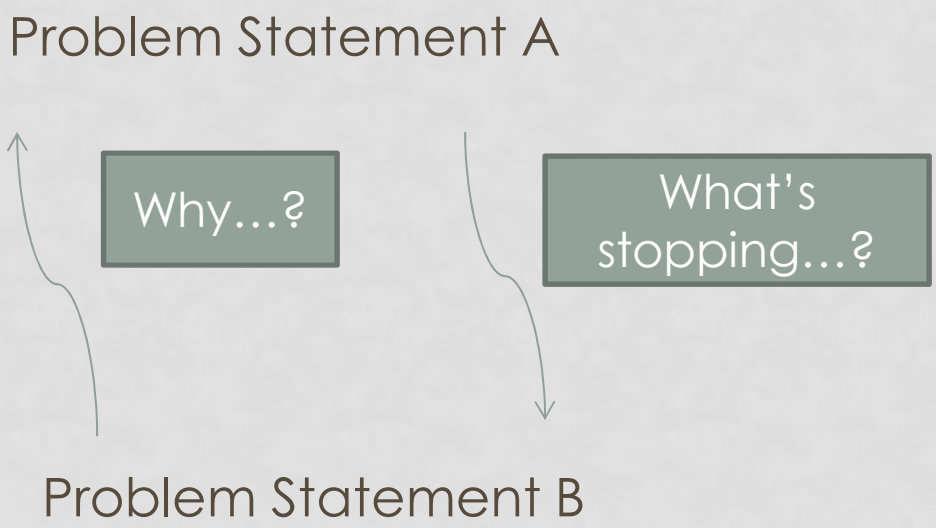
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THE WHY-WHAT'S STOPPING TECHNIQUE

- Starting from the initial problem statement, ask:
  - **"Why…?"** or **"why else…?"** to generate more general problem statements and expand network upwards.
  - **"What's stopping us/me…"** or **"what else is stopping us/me…?"** to generate more specific problem statements and expand network downwards.
- Divergent thinking implies **no evaluation** and **no/little criticism** of responses.

THE WHY-WHAT'S STOPPING TECHNIQUE

- **Reverse** process should work correctly:



THE WHY-WHAT'S STOPPING TECHNIQUE

- When to stop the process:
  - **Upwards**: *when the problem statement becomes "How might we/I achieve happiness and bliss".*
  - **Downwards**: *when the problem statement is "How might we/I do …" (i.e., the statement is a solution alternative, and the only way to address the problem is to "just do it").*

THE WHY-WHAT'S STOPPING TECHNIQUE: EXAMPLE

- Initial problem statement:

  "There are too many defects in our main product".

- Transform to:

  "***How might we*** *reduce the number of defects in our main product?"*

THE WHY-WHAT'S STOPPING TECHNIQUE: EXAMPLE

- Now ask the question:

  "***Why*** *do we want to reduce the number of defects in our main product?*"

- Answer(s):

  "So that our main product has a better reputation", and (from "why else"):

  "So that we can spend less money in reworking".

THE WHY-WHAT'S STOPPING TECHNIQUE: EXAMPLE

- These latter two problem statements are restated as:

"***How might we*** *obtain a better reputation for our main product?*"

and

"***How might we*** *spend less money on rework?*"

THE WHY-WHAT'S STOPPING TECHNIQUE: EXAMPLE

- Now, answers to the question:
  - *"**What's stopping us** from reducing the number of defects in our main product?"*

- might be:

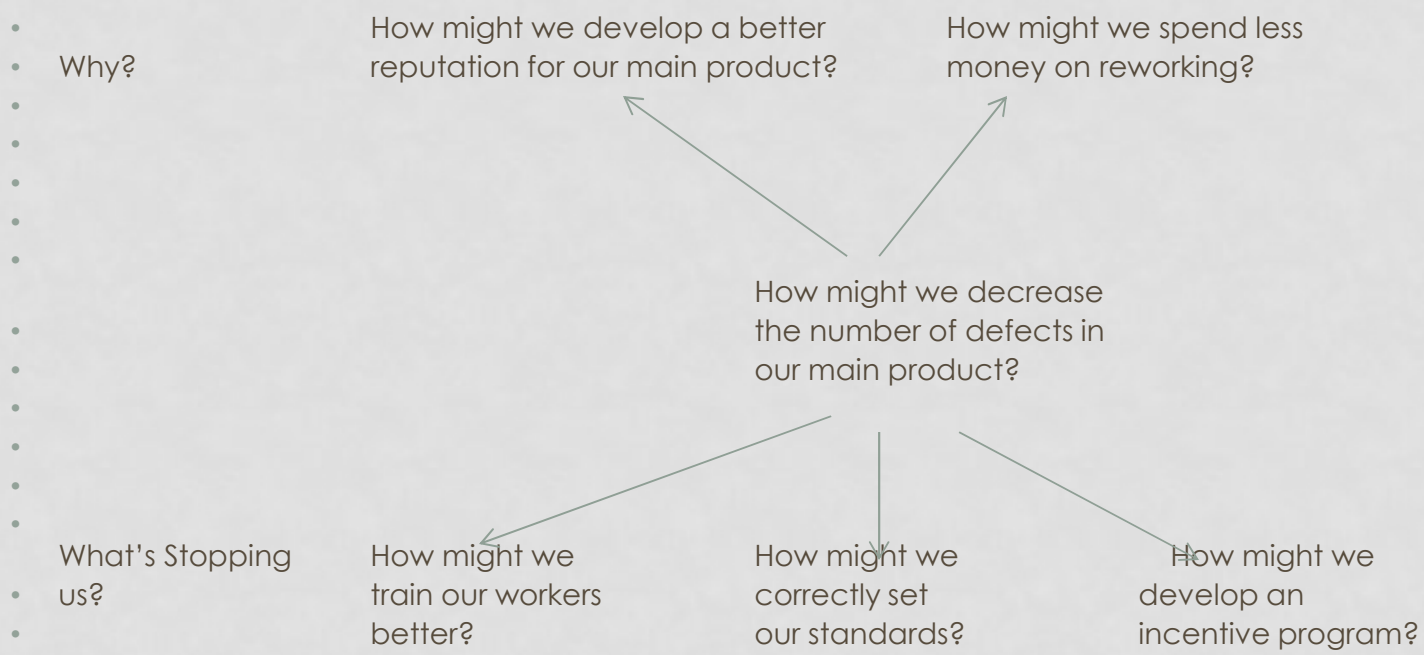
  "Our workers are not well-trained",

  "Our standards are too high",

  "We have no incentive program to reward our workers for quality work".

THE WHY-WHAT'S STOPPING TECHNIQUE: EXAMPLE

- At this point, we have expanded from one problem statement to 6 problem statements:



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THE WHY-WHAT'S STOPPING TECHNIQUE: EXAMPLE

- The "reverse question" should be asked as a "check" throughout the process:
- For example, the answer to the question:
  - ***"What's stopping us from developing a better reputation for our main product?"***
- should be:
  - ***"We have too many defects in our main product."***

THE WHY-WHAT'S STOPPING TECHNIQUE

- The answers given to the "why questions" result in problem statements corresponding to a **higher level** perspective than the problem statement used to generate the "why question".
- Problem statements resulting from the "what's stopping us questions" result in problem statements corresponding to a **lower level** perspective than the problem statement used to generate the "what's stopping us question".
- One could extend either **upwards** (by asking the "why question") or **downwards** (by asking the "what's stopping question") from **any** problem statement in the network.

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THE WHY-WHAT'S STOPPING TECHNIQUE

- Partial Problem Network
  - *Focusing on a **specific part** of the problem network rather than some other part can very easily lead to solutions that would not have been thought of otherwise.*

What's stopping us from developing a better reputation for our main product?

↓

Our main product is not very highly desired by consumers.

↓

How might we develop a main product that is highly desired by consumers?

↓

What's stopping us from having a main product that is highly desired by consumers?

↓

Our main product is not very good.

How might we develop a new good main product?

How might we redesign our main product?

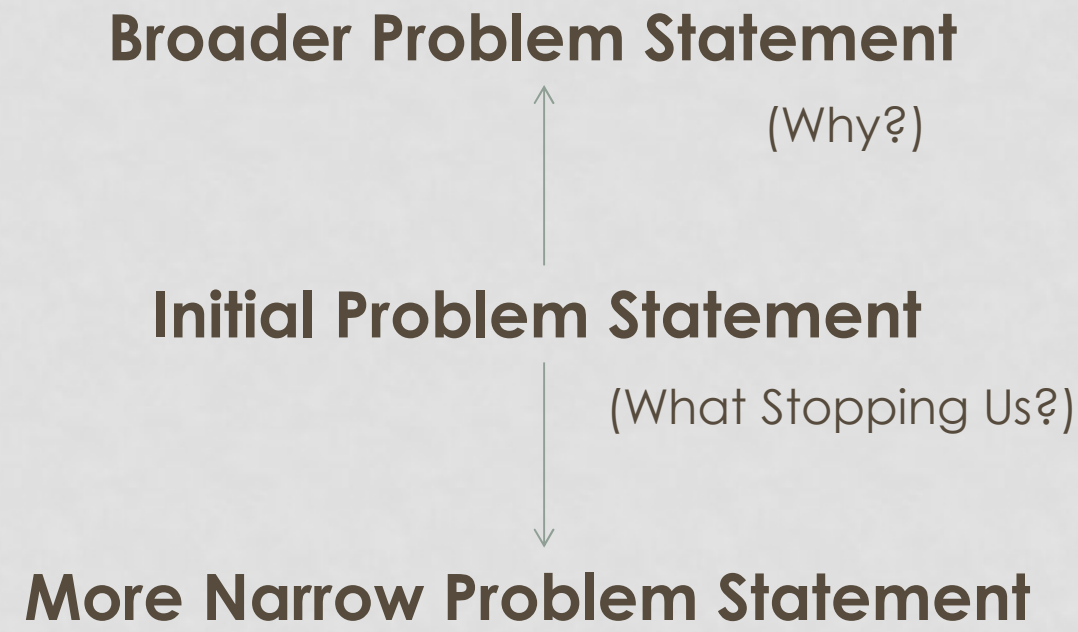
THE WHY-WHAT'S STOPPING TECHNIQUE

- Overview
  - *Allows the focus to shift from one problem to another.*
  - *Some of the answers, in addition to providing alternative problem statements, also provide solution alternatives.*
  - *One needs to be concerned with how far to extend the problem map.*
  - *Keep in mind that the basic purpose of the technique is to allow a "better" problem formulation.*

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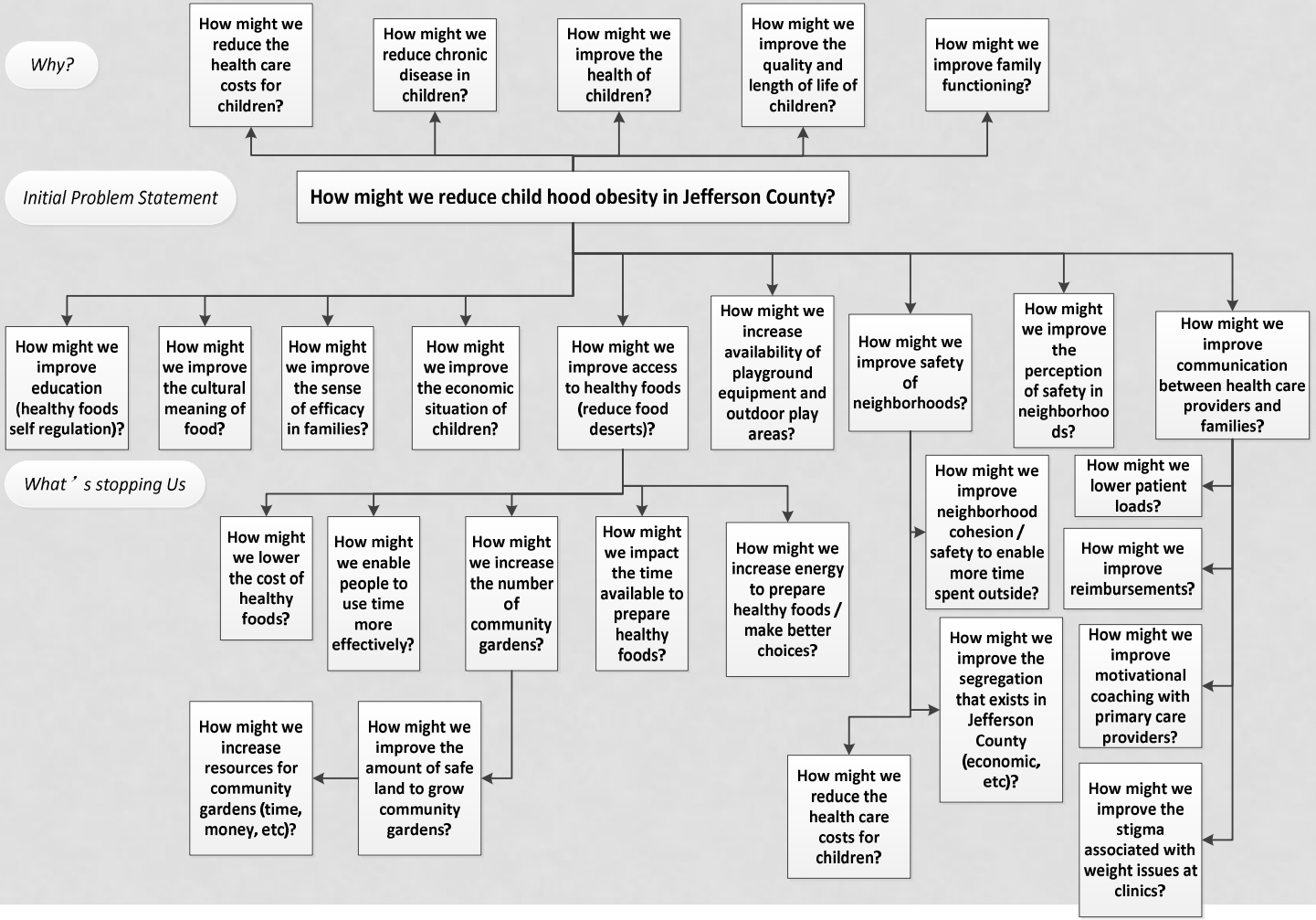
THE WHY-WHAT'S STOPPING TECHNIQUE

- Overview



THE WHY-WHAT'S STOPPING TECHNIQUE

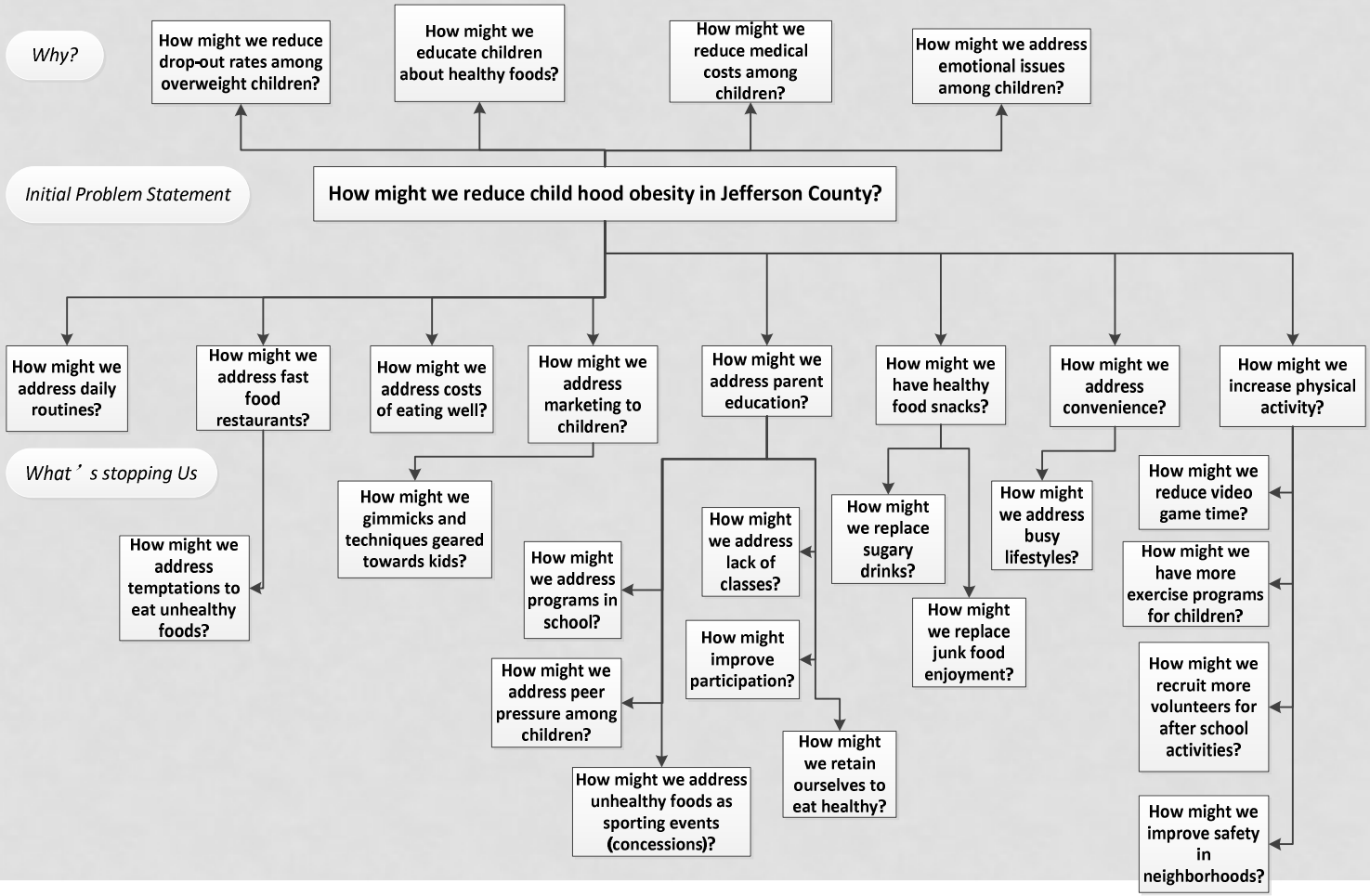
- WWS Network Determined from Interaction with Staff of Healthy for Life Clinic



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THE WHY-WHAT'S STOPPING TECHNIQUE

- WWS Network Determined from Interaction with Parents' of Patients of Healthy for Life Clinic



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CHAPTER 2.5
ADDITIONAL METHODS FOR PROBLEM STRUCTURING

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ADDITIONAL METHODS FOR PROBLEM STRUCTURING

- The *Kepner and Tregoe Method*
  - Not only an approach to problem structuring, but even more broadly as an approach to problem solving.
  - Four "patterns of thinking" (Four questions)
    - ***Assessing and clarifying (what's going on?).***
    - ***Cause and effect (why did this happen?).***
    - *Making choices (which course of action should we take?).*
    - *Anticipating the future (what lies ahead?).*

ADDITIONAL METHODS FOR PROBLEM STRUCTURING

- Cognitive Map
  - *A "representation of thinking about a problem that follows from the process of mapping" (Eden, 2004).*
  - *Consists of **nodes** and **arrows**, nodes represent statements concerning a problem and the arcs represent causality.*
  - *Leads to the development of a related influence diagram.*
  - *A computer software package (Decision Explorer) has also been developed as an aid for cognitive mapping.*

ADDITIONAL METHODS FOR PROBLEM STRUCTURING

- Other problem structuring techniques/approaches
  - *Mind-Mapping (Buzan, 1983).*
  - *Cause and Effect Diagrams (Ishikawa, 1990).*
  - *Stairstepping (Huge, 1990).*
  - *Brightman's Alternative Worldview Method (Brightman, 1988).*
  - *The Five W's and H Technique (Chapter 3 of VanGundy, 1988).*
  - *Dimensional Analysis (Chapter 3 of VanGundy, 1988).*
  - *Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis (Fine, 2009).*
  - *The Smith Framework (Smith, 1988).*

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CHAPTER 2.6
GENERATING OBJECTIVES AND ATTRIBUTES FOR A DECISION SITUATION

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TERMINOLOGY: CRITERIA, VALUES, OBJECTIVES, GOALS, CONSTRAINTS, AND ATTRIBUTES

- A **criterion** is "a standard on which a judgment or decision may be based" (http://www.merriamwebster.com/dictionary/criteria).
- **Values** are "principles used for evaluation" (Keeney (p. 6 , 1992)).
  - *By focusing on one's **values**:*
    - *more and better **alternatives** can be generated.*
    - *A good set of **attributes** can be generated.*
- An **objective** can be thought of as a desired direction of improvement for some performance measure.
  - *Objectives for a particular situation are typically **conflicting** in nature.*
- A **goal** is a desired level for a performance measure.
- A **constraint** is a restriction placed on a performance measure value.
- **Attributes** are the **performance measures** that we use to evaluate decisions.

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ATTRIBUTES

- An **attribute** can be thought of as a measure of how well an objective is achieved.
- Note that an attribute should be defined in such a way, as much as possible, so that there is **no question as to its interpretation**.
- Four types of attributes:

natural and nonproxy	*constructed and nonproxy*
natural *and* ***proxy***	***constructed*** *and* ***proxy***

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NATURAL VS. CONSTRUCTED ATTRIBUTES

- An attribute will be either **natural** or **constructed** (no question).
- **Natural Attributes**:
  - *Preferred over a constructed attribute.*
  - *Quantitative in nature.*

- **Constructed Attributes**:
  - *Interpretation of meaning **not as clear** as with a natural attribute.*
  - ***subjective** in nature, and also normally require the **use of a scale** with numbers and associated meanings assigned to the numbers.*
  - *Typically associated with objectives that are **nebulous** in nature (often higher in the objectives hierarchy).*

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NATURAL ATTRIBUTES: EXAMPLES

Objective	Natural Attribute
Minimize Transportation Cost	*Transportation Cost in Thousands of Dollars*
Minimize Mean Number of Defective Parts Produced per Day Over the Month of May	*Mean Number of Defective Parts Produced per Day Over the Month of May*
Minimize Cost per Purchased Part for Vendor Selected	*Cost per Purchased Part for Vendor Selected*

CONSTRUCTED ATTRIBUTES: EXAMPLES

Optimize **Reputation** of Selected Vendor	**Reputation as measured on a subjective scale**
Optimize **Quality of Written Report**	*Quality as measured on a subjective scale*
Optimize **Comfort**	*Comfort as measured on a subjective scale*
Minimize **Pain**	*Pain as measured on a subjective scale*
Optimize **Public Acceptance**	*Public Acceptance as measured on a subjective scale*
Optimize **Appearance**	*Appearance as measured on a subjective scale*

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CONSTRUCTED ATTRIBUTES: EXAMPLE OF A SUBJECTIVE SCALE FOR "QUALITY OF A WRITTEN REPORT"

4--Excellent	***Clearly identifies the purpose including all complexities of relevant questions. Accurate, complete information that is supported by relevant evidence. Complete, fair presentation of all relevant assumptions and points of view. Clearly articulates significant, logical implications and consequences based on relevant evidence.***
3--Good	*Clearly identifies the purpose including some complexities of relevant questions.* *Accurate, mostly complete information that is supported by evidence.* *Complete, fair presentation of some relevant assumptions and points of view.* *Clearly articulates some implications and consequences based on evidence.*
2--Satisfactory	*Identifies the purpose including irrelevant and/or insufficient questions.* *Accurate but incomplete information that is not supported by evidence.* *Simplistic presentation that ignores relevant assumptions and points of view.* *Articulates insignificant or illogical implications and consequences that are not supported by evidence.*
1--Poor	*Unclear purpose that does not includes questions.* *Inaccurate, incomplete information that is not supported by evidence.* *Incomplete presentation that ignores relevant assumptions and points of view.*

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CONSTRUCTED ATTRIBUTES: EXAMPLE OF A SUBJECTIVE SCALES FOR "AMOUNT OF PAIN"

- Amount of Pain (*taken from: S.C. Hodder et al, "Multiattribute utility assessment of outcomes of treatment for head and neck cancer," British Journal of Cancer 75 (6), 898-902, 1997*).

Score	Description
1	*No Pain*
2	*Pain requiring intermittent mild analgesics (paracetamol)*
3	*Pain requiring analgesics (paracetamol or non-steroidal)*
4	*Pain requiring non-steroidal or intermittent synthetic opiates*
5	*Pain requiring regular opiates*

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CONSTRUCTED ATTRIBUTES: EXAMPLE OF A SUBJECTIVE SCALES FOR "AMOUNT OF NAUSEA"

- Amount of Nausea (*taken from: S.C. Hodder et al, "Multiattribute utility assessment of outcomes of treatment for head and neck cancer," British Journal of Cancer 75 (6), 898-902, 1997*).

Score	Description
1	*No Nausea*
2	*Nausea once or twice a week*
3	*Nausea every day, requires antiemetic on a regular basis*
4	*Nausea for which second line antiemetics are required*
5	*Nausea not controlled with oral medication, continuous infusion required*

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PROXY ATTRIBUTES

- As noted by *Keeney and Raiffa (page 55, 1992)*, "a proxy attribute is one that reflects the degree to which an associated objective is met but **does not directly measure** an objective".
- Hence, a **proxy** attribute measures an objective in an indirect fashion.
- **Advantage**: ease of measurement.
- **Disadvantage**: not a direct measurement of the objective.

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PROXY ATTRIBUTES: SOME EXAMPLES

Objective	Proxy Attribute
Optimize Comfort	*Deviation of Temperature from 70 degrees, Farenheit*
Optimize Condition of Patients Delivered to the Hospital by an ambulance service	*Response Time*

PROXY ATTRIBUTES

- Avoid the mistake of using an **input** to a system as a measure of the system's **quality** (*e.g., using funds spent per student as a measure of the quality of a school system*).

AN ORGANIZATION'S MISSION STATEMENT

- Can be very useful in the development of a hierarchy of objectives and attributes for the organization.

- Three Main Elements (*Bart, 1997*):
  - *Key markets*
  - *The organization's contribution (in terms of product/service)*
  - *The distinction of the organization's contribution*

EXAMPLES OF MISSION STATEMENTS

- General Motors Mission Statement:

  "G.M. is a multinational corporation engaged in socially responsible operations, worldwide. It is dedicated to provide products and services of such quality that our customers will receive superior value while our employees and business partners will share in our success and our stock-holders will receive a sustained superior return on their investment." (see http://wiki.answers.com/Q/What_is_General_Motors_mission_statement).

- McDonald's Mission Statement:

"To provide the fast food customer food prepared in the same high-quality manner world-wide that is tasty, reasonably-priced & delivered consistently in a low-key décor and friendly atmosphere." "To provide the fast food customer food prepared in the same high-quality manner world-wide that is tasty, reasonably-priced & delivered consistently in a low-key décor and friendly atmosphere."

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FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- Consists of **nodes** (representing objectives/attributes) and **arcs**(representing relationships between the various objectives/attributes).
- "**Triangular form**".
- More general (**fundamental**) objectives towards the top.
- More specific (**means**) objectives and **attributes** towards the bottom.
- Any particular means objective can be related to **multiple** fundamental objectives.
- For a **system/organization** or for a **decision situation**.
- Difference between a network and a hierarchy: in a network a lower level objective can be connected to multiple higher level objectives.

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FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

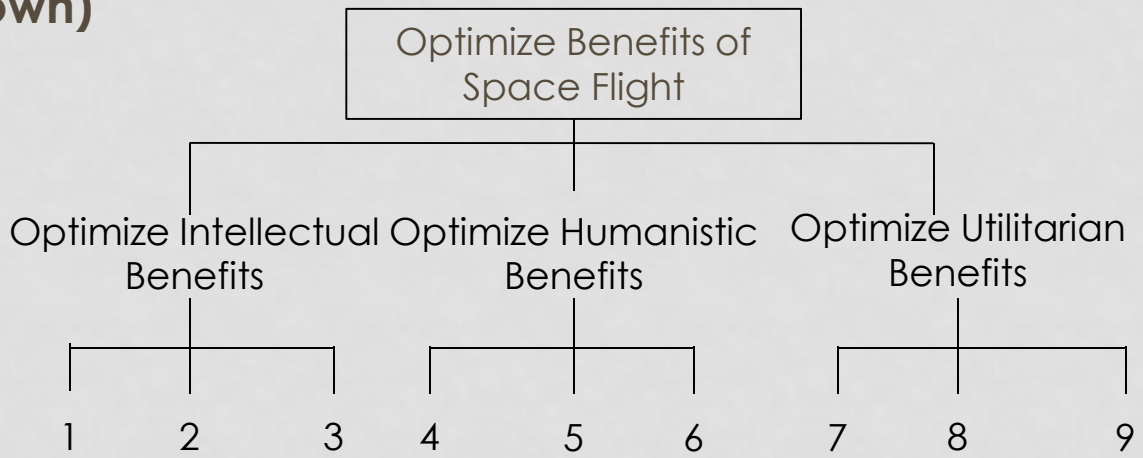
- **Subjective** process for development.
- Three complementary approaches (*MacCrimmon, 1969*):
  1) *examine the **relevant literature** (particularly useful for public systems),*
  2) *conduct an **analytical study** (build a model),*
  3) *perform causal empiricism (**interviews** of DMs and stakeholders).*

FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- Two systematic approaches suggested for formation:
  - **Top Down** *(from most general objective down to the most specific, and finally to the attributes) for* ***strategic*** *decision problems.*
  - **Bottom Up** *(from the attributes, up through the specific objectives to the most general objective) for* ***tactical*** *decision problems.*
    - *(often initiated through determination of* ***differences*** *between alternatives).*

FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- Hierarchy of Objectives Associated with the Benefits of Space Flight **(Top Down)**



Where the numbers denote the following sub-objectives:

1. *Optimize mapping morphology and mineralogy of moon, planets and asteroids.*
2. *Optimize benefits associated with research beyond the solar system.*
3. *Optimize benefits associated with improving our understanding of astronomy, biology, geology, and meteorology.*
4. *Optimize benefits associated with improving domestic/global communications.*
5. *Optimize benefits related to understanding/controlling of the earth's climate.*
6. *Optimize benefits associated with understanding of the earth's upper atmosphere.*
7. *Optimize benefits associated with the research and development of industrial processes.*
8. *Optimize benefits associated with providing services such as satellite repair, maintenance, refueling, etc.*
9. *Optimize benefits associated with mining of minerals and other resources.*

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FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- Devices for identifying relevant objectives (***Bottom Up*** *by Keeney, 1992*):
  - *A wish list*
  - *Problems and shortcomings*
  - *Consequences*
  - *Goals, constraints, and guidelines*
  - *Different perspectives*
  - *Strategic objectives*
  - *Generic objectives*
  - *Structuring objectives*
  - *Quantifying objectives*

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FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- Four useful concepts:
  - *Specification*
  - *Categorization (e.g., of stakeholders, of benefits, etc.)*
  - *Means-Ends*
  - *Four types of questions*

FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- **Specification**:
  - To expand **downwards** from a general objective to more specific objectives.
  - State in more detail what is meant by an objective.

- **Example:**
  - Specify what is meant by "Optimize the benefits of space flight":
    - *Optimize Intellectual Benefits*
    - *Optimize Humanistic Benefits*
    - *Optimize Utilitarian Benefits*

FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- **Categorization:**
  - To expand **downwards** from a general objective by stating the various categories of, e.g., of stakeholders/decision makers.

- **Example:**
  - **Optimize Well Being of the University**
  - Can be expanded by considering stakeholders of the University into:
    - ***Optimize Considerations of the State's Residents***
    - ***Optimize Considerations of the University Students***
    - ***Optimize Considerations of the University Faculty***

FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- **Means-Ends**:
  - *To expand in either direction in a hierarchy.*
  - *To expand **downwards**, one could ask the question: "What is the **means** by which this higher level objective could be achieved?".*
  - *To expand **upwards**, one might the question: "To what **end** do we want to achieve this objective?".*
  - *Note that the answer and question for the "means" should **interchange** with the question and answer for the "ends" question.*
- **Example:**
  - *The **means** by which one **optimizes the humanistic benefits of space flight** is by 1) optimizing benefits associated with improving domestic/global communications, 2) optimizing benefits related to understanding/controlling of earth's climate, and 3) optimizing benefits associated with understanding of earth's atmosphere.*
  - *The **end** to which we want **to optimize the benefits associated with improving domestic/global communications** is to **optimize the humanistic benefits of space flight.***

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FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- Useful questions for forming a hierarchy (*Clemen, 1994*)
  - To move **downwards** in the hierarchy:
  - Ask: ***"What do you mean by that?"***, or ***"How could you achieve this?"***.
  - To move **upwards** in the hierarchy:
  - Ask: ***"Of what more general objective is this an aspect?"***, or ***"Why is that important?"***.

FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- A good set of objectives for a specific decision situation:
  - *Cover all aspects of concern of the DMs and stakeholders.*
  - *Be understandable to the DMs and stakeholders and therefore allow for careful consideration of tradeoffs between these objectives.*
  - *Have associated values (attributes) which are reasonably computable for any alternative under investigation.*
  - *Allow for differing outcomes for the various alternatives.*

FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES

- Two impediments to generation of most of the relevant objectives (Bond, Carlson, and Keeney, 2010):
  - *Not thinking broadly enough about the possible objectives,*
  - *Not thinking deeply enough about the situation.*
- Two-stage approach to the generation of objectives.
  1) *Just having the DM (or DMs) just generate a list of objectives for the decision situation for analyst/facilitator organizing the objectives.*
  2) *Analyst/facilitator ask the DM(s) to add additional objectives to the list, by considering additional categories which may not have been considered in the first stage.*

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DESIRABLE PROPERTIES OF FUNDAMENTAL OBJECTIVES KEENEY, PAGE 82, 1992)

- **Essential**, *to indicate consequences in terms of the fundamental reasons for interest in the decision situation.*
- **Controllable**, *to address consequences that are influenced only by the choice of alternatives in the decision context.*
- **Measurable**, *to define objectives precisely and to specify the degrees to which objectives may be achieved.*
- **Operational**, *to render the collection of information required for an analysis reasonable considering the time and effort available.*
- **Decomposable**, *to allow the separate treatment of different objectives in the analysis.*
- **Nonredundant**, *to avoid double counting of possible consequences.*
- **Concise**, *to reduce the number of objectives needed for the analysis of the decision.*
- **Understandable**, *to facilitate generation and communication of insights for guiding the decision making process.*

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FORMATION OF A HIERARCHY/NETWORK OF OBJECTIVES AND ATTRIBUTES: EXAMPLE

- **Optimize Overall Well Being from Apartment Rental**
  - **Optimize Financial Considerations**
    - Minimize Monthly Rent (Monthly rent in dollars)
    - Minimize Monthly Utility Bills (Average monthly utility bill in dollars)
    - Minimize Distance Traveled from Apartment to Other Locations (Average weekly miles traveled)
  - **Optimize Safety Considerations**
    - Minimize Distance Traveled from Apartment to Other Locations (Average weekly miles traveled)
    - Optimize Apartment Age (Apartment age in years)
    - Optimize Apartment Layout (Layout desirability)
    - Optimize Neighbors (Quality of neighbors)
    - Optimize Apartment Neighborhood (Quality of neighborhood)
    - Optimize Apartment Amenities (Quality of apartment amenities)
  - **Optimize Life Style Considerations**
    - Optimize Apartment Age (Apartment age in years)
    - Optimize Apartment Layout (Layout desirability)
    - Optimize Neighbors (Quality of neighbors)
    - Optimize Apartment Neighborhood (Quality of neighborhood)
    - Optimize Apartment Amenities (Quality of apartment amenities)
    - Optimize Apartment Size (Apartment size in square feet)

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ADDITIONAL EXAMPLES OF HIERARCHIES

- A hierarchy related to cost and environmental concerns for the decisions associated with the scheduling of refueling for a nuclear power plant (*Dunning et al, Interfaces, 2001*)
- A hierarchy useful in evaluating alternatives for the disposition of excess waste plutonium from dismantled nuclear weapons (*Butler et al, Interfaces, 2005*)
- A means-end objectives hierarchy for a software company in evaluation of various vision and mission statements (*Keeney, Interfaces, 1999*)
- A "values hierarchy" for investigating alternatives associated with the regional organization of the US Army's Installation Management Agency (*Trainor et al, Interfaces, 2007*)
- A hierarchy of objectives and attributes for selecting a GIS (*Ozernoy, Smith, and Sicherman, Interfaces, 1981*)
- A goals hierarchy for ranking 542 hydroelectric projects in Norway (*Wenstop and Carlson, Interfaces, 1988*)
- A hierarchy of objectives related to the areas of cost, theft, environment, health, and safety for selection of a technology for the disposition of surplus weapons grade plutonium (*Dyer et al, Operations Research, 1998*)
- An objectives hierarchy used by an electric utility for evaluating various types of plants for generating electricity (*Keeney, Lathrop, and Sicherman, Operations Research, 1986*)

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EVALUATING THE QUALITY OF THE GENERATED ATTRIBUTES AND OBJECTIVES

- Any particular attribute should be both **comprehensive** and **measurable.**
  - Comprehensive: "relevant to the particular alternative courses of action, and not subject to other extraneous conditions" (*see page 39 of Keeney and Raiffa*).
  - Measurable:
    - *can obtain a probability distribution for each alternative over possible levels of the attribute.*
    - *DM's preferences can be assessed over the levels (see page 39 of Keeney and Raiffa).*

EVALUATING THE QUALITY OF THE GENERATED ATTRIBUTES AND OBJECTIVES

- An entire set of attributes for a particular problem should have the following characteristics (*see pages 50 to 53 of Keeney and Raiffa*):
  - ***Completeness***—*adequate in describing the degree to which the degree of the overall objective is met*
  - ***Operational***—*meaningful to the decision maker, facilitate explanations to others, able to obtain "measurements" for each alternative*
  - ***Decomposable***
  - ***Nonredundancy***—*avoid double counting of consequences*
  - ***Minimum Size***—*(in contrast to completeness), easir to obtain a value/utility function*

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DESIRABLE PROPERTIES OF ATTRIBUTES KEENEY, PAGES 112-118, 1992)

- If the fundamental objectives are carefully chosen, then the corresponding attributes should be:
  - *Measurable*
  - *Operational*
  - *Understandable*

FIVE DESIRABLE PROPERTIES OF GOOD ATTRIBUTES (KEENEY AND GREGORY, 2005)

- **Unambiguous:** *A clear relationship exists between consequences and descriptions of consequences using the attribute.*
- **Comprehensive:** *The attribute levels cover the range of possible consequences for the corresponding objective, and value judgments implicit in the attribute are reasonable.*
- **Direct:** *The attribute levels directly describe the consequences of interest.*
- **Operational:** *In practice, information to describe consequences can be obtained and value trade-offs can reasonably be made.*
- **Understandable:** *Consequences and value trade-offs made using the attribute can readily be understood and clearly communicated.*

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CHAPTER 2.7
IMPORTANT ATTRIBUTES FOR SPECIFIC CATEGORIES OF DECISION SITUATIONS

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IMPORTANT ATTRIBUTES FOR SPECIFIC CATEGORIES: ENGINEERING ECONOMICS

- Important performance measures (or attributes) used in engineering economics include:
  - *Net present value*
  - *Rate of return*
  - *Internal rate of return*
  - *Payback period*

**Note: These performance measures are used to consolidate cash flows (both incoming and outgoing) over time into a single measure of performance.*

IMPORTANT ATTRIBUTES FOR SPECIFIC CATEGORIES: LOCATION AND LAYOUT DESIGN

- Selected Attributes
  - Location
    - *Country*
    - *Region*
    - *Site*
  - Layout
    - *Placement/location of machines*
    - *Equipment*
    - *Departments*
    - *The amount of space allocated to various departments*

IMPORTANT ATTRIBUTES FOR SPECIFIC CATEGORIES: PROJECT MANAGEMENT

- As noted by the American Society of Quality (http://asq.org/glossary/q.html), *quality* can have either of two meanings:
  1) *"the characteristics of a product or service that bear on its ability to satisfy stated or implied needs";*
  2) *"a product or service free of deficiencies".*

- Selected Attributes
  - *Acceptable quality level (AQL)*
  - *Lot tolerance percent defective (LTPD)*
  - *Producer's Risk (α)*
  - *Consumer's Risk (β)*
  - *Average outgoing quality (AOQ)*

IMPORTANT ATTRIBUTES FOR SPECIFIC CATEGORIES: QUALITY MANAGEMENT

- "***project management*** involves the coordination of group activity wherein the manager plans, organizes, staffs, directs, and controls to achieve an objective with constraints of time, cost, and performance of the end project" (*Page 3 of Moder, Phillips and Davis, 1995*)

- Selected Attributes
  - *Direct Cost*
  - *Indirect Cost*
  - *Project Duration*
  - *Weighted Sum of the Sums of Squares of the Resource Usages*

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IMPORTANT ATTRIBUTES FOR SPECIFIC CATEGORIES: MEDICAL DECISION MAKING

- There are many diverse areas in health care which have greatly benefited from the contributions of industrial engineers:
  - *Quality Adjusted Life Years (QALY)*
  - *Sensitivity (of a medical test)*
  - *Specificity (of a medical test)*
  - *Fraction of Patients who Leave (or Left) Without Being Seen (LWOBS)*