Risk Management and Decision Analysis

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Recall

Introduction to Risk Management & Decision Analysis

- Risk
  - An uncertain event or condition that, if it occurs, has a positive or a negative effect on a project objective
- Decision Analysis
  - Prescriptive approach for people who want to think hard and systematically about decision problem
- Element of Decision Problems
  - 3 Elements: Decision to made, Risks, Outcomes
- Importance of RM & DA

Class Survey

Risk

- 손실이 생길 우려가 있는 상태
- 위험한 상황에 노출될 또는 위험 상황이 발생할 확률
- 인명과 재산 피해 및 손실(물적/인적 피해)을 초래할 수 있는 사건
- 어떤 사건에 부정적인 영향을 끼칠 수 있는 잠재가능성
- 나에게 손상이나 위협을 끼치는 요소
- 계획에 영향을 미칠 수 있는 이슈
- 예상하고 있거나 예상하지 못하는 문제점, 사고, 기회
- 현재와 다른 것
- 성공을 위해 충족해야 하는 특정조건

Class Survey

Risky Situation in Daily Life

- 음주, 흡연, 건강
- 출근 길에 배가 아픈데 지하철이 정차
- 재난재해, 날씨
- 실수, 부주의
- 자동차에 탔을 때, 교통사고, 교통체증, 경로선택
- 코로나, No-마스크와 함께 있을 때
- 눈 오는날, 미세먼지 농도 높은 날
- 해킹, 보이스피싱, 스팸메일, 악성코드
- 난간에 기댐
- 상사, 가족의 기분
- 동료의 부재, 경조사, 휴가

Class Survey

Risky Situation in a Highway Project

- 불안전한 작업환경, 관리소홀, 건설 중장비 자체 및 손상
- 토지보상 알박기
- 졸음운전에 따른 사고, 안전사고
- 교량 또는 사면 붕괴, 싱크홀
- 환경 오염, 자연재해, 날씨
- 공사 지연, 자재 조달 지연, 콘크리트 배송
- 추가 공사비, 발주처 예산 삭감
- 민원, 노조 파업
- 인허가 거절
- 품질 하자
- 계약 파기, 협력사 파산

Class Survey

Main Consideration for Decision Making

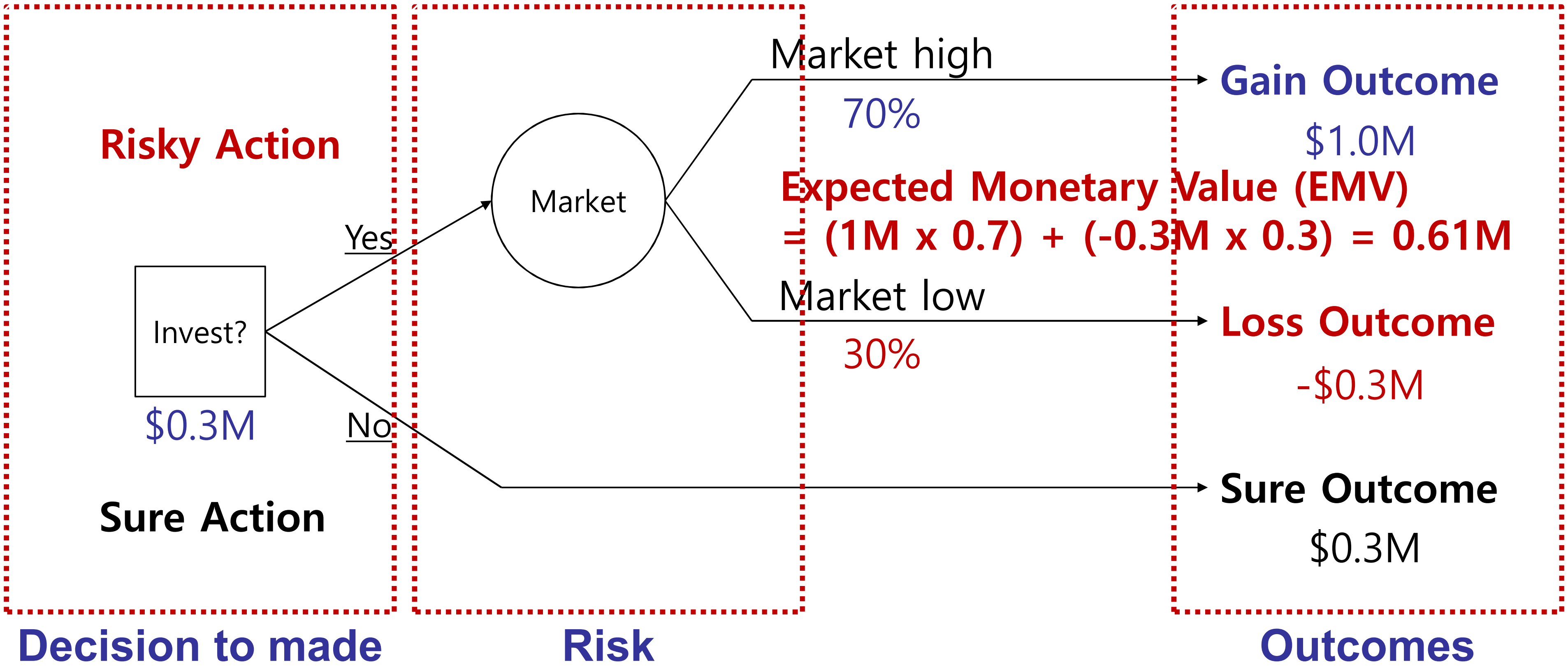
- 위험, 영향력의 정도
- 다른 사람들의 의사결정 사례, 경험자들의 지식, 역사적인 판단
- 시간 투자 대비 가성비/이득
- 재산보호, 신용 및 경제적 우선순위
- 객관적인 정보, 고려할 수 있는 모든 변수에 대한 정보
- 목적과의 부합성
- 안전
- 개인/기업 이미지
- 인권
- 법적, 행정적, 기술적인 문제

PART I

STRUCTURING DECISIONS

Elements of Decision Problems

- **Inherently, Involving Risks**
- **3 Elements: Decision to made, Risks, Outcomes**



Elements of Decision Problems

1. Values and Objectives

- Person's Values: Collection of objectives
  - No values → No objectives → No Decisions
- Common categories of Objectives
  - Profit & costs objectives: Making Money!!
  - Performance objectives
  - Quality objectives
  - Reliability objectives
  - Compatibility objectives
  - Adaptability or flexibility objectives
  - Safety objectives
  - Environmental objectives
    - Often a tradeoff has to be made between "money making" objective and other fundamental objectives *(Sage & Armstrong 2000)*

Elements of Decision Problems

1. Values and Objectives

- Boeing's Supercomputer

Super Computer Objectives

Price
- Five-Year Costs
- Cost of Improved performance

Performance
- Speed
- Throughput
- Memory Size
- Disk Size
- On-Site performance

User Needs
- Installation Date
- Rollin/Roll out
- Ease of Use
- Software Compatibility
- Mean Time to Failure

Operational Needs
- Square Footage
- Water Cooling
- Operator Tools
- Telecommunications
- Vendor Support

Management Issues
- Vendor Health
- US Ownership
- Commitment to super computer

Barnhart, D. (1993) "Decision Analysis Software Helps Boeing Select Supercomputer." *OR/MS Today,* April, pp.62-63.
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Elements of Decision Problems

2. Decision to Make

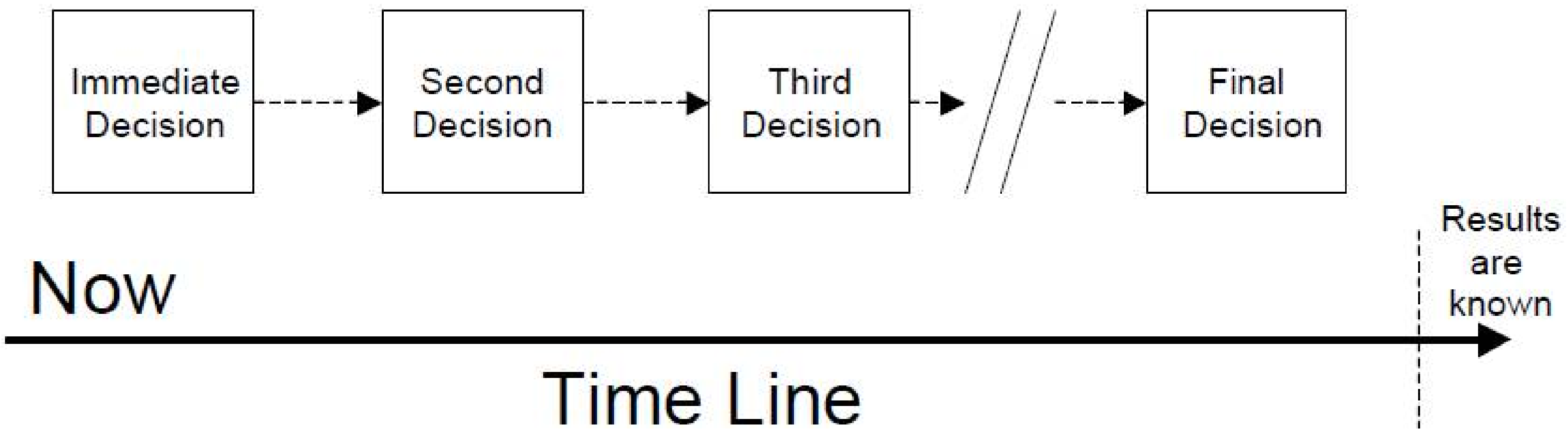
- Most decisions call for: the Immediate Decision
  - Go, No Go
  - Accept bet or not
  - Invest amount of money – may vary in range of values
- Look at all possible decision alternatives: **Be Creative!**
  - Do nothing
  - Wait for information and decide later on
  - Execute Hedging(위험분산, 위험회피)
- Decision may be of a sequential nature:

Future decisions may need to be taken into account when making immediate decision

Elements of Decision Problems

2. Decision to Make

- Future decisions may depend on:
  - Past Decisions
  - Past Events
  - Both
- List of possible decisions is important, but more important is the order in which they occur.



Elements of Decision Problems

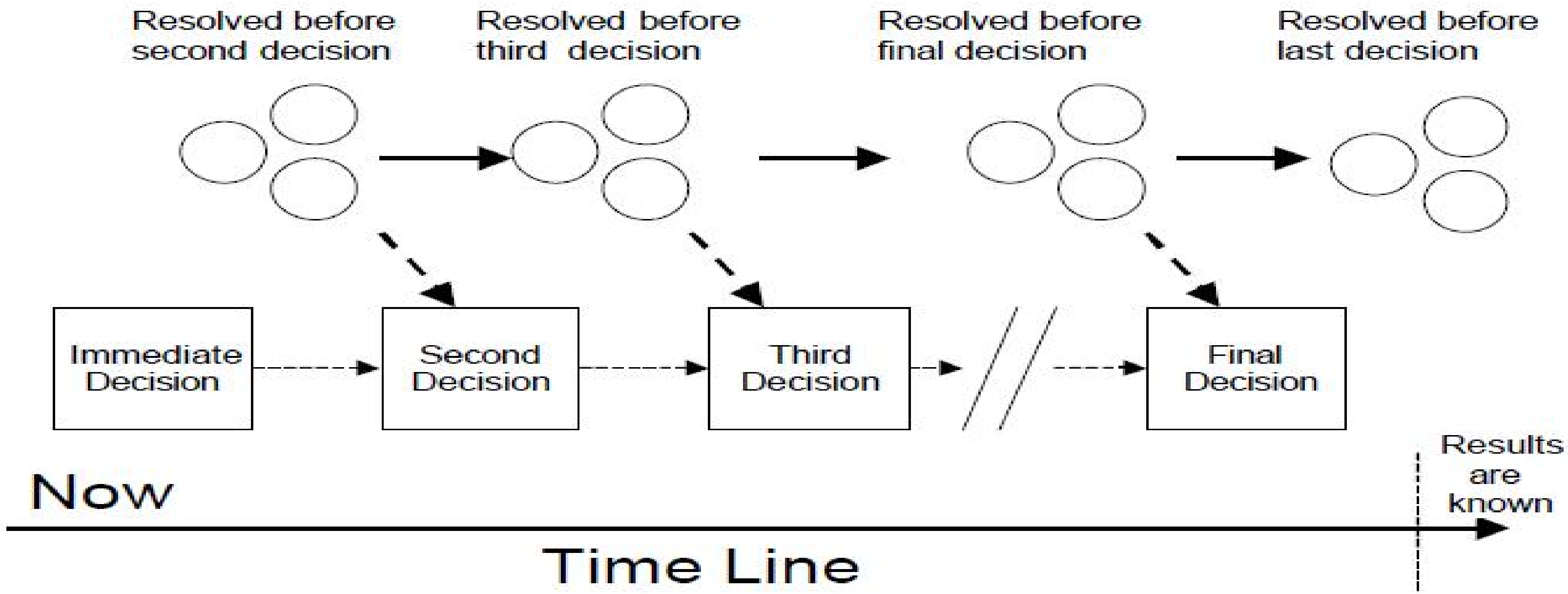
3. Risk: Uncertainty

- Many decisions are made under the presence of uncertainty.
  - Investment decision: Will stock of company go up or not?
  - Camping decision: Will the weather be good or not?
  - Mutual fund decision: Will entire stock market go up?
- A decision problem becomes more complicated when the number of relevant uncertain events increases.
- Nature of Uncertain Events:
  - Outcomes are measured in distinct classes (Discrete)
  - Outcomes may fall in a range of values (Continuous)
  - Interdependence between different uncertain events

Elements of Decision Problems

3. Risk: Uncertainty

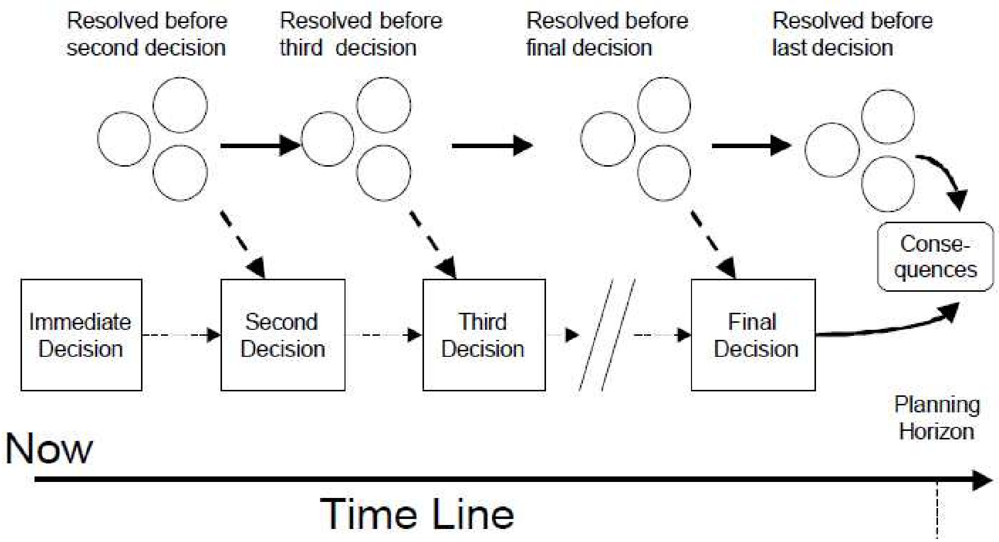
- The time sequence of uncertain events related to the sequence of decision is important.
- **Why?**
  - Tells you what information becomes known before a decision has to be made
  - Uncertain events may be unknown at the time of the immediate decision, but may be known by subsequent decisions



Elements of Decision Problems

4. Outcomes & Consequences

- Planning Horizon = Time when decision maker finds out the results:



- **For requisite decision models**(whose form and content are sufficient to solve a particular problem; when no new intuitions arise the model is considered requisite; Lawrence D. Phillips 1984):
  - **Stop** when future decisions and future uncertain events are not essential to **the immediate decision**.

Elements of Decision Problems

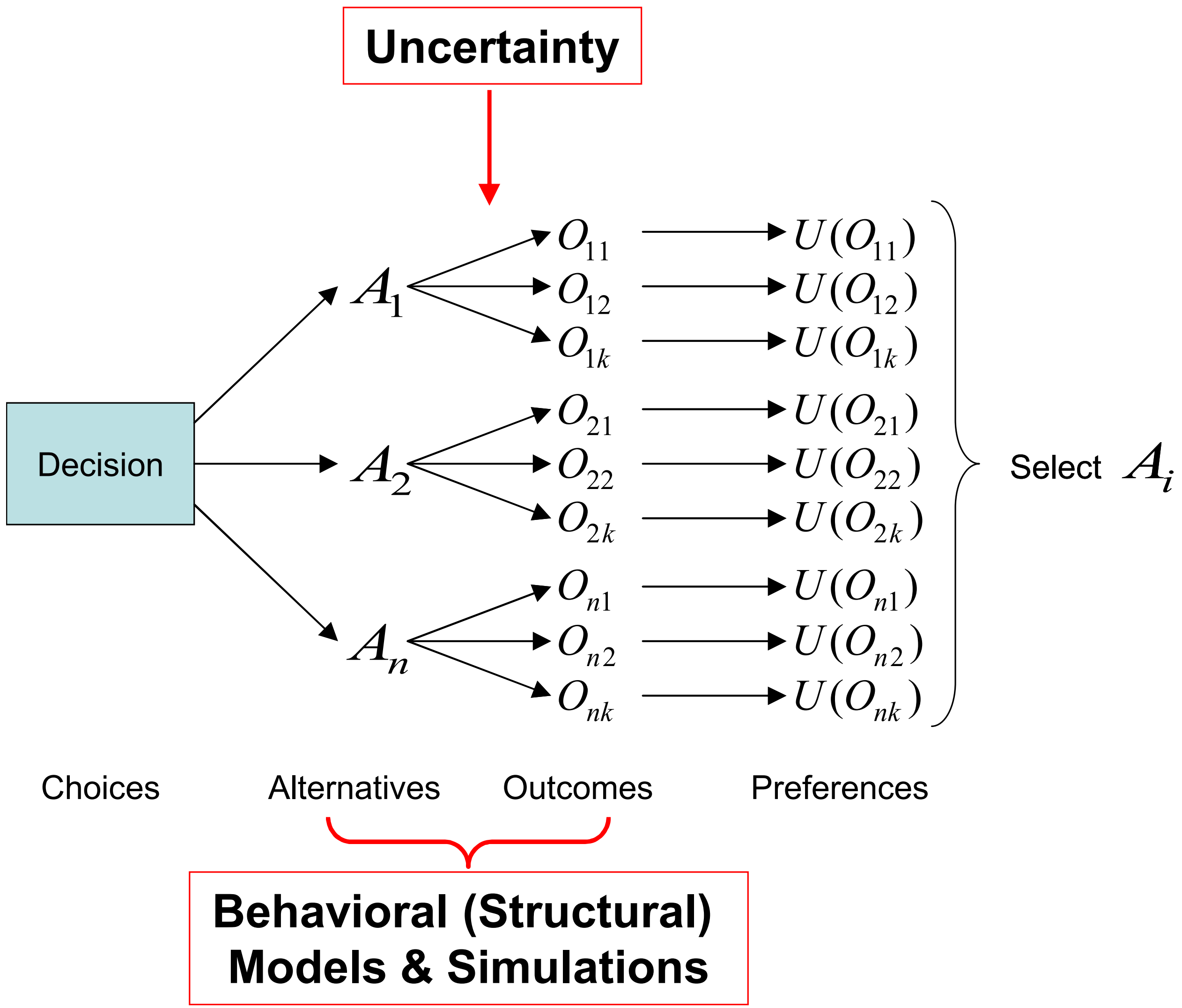
4. Outcomes & Consequences

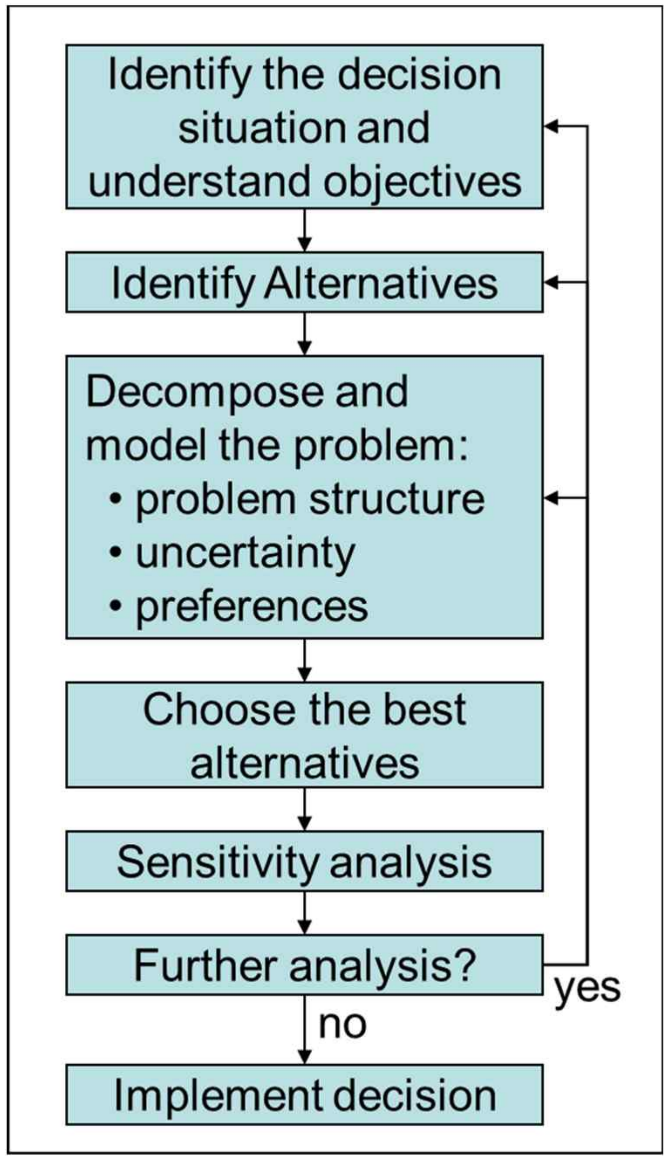
- Evaluation of Outcomes:
  - Profit – Measured in # Dollars
  - Casualties(사상자) – Measured in # Deaths
  - Environmental Damage – Measured in # Polluted Soil
  - Health Risk – Measured in # Infected People

Trade off between has to be made in almost any decision problem

- Profit, Casualties, Environmental Damage, Health Risk – Single measure modeling trade-off needs to be developed.
- This is the topic of multi-attribute utility theory.

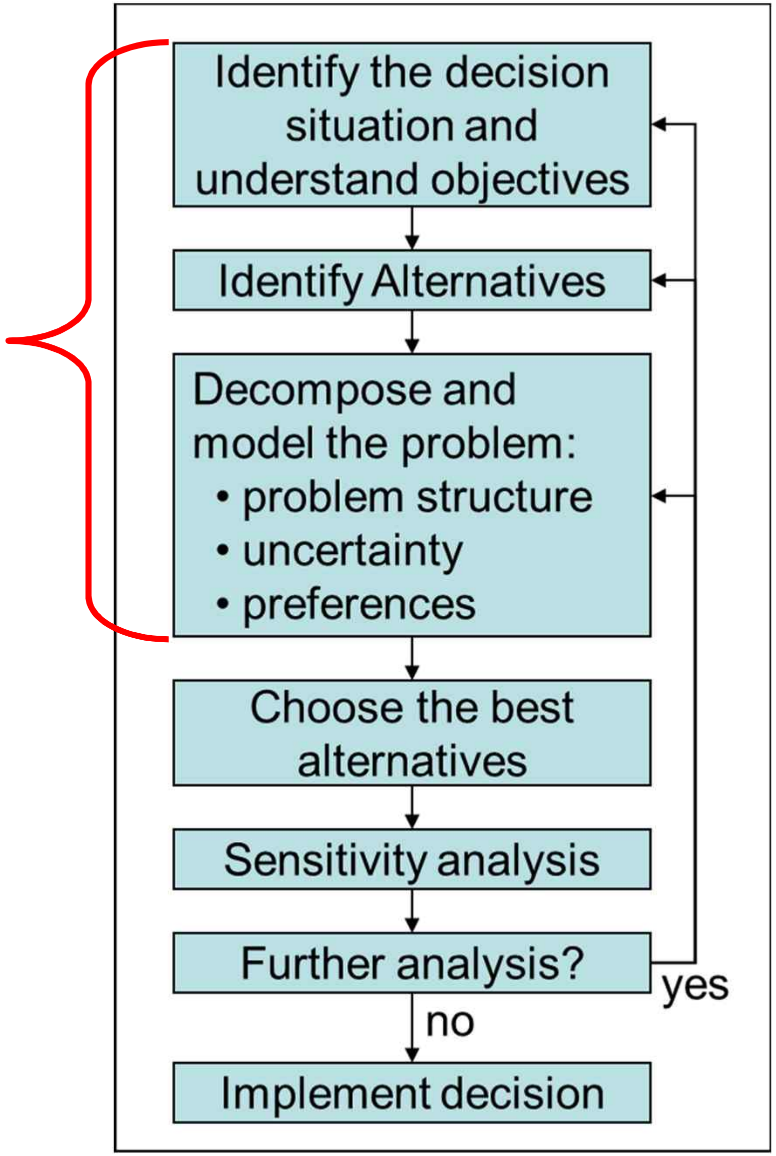
Decision Analysis Process





Decision Analysis Process

- Current focus is on the first three blocks of this flow chart
- Use Influence Diagrams (or Decision Trees) to model the problem structure
- Identify and then Model uncertainty and preferences



Structure Decision Problems

- Given a complicated problem, how should one begin?

- Critical steps in the process of structuring a decision problem
  - Step 1: Define the scope
  - Step 2: Identify the objectives
  - Step 3: Choose the attributes
  - Step 4: Identify decision alternatives
  - Step 5: Model the structure of the decision problem using influence diagrams & decision trees

Step 1: Define the Scope

- What is the scope of the decision?
  - What does the decision maker have control over?
  - Are there constraints that have been imposed?
  - How much detail is needed?
- Getting the Decision Context right
  - Enlarging decision context may increase the number of objectives and alternatives that are relevant
  - Decreasing the decision context may cause current relevant objectives or alternatives to become irrelevant
  - Three questions need to be answered affirmatively
    - Are you addressing the right problem?
    - Can you make the decision? (Decision Ownership)
    - Do you have the resources (Time & Money) to analyze the decision problem in the current decision context?

Example

An Office Location Problem

- A small construction firm must move from its existing office because the site has been acquired for redevelopment.
- The company is considering five possible new offices, all of which would be rented.
  - Details of the location and the annual rent payable are specified
- While the company would like to keep his costs as low as possible, he would like to take other factors into account. For example, one office is in a prestigious location but not close to current job sites and it is expensive to rent.
  - In contrast, one of the locations is a new building, which will provide excellent working conditions, but it is several miles away from where most of the current employees live.
- The company is unsure how to set about making his choices, given the number of factors involved

(Goodwin & Wright 2004)

Example: Define the Scope

- The scope of the office location decision
  - Decision Makers: President?
  - Constraints
    - Details of the location and the annual rent payable are specified
    - Budgeting constraints
    - Availability of leasing options on locations
    - Employee concerns
  - Stakeholders
    - Employees
    - Clients
    - President
  - Details are determined in terms of specific decision objectives

Step 2: Determine the Objectives

- What is the difference between Objectives, Attributes, & Goals?
- What is an objective? → easily, something the DM wants to achieve

A direction in which we should strive to do better

An indication of preferred direction of movement, i.e. ‘minimize’/‘maximize’

To (action word) + (object) + (qualifying phrase)

- What is an attribute? → *also called Measure of Effectiveness*

A quantity by which the attainment of an objective can be measured

An attribute is used to measure performance in relation to an objective

- What is a goal?

A target level of achievement of an objective

Objectives/Attributes/Goals

- Example: Construction projects
  - Objective
    - Complete the project on time

    or

    - Minimize the duration of the project
  - Attribute
    - Time takes to complete the project
      - Measured in time units (number of days)
  - Goal
    - Finish the project in 120 days
- Yes/No dichotomy(이분) for goals
  - At the end, ***anybody*** should be able to say whether the goal is achieved or not

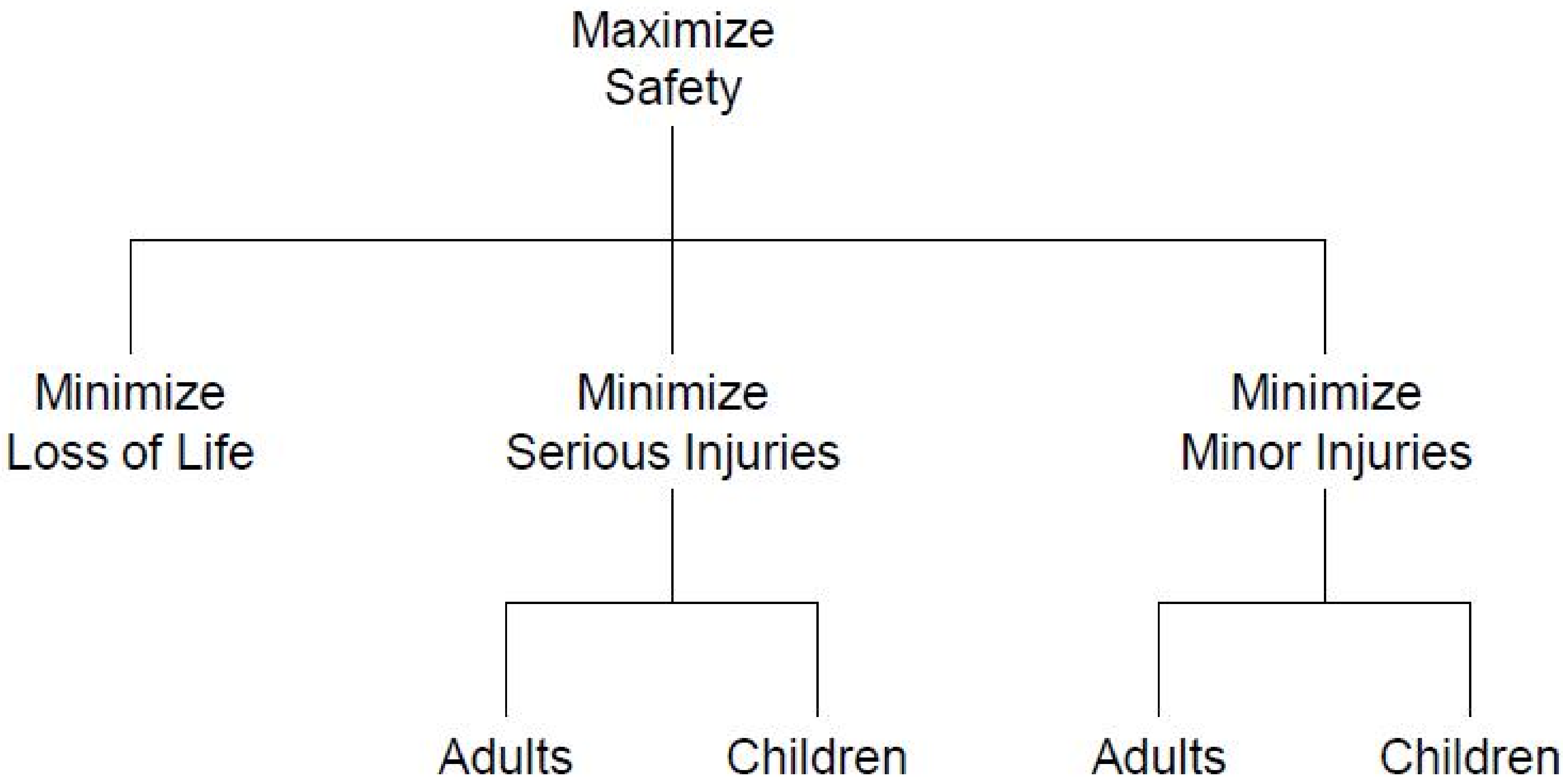
Fundamental objectives vs. Means objectives

- Fundamental objectives
  - Direct expression of DM's values
  - Can be decomposed hierarchically into a tree
  - There should be no overlap between different branches of the tree
- Means objectives
  - Help to achieve fundamental objectives
  - Organized into a network of objectives
- Which objectives should we focus on?
  - Fundamental objectives are the most important
  - Means objectives are good for discovering and implementing the fundamental objectives and for identify solution alternatives

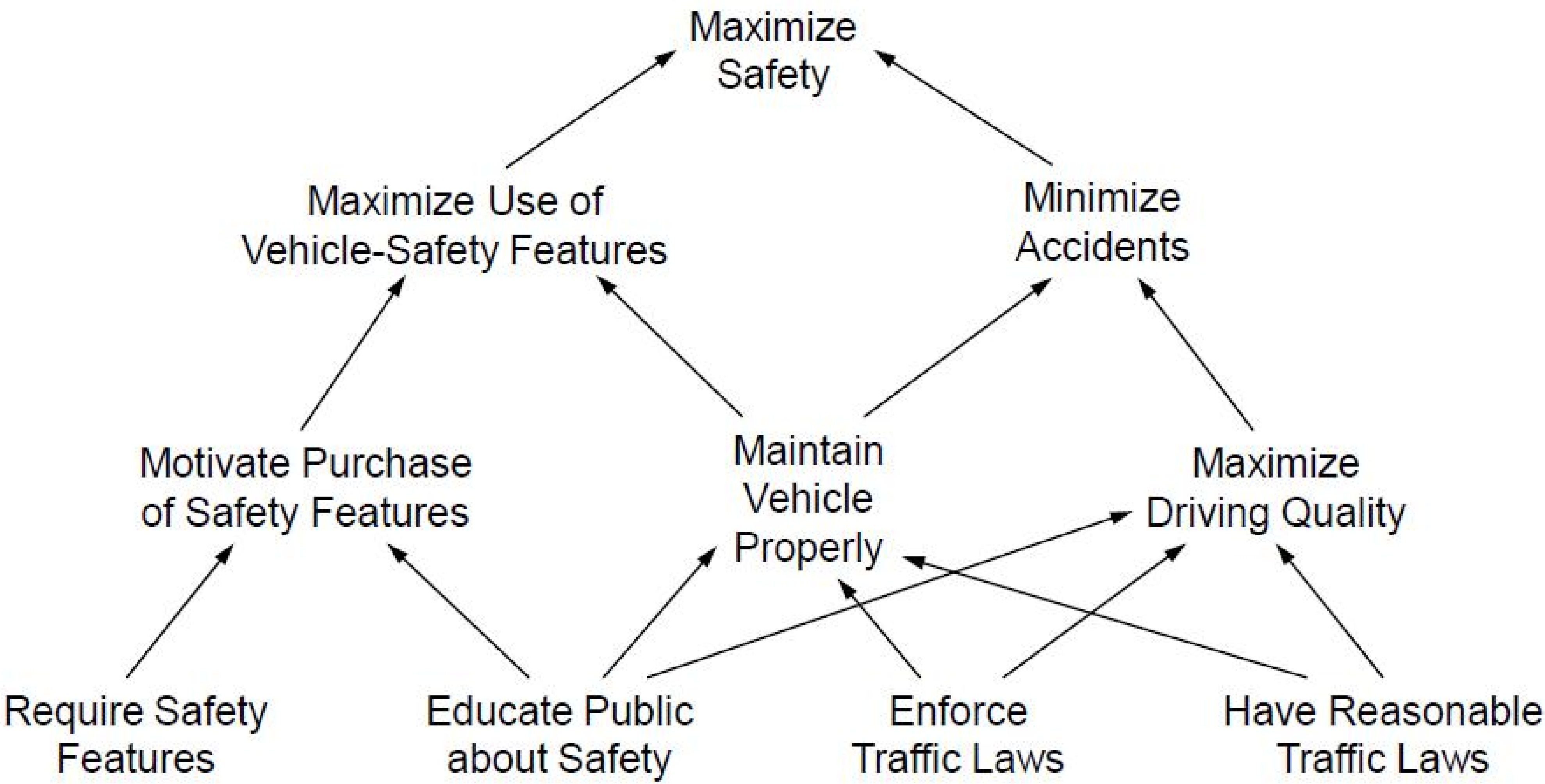
Mean objectives for one DM could become fundamental objectives for another
→ Policy maker generates vehicle safety code for driving safety → Designer needs to satisfy the safety code

Fundamental Objectives Hierarchy

- The context of defining vehicle regulations
  - The higher-level fundamental objective is to maximize safety



Means Objectives Hierarchy



Elicitation of Objectives

	Fundamental Objectives	Means Objectives
To Move: Ask:	*Downward in the Hierarchy:* "What do you mean by that?"	*Away from Fundamental Objectives:* "How could you achieve this?"
To Move: Ask:	*Upward in the Hierarchy:* "Of what more general objective is this an aspect?"	*Toward Fundamental Objectives:* "Why is that important?"

Example

An Office Location Problem

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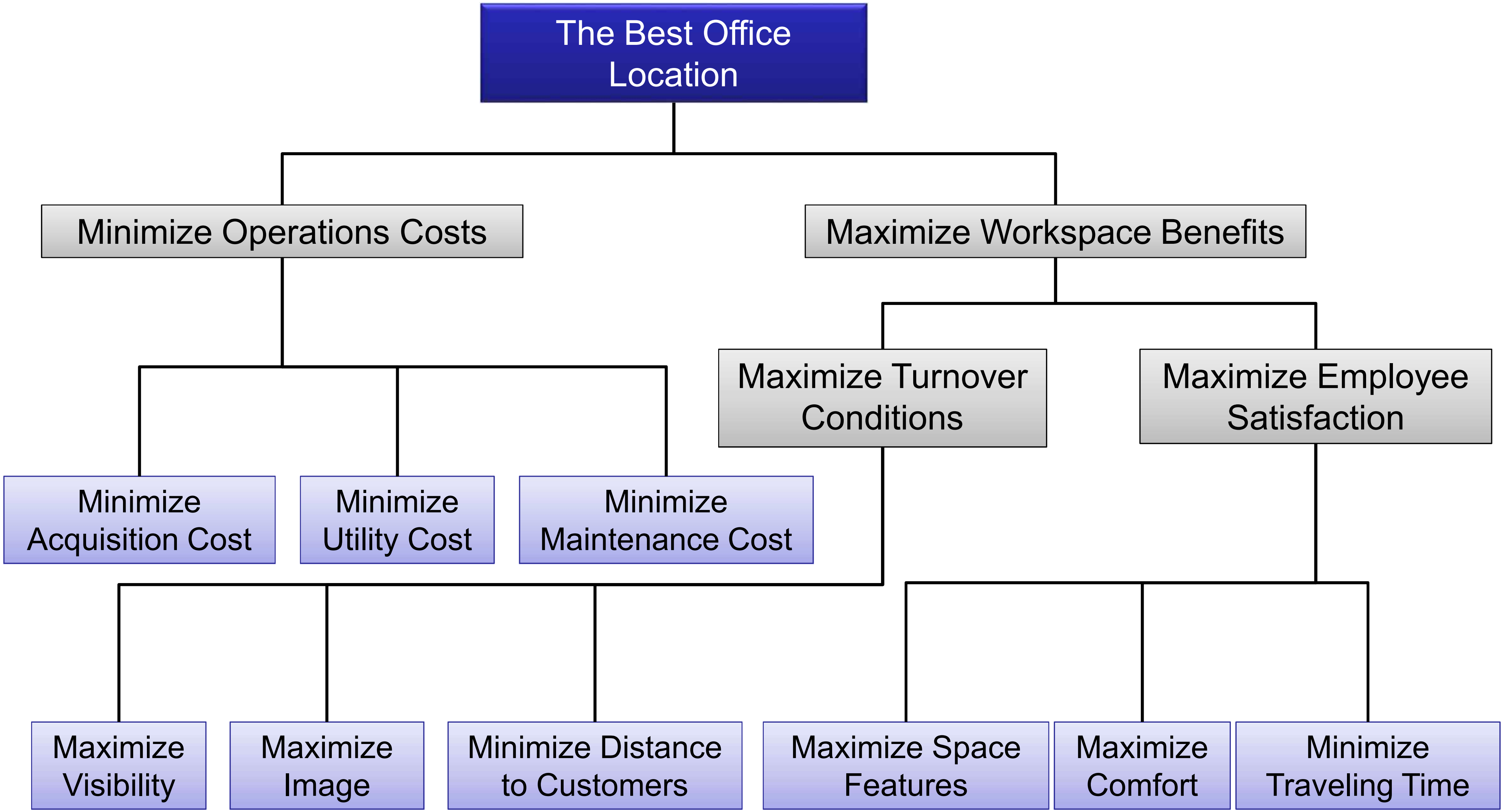
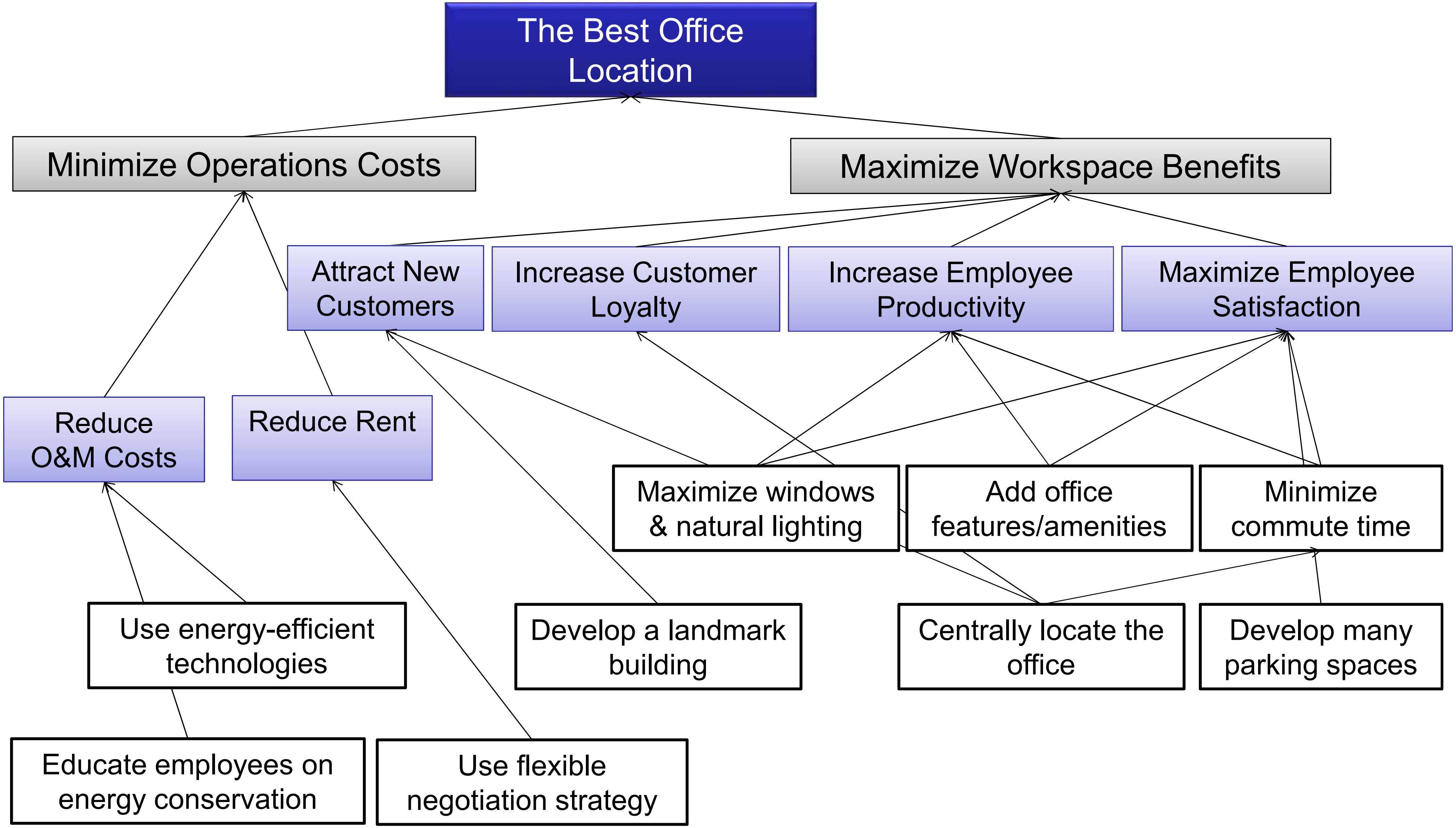
(Goodwin & Wright 2004)

Fundamental Objectives Hierarchy



Means Objectives Hierarchy



Techniques for Identifying Objectives

- Identifying objectives is a Creative Process
  1. Develop a wish list

     What do you want? What should you want?
  2. Identify alternatives

     What is the perfect alternative, a terrible alternative, some reasonable alternatives, what is good or bad about each?
  3. Consider problems and shortcomings

     What is wrong or right with your organization? What needs fixing?
  4. Predict consequences

     What has occurred that was good or bad? What might occur that you care about?
  5. Identify goals, constraints, and guidelines

     What are your aspirations? What limitations are placed on you?

(Keeny 1994)

Techniques for Identifying Objectives (Cont’d)

- Identifying objectives is a Creative Process (Cont’d)

6. Consider different perspectives

   What would your competitor or constituency be concerned about? At some time in the future, what would concern you?

7. Determine strategic objectives

   What are your ultimate objectives? What are your values that are absolutely fundamental?

8. Determine generic objectives

   What objectives do you have for your customers, your employees, your shareholders, yourself? What environmental, social, economic, or health and safety objectives are important?

(Keeny 1994)

[Increase seat belt use]
Yearly number of casualties in car accidents
Yearly number of casualties avoided by wearing seat belts

Step 3: Choosing the Attributes

Comprehensive?
Measurable?

- Comprehensive?
  - Theoretical: Does the attribute give us the right information?
  - Level of attribute → DM has complete understanding of the extent that the objective is achieved
  - Example: Objective = reduce operations & maintenance costs by using a new HVAC system
    - Attribute = annual percentage decrease in utility bills
      - *Comprehensive?*
- Measurable? (predictable?)
  - Practical: Can we get the information?
  - Example: Attribute = annual percentage decrease in utility bills due to the new HVAC systems
    - *Measurable?*
- A well-defined objective should lead to a comprehensive & measurable attribute

Step 3: Choosing the Attributes (2)

- Common Objectives & Their Natural Attributes

Objectives	Attributes
Maximize profit Maximize revenue Maximize savings Minimize cost	Money (for instance, dollars)
Maximize market share Maximize rate of return	Percentage
Maximize proximity	Miles, minutes
Maximize fuel efficiency	Miles per gallon
Maximize time with friends & family	Days, hours

Characteristics of Sets of Attributes

- Complete
  - Does the set cover all the important aspects of the problem?
- Operational
  - Can it be measured and meaningfully used in the analysis?
- Decomposable
  - Decomposing leads to simpler objectives and corresponding attributes
- Non-redundant
  - Make sure we are not taking certain aspects into account twice
- Minimal
  - To keep the problem as simple as possible, do not include objectives that do not influence the choice of the most preferred alternative.

So What about Goals or Targets?

- Goal = A target level of achievement of an objective
  through attributes

Step 4: Identify Decision Alternatives

- Creative portion of decision process
  - Objective: Identify promising alternatives
- Methods
  - Study existing systems
  - Creativity methods or techniques
    - Analysis of natural systems (biologically inspired design)
    - Analogies
    - Brainstorming
    - Brainwriting (635 method)
    - Gallery method
    - (http://www.mycoted.com lists 183 techniques!)
  - Systematic decomposition methods

Step 5: Modeling the Structure of the Problem

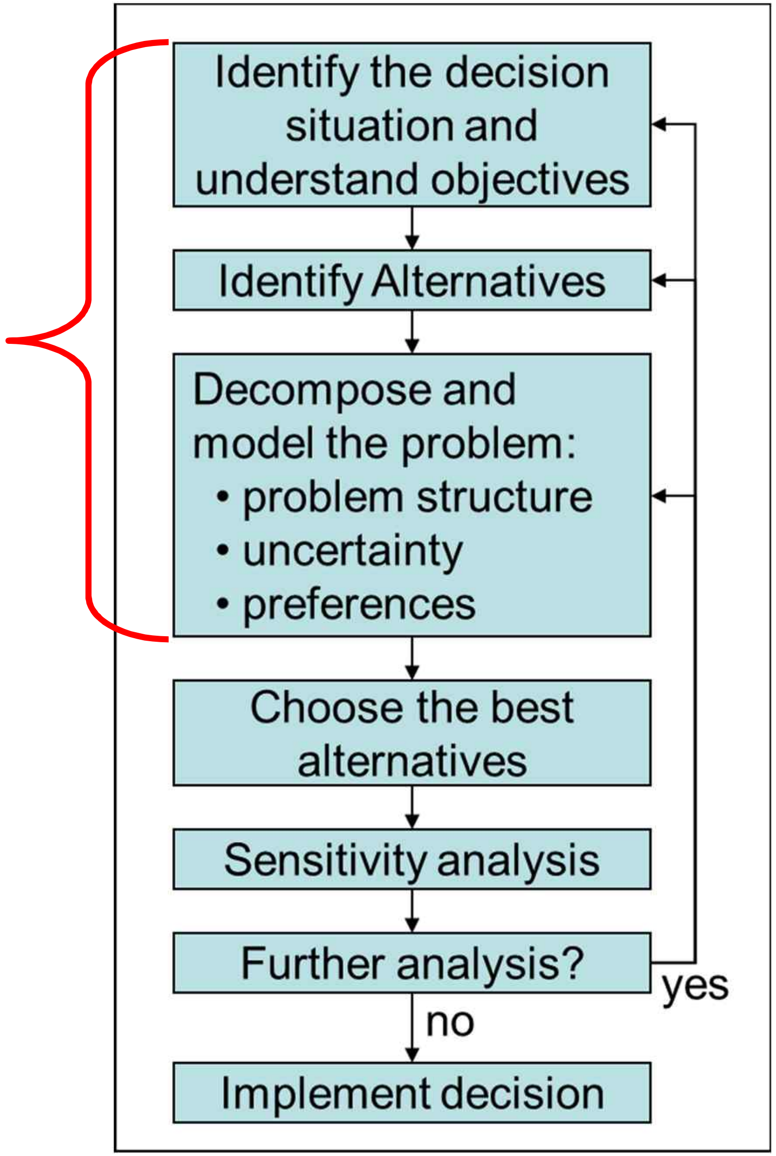
- Suppose elements of a decision problem are available
  - Objectives that apply to the decision context
  - Immediate decision and subsequent decision(s)
  - Alternatives for each decision
  - Uncertain elements (events)
  - You know how to evaluate consequences
- Structure the elements in a logical framework
  - Structure Logic and time sequence between decisions
  - Structure Logic (dependence) between the uncertain events
  - Structure time sequence of uncertain events related to the sequence of decisions
  - Represent Logic by using Influence Diagrams or Decision Trees

PART II

MODELING
THE STRUCTURE OF THE PROBLEM

Recap

- Current focus is on the first three blocks of this flow chart
- Use Influence Diagrams (or Decision Trees) to model the problem structure
- Identify and then Model uncertainty and preferences



Influence Diagrams

- Graphical model of all significant variables that can influence a decision and the decision's objective function (dead-end at bottom of diagram)
- Model their relationships with each other and with the decisions
- Result of brainstorming & analysis
- Useful in understanding risk drivers and nature of relationships

Influence Diagrams

Notations

Uncertain(State) variable

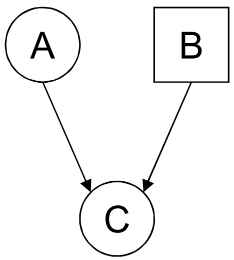
(e.g., consequences or values)

Calculated Quantity

Place at top of diagram
Which variables depend on it?

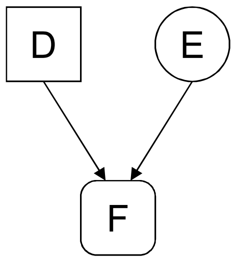
Arrows can mean either relevance or temporal sequence

Relevance



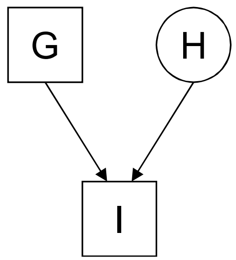
The probability of C depends on A and B

Relevance



F is computed from D and E

Sequence



G and H are known before deciding I

Influence Diagrams

Structure Elements in a Logical Framework

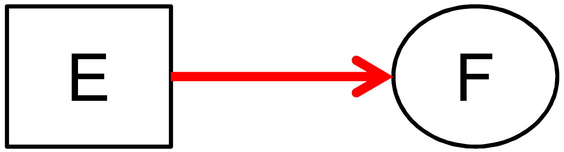
Logical relationships are represented by arrows

Indicates Sequence; points only to Decision Nodes

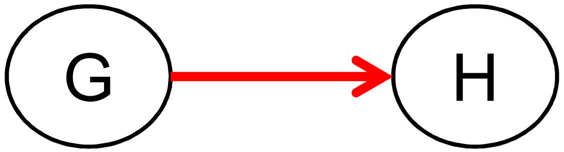
Indicates Dependence; points only to Chance Nodes & Consequence Nodes

Decision A is made before Decision B

Outcome of C is known before Decision D is made



Decision E is relevant to assessing probabilities of outcomes of F



Outcome of G is relevant to assessing probabilities of outcomes of H

Influence Diagrams

Building an Influence Diagram

1. List all the decisions
2. Draw **sequence arcs** between decisions
3. Identify the consequence node
4. Breakdown the consequence node using the Fundamental Objective Hierarchy
5. Draw **relevance arcs** from decision nodes to the intermediate calculation nodes
6. List all the uncertainty nodes
7. Draw **relevance arcs** between uncertainty nodes
8. Draw the **sequence arcs** from uncertainty nodes to the decision nodes
9. Draw the **relevance arcs** from the decision nodes to the uncertainty nodes
10. Draw the **relevance arcs** from the uncertainty nodes to the intermediate calculation nodes

(van Dorp & Mazzuchi 2006)

Example: Condo Complex Size

The statement of a developer's decision problem

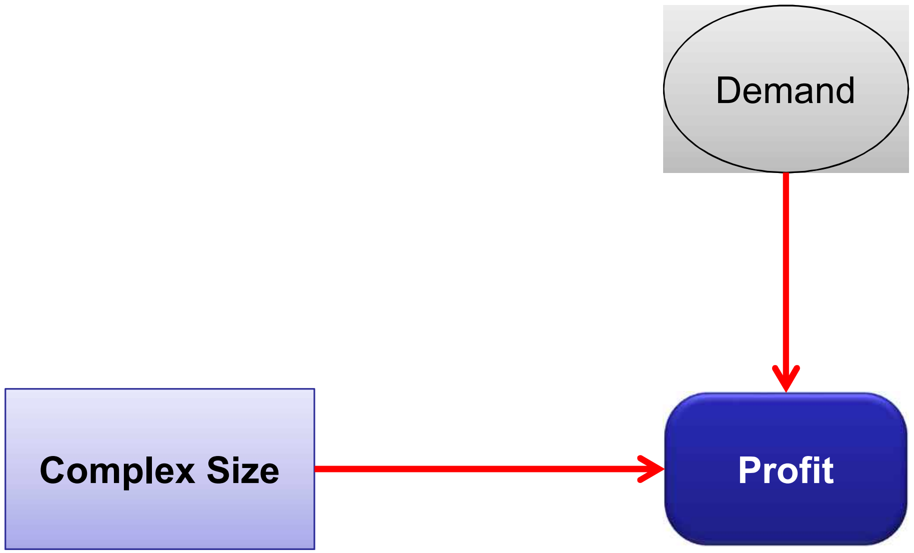
- To select the size of the new luxury condominium project that will lead to the largest profit
  - Given the uncertainty concerning the demand for the condominium

- Three decision alternatives
  - D1 = a small complex with 30 condos
  - D2 = a medium complex with 60 condos
  - D3 = a large complex with 90 condos

- Two states of nature concerning the chance event of the demand for the condominium
  - S1 = strong demand for the condos
  - S2 = weak demand for the condos

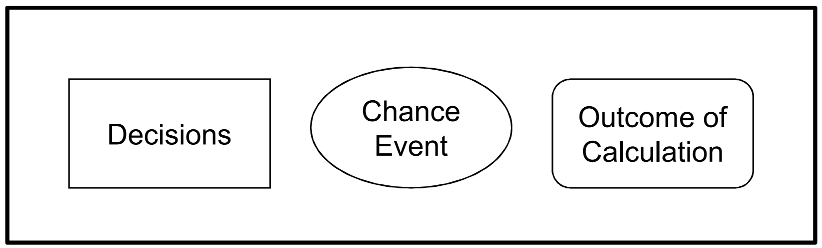
Example: Condo Complex Size

States of Nature
Strong demand (S1)
Weak demand (S2)



Decision Alternatives
Small complex (D1)
Medium complex (D2)
Large complex (D3)

Consequence
Profit



Exercise: Personal Investment

The statement of your decision problem

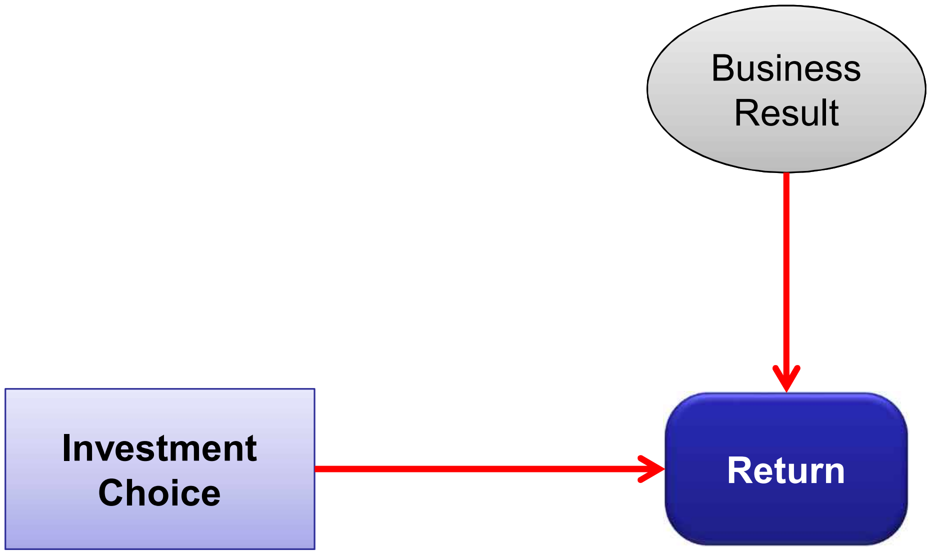
- You have $2,000 to invest, with the objective of earning as high return on your investment as possible.

- Two opportunities exist, investing in a friend's business or keeping the money in a savings account with a fixed interest rate.

- If you invest in the business, your return depends on the success of the business,
  - which your figure could be wildly successful, earning you $3,000 beyond your initial investment (and hence leaving you with a total of $5,000),
  - or a total flop, in which case you will lose all your money and have nothing.

- On the other hand, if you put the money into a savings account, you will earn $200 in interest (leaving you with a total of $2,200) regardless of your friend's business.

Exercise: Personal Investment



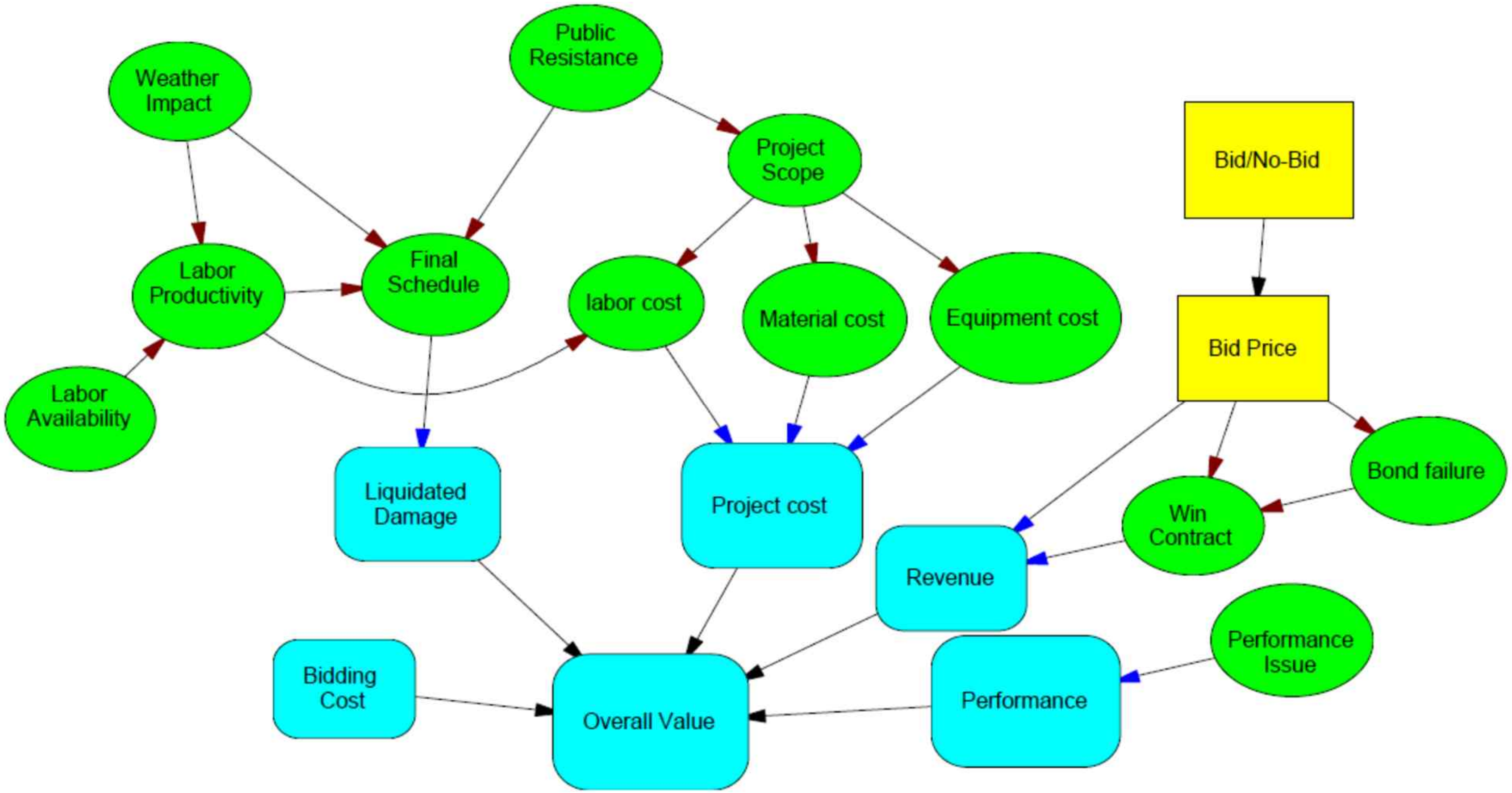
States of Nature
- Wild Success
- Flop

Decision Alternatives
- Savings
- Business

Choice	Business Result	Final Cash Position ($)
Savings	Success	2,200
	Flop	2,200
Business	Success	5,000
	Flop	0

Example: Bid-decision Model

- **Making bid decision for overseas projects**



Source: Han et al. (2001) ASCE J. of Const. Eng. and Mgmt., 127(4).

O'Connor's Influence Diagram

Steps

- Brainstorm advantages, disadvantages, and consequential events from decision
- Identify causal or driving factors relevant to advantages, disadvantages, and consequential events
- Employ graphic network to illustrate factors & relationships
- Continue until comfortable with level of detail

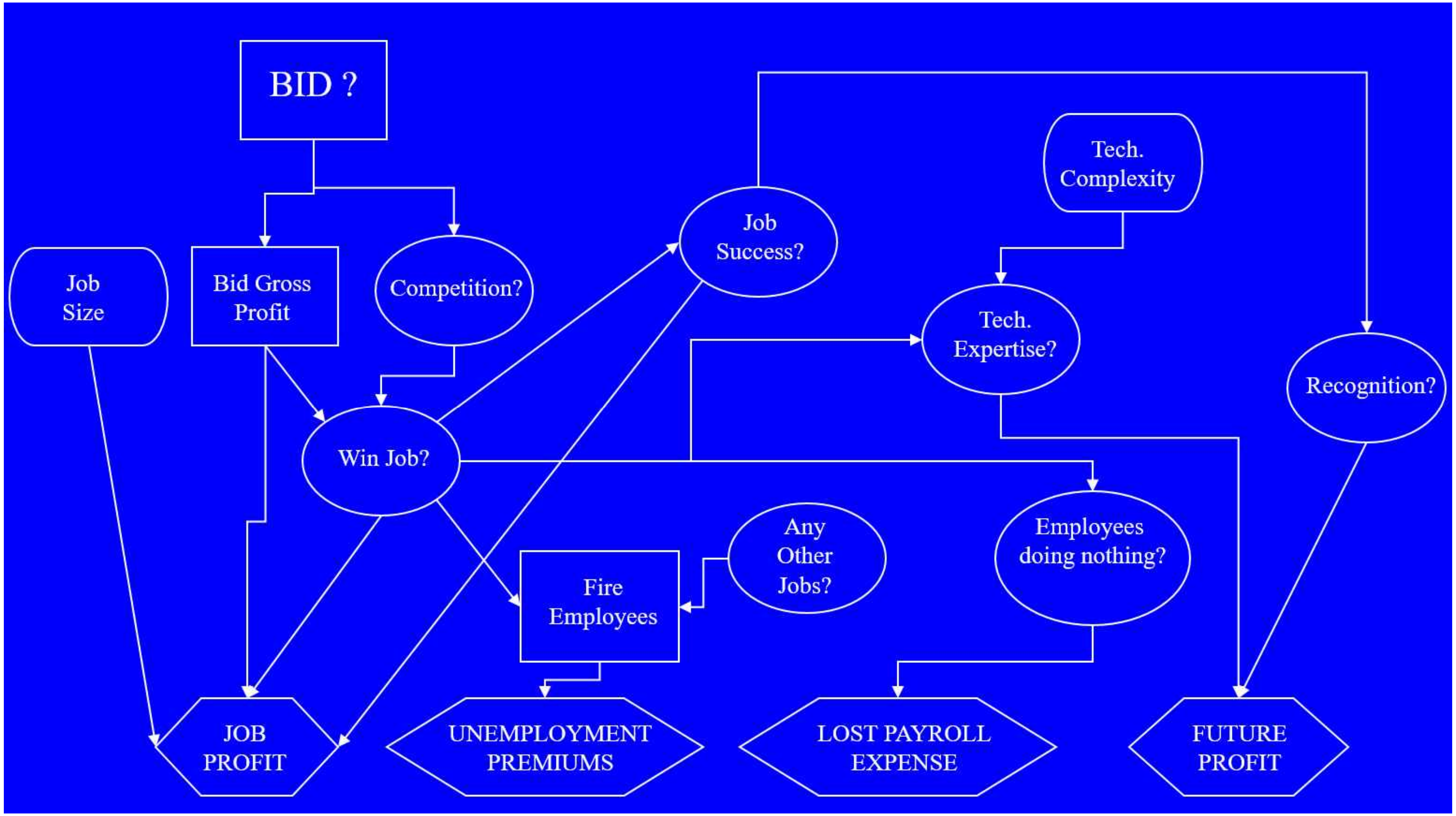
Variable types and graphic representation

- Decision Variable: Square
- State (uncertain) Variable: Circle (random)
- Calculated Quantity: Hexagon (objective function)
- Nominal Quantity: Rounded Box

Example: Bid-decision Model

- Another example

Hexagon: Calculated Quantity (rounded box in the previous)
Rounded Box: Nominal Quantity



Influence Diagrams

- **The nature of the arc – relevance or sequence – can be ascertained by the context of the arc within the diagram.**
- **Sequence arc represent information flow and relevance arcs indicate calculation.**
  - Influence diagram captures current state of knowledge.
  - An influence diagram should NEVER contain cycles.
  - Interpreting an influence diagram is generally easy.
  - Creating influence diagrams is difficult.
- **Influence diagrams could also be used to reflect the possibility of obtaining imperfect information about some uncertain event that will affect the eventual payoff.**

Influence Diagrams

Data Attribute Table for Decision Analysis

DATE:

Ref. #	**Variable or Data Element**	**Variable Type**	**Best Unit of Measure**	**Variable Value(s) or Range**	**Best Source(s) of Information**	**Current Reliability of Information/ Source**	**Need to Modify Data?**
		Decision State Nominal Calculated Quantity					

Influence Diagrams

- **All details (outcomes, choices, payoff) should be developed in a *tabular format* for each node in the influence diagram.**

Product	Delay	Price	Sales	Profit
A	Y	H	H	5.0

- **Common Mistakes:**
  - See influence diagrams as flow charts.
  - Many chance nodes going into the immediate decision node to reflect uncertainty.
  - The inclusion of cycles.

Decision Tree Analysis

A decision tree is a graphical representation of the expected value calculations and consists of

- Decision Nodes: represented by squares, are variables or actions that the decision maker controls
- Chance Event Nodes: represented by circles, are variables or events that cannot be controlled by the decision maker
- Outcome (Terminal or End) Nodes: represented by unconnected branches, are endpoints where outcome values are attached

Influence diagram → Then, Decision tree

By convention, the tree is drawn from left to right & Calculations are done from right to left, as follows

- Chance node: calculate EV
- Replace a decision node with the value of its best alternative
- If a cost value lies along a branch, recognize it as the cost of passing from right to left

Example: Condo Complex Size

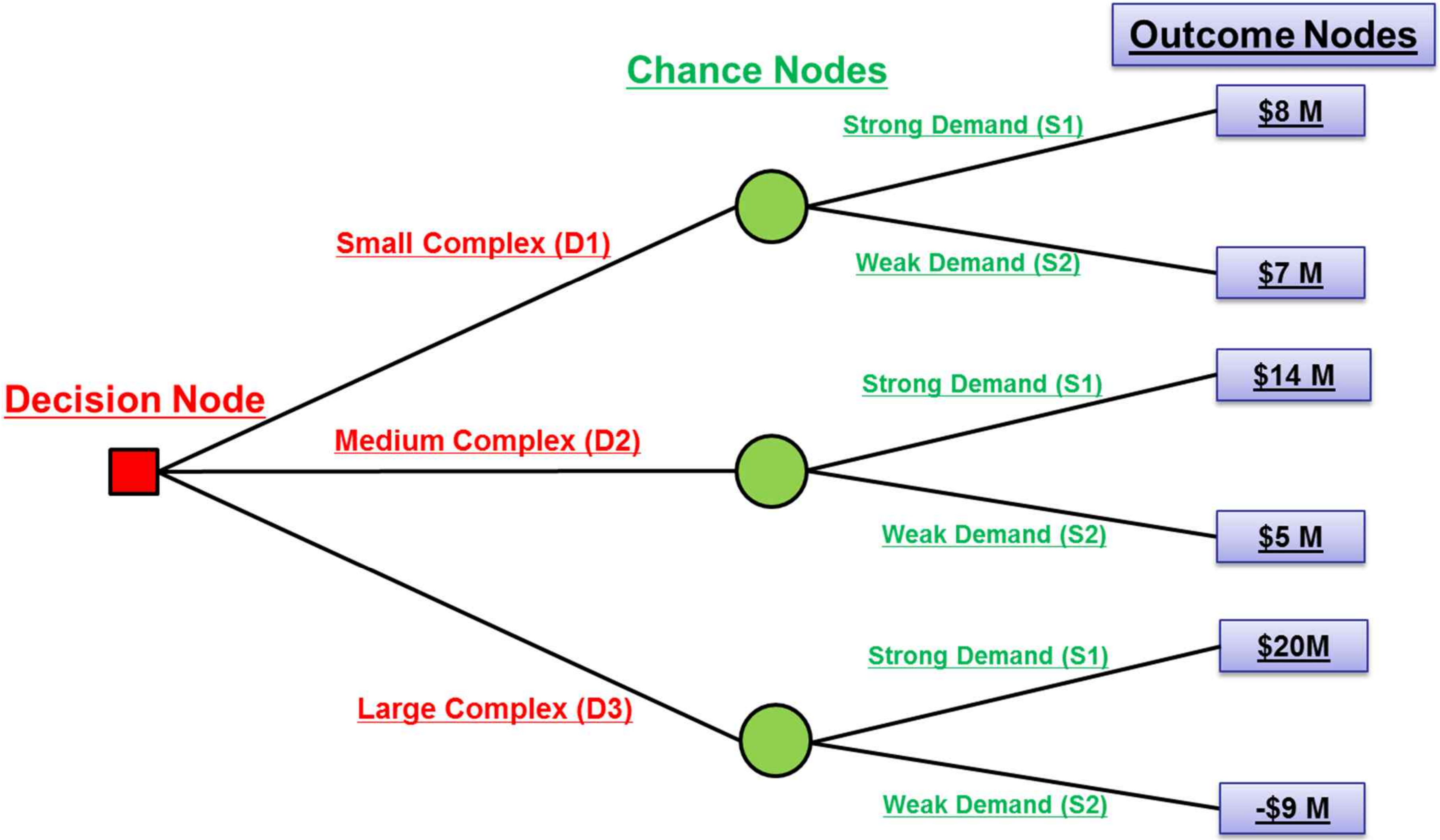
The statement of a developer's decision problem

- To select the size of the new luxury condominium project that will lead to the largest profit
  - Given the uncertainty concerning the demand for the condominium

- Three decision alternatives
  - D1 = a small complex with 30 condos
  - D2 = a medium complex with 60 condos
  - D3 = a large complex with 90 condos

- Two states of nature concerning the chance event of the demand for the condominium
  - S1 = strong demand for the condos
  - S2 = weak demand for the condos

Example: Condo Complex Size



Exercise: Personal Investment

The statement of your decision problem

- You have $2,000 to invest, with the objective of earning as high return on your investment as possible.

- Two opportunities exist, investing in a friend’s business or keeping the money in a savings account with a fixed interest rate.

- If you invest in the business, your return depends on the success of the business,
  - which you figure could be wildly successful, earning you $3,000 beyond your initial investment (and hence leaving you with a total of $5,000),
  - or a total flop, in which case you will lose all your money and have nothing.

- On the other hand, if you put the money into a savings account, you will earn $200 in interest (leaving you with a total of $2,200) regardless of your friend’s business.

Exercise: R&D Decision

The statement of the decision problem

- The DMr. is a company that must decide whether to spend $2 million to continue with a particular research project.

- The success of the project (as measured by obtaining a patent) is not assured, and at this point the DMr. Judges only a 70% chance of getting the patent.

- If the patent is awarded, the company can either license the patent for an estimated $25 million or invest an additional $10 million to create a production and marketing system to sell the product directly.

- If the company choose the latter, it faces uncertainty of demand and associated profit from sales as follows:
  - $P(Demand\ High) = 0.25 \rightarrow Profit = \$55M$
  - $P(Demand\ Medium) = 0.55 \rightarrow Profit = \$33M$
  - $P(Demand\ Low) = 0.20 \rightarrow Profit = \$15M$

Example: Decision to Crash a Project

A site manager of an offshore plant project is reviewing progress on July 1

- If normal progress is maintained and no time is lost due to hurricanes, the job will be completed on July 31
- However, due to the poor weather conditions in the area after July 16, there will be only a 40 percent chance of finishing on time
- It is estimated that there is a 50 percent chance of a minor hurricane, which will cause a delay of 5 days
- There is a 10 percent chance of a major hurricane, which will cause a delay of 10 days

Example: Decision to Crash a Project

Immediate Decision

It must be decided now whether to start a crash program (the 1st decision alternative) on July 2

- An additional cost of $75 per day should be taken into account to finish the project on July 16

The 2nd decision alternative is to maintain the normal schedule and review the progress on July 31

Secondary Decisions

ane has occurred and the project is delayed

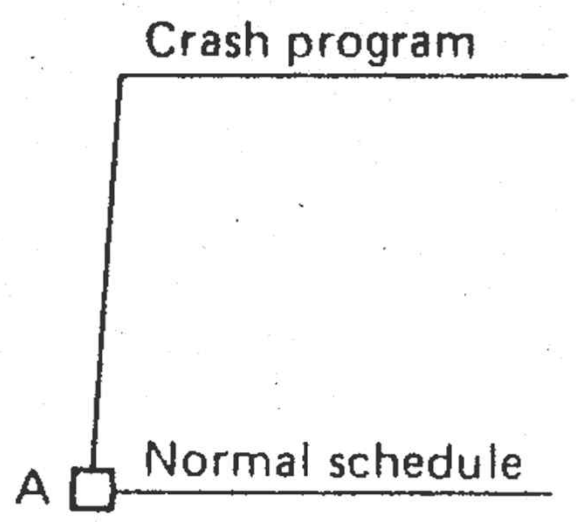
- There will be a choice of accepting the delay at a certain penalty cost or trying to crash the program
  - The penalty cost for delay of completion will be $400 per day for the first 5 days and $600 per day for the second 5 days
  - The additional cost of a crash program after the hurricane will be $200 per day

Outcome: the total additional cost is computed as the sum of delay penalty cost and crash cost

Example: Decision to Crash a Project

A decision Node (□) is drawn to represent the most immediate decision that the contractor must make

- A branch is drawn from the node to represent each alternative that is available to the decision-maker at this decision point

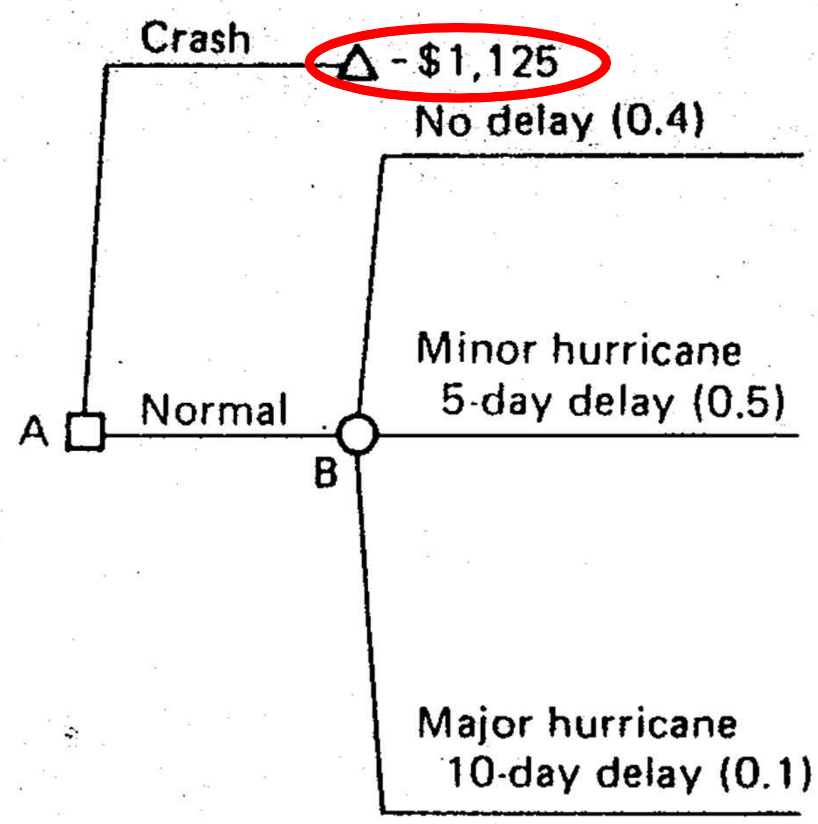


(a) Most immediate decision

Example: Decision to Crash a Project

The potential results of each of the decision alternatives are then modeled

- The outcome of immediately launching a crash program is that the project will be completed at an added cost of $75 per day for 15 days, or a total of $1125
- This is represented by assigning a terminal node with -$1125

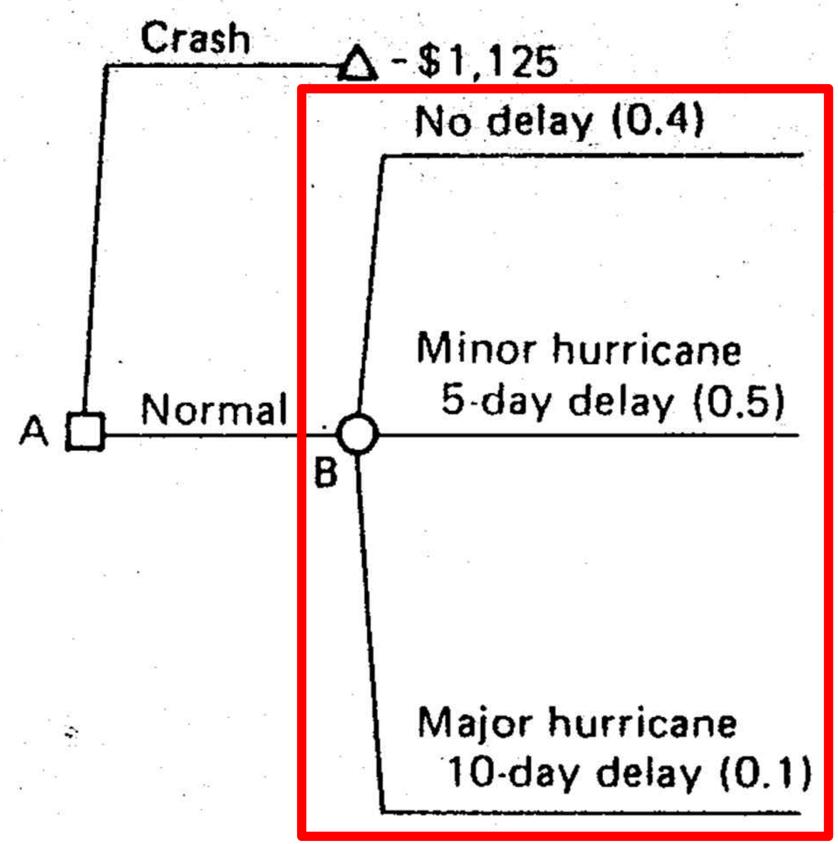


(b) Possible outcomes from first decision

Example: Decision to Crash a Project

The second alternative (normal) has three possible outcomes

- No delay with a probability of 0.4
- 5-day delay with a probability of 0.5
- 10-day delay with a probability of 0.1
- This is represented as a chance Node (◯), where each possible result is represented by a branch and the probability of occurrence is entered along the branch



(b) Possible outcomes from first decision

Example: Decision to Crash a Project

The probabilities can be determined in a number of ways

- Educated guess by the manager, whose judgment is based on present weather conditions and on recollection or weather conditions at the same period in previous years
- Historical records or local weather conditions
  - Suppose that the past 50 years of weather records for the area are available to the contractor
  - The number of years in which there was either a minor or major hurricane during the period July 16-31 can be counted

$$P(\text{no delay}) = \frac{\text{number of years with no hurricane}}{\text{total number of years counted}} = \frac{20}{50} = 0.4$$

$$P(\text{minor hurricane}) = \frac{\text{number of years with a minor hurricane}}{\text{total number of years counted}} = \frac{25}{50} = 0.5$$

$$P(\text{major hurricane}) = \frac{\text{number of years with a major hurricane}}{\text{total number of years counted}} = \frac{5}{50} = 0.1$$

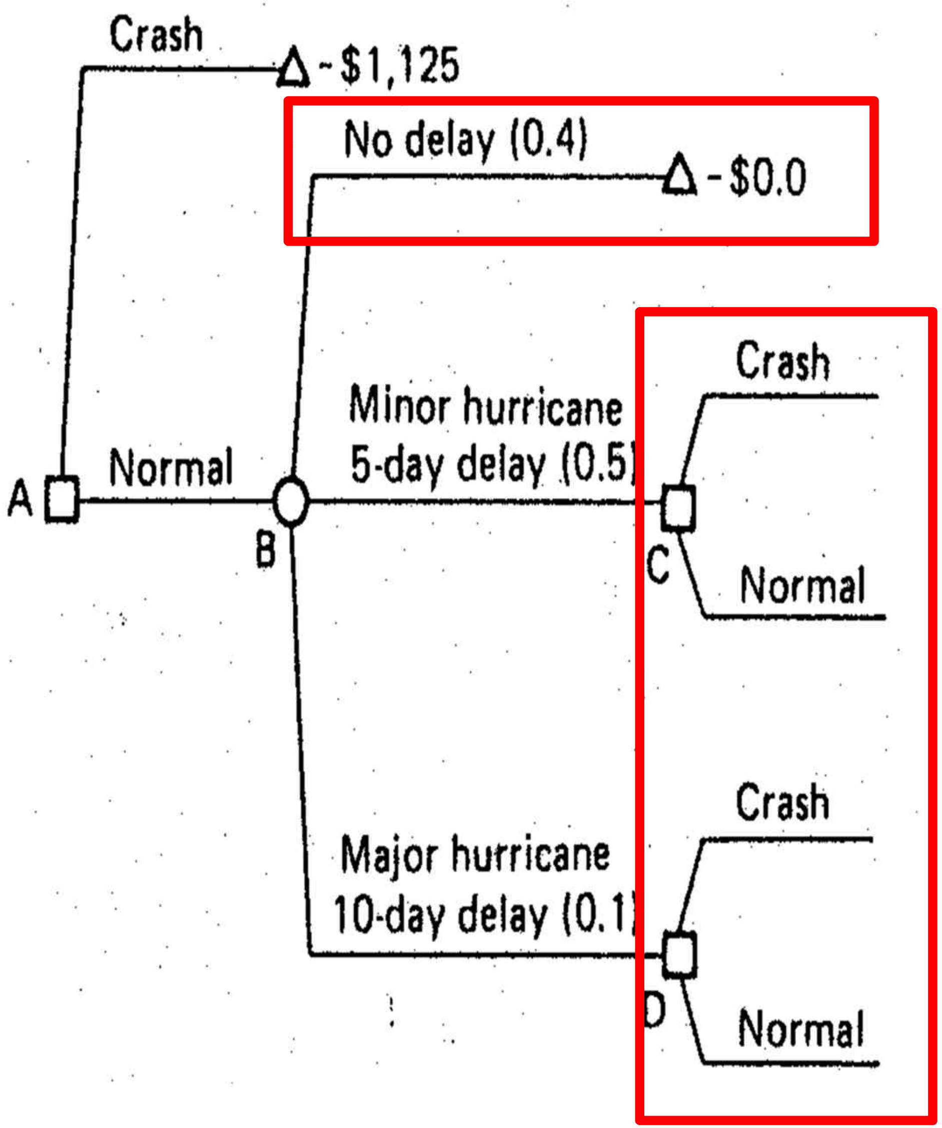
Example: Decision to Crash a Project

The only possible result of no delay on July 31 is that the project is completed on time with no delay cost

- Represented by a terminal node with a value of -$0.0

For the other two outcomes

- The manager must decide next whether to launch a crash program or to maintain a normal pace (Secondary Decisions)



Example: Decision to Crash a Project

The possible results (outcomes) of a **crash program** after a ***minor hurricane*** causes a 5-day delay

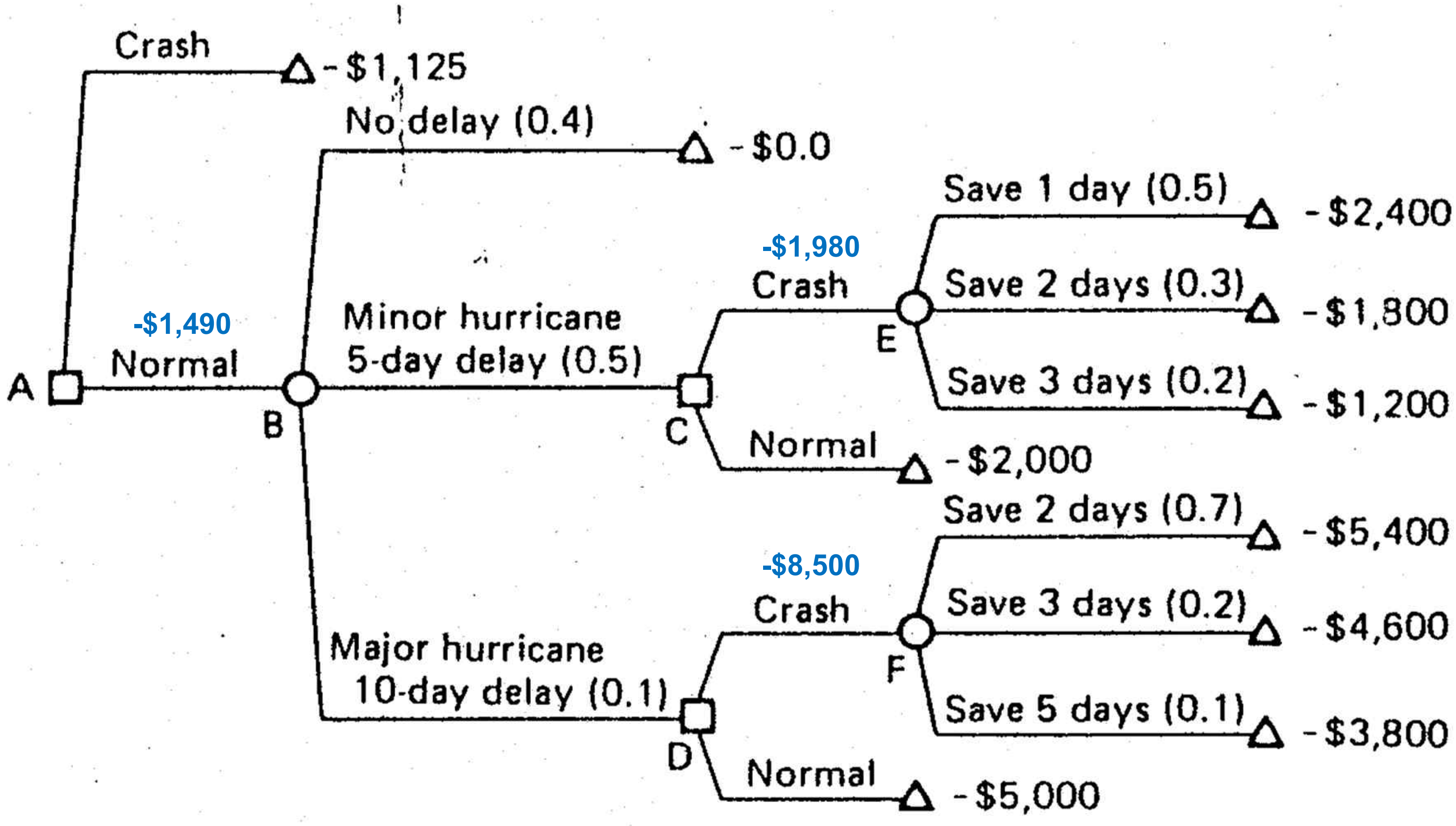
Crash Program Result	Probability	Total Additional Cost = Penalty Cost + Crash Cost
Save 1 day	0.5	\$1600 + 800 = \$2400
Save 2 days	0.3	\$1200 + 600 = \$1800
Save 3 days	0.2	\$800 + 400 = \$1200

The possible results of a **crash program** after a ***major hurricane*** causes a 10-day delay

Crash Program Result	Probability	Total Additional Cost
Save 2 days	0.7	\$(2000 + 1800) + 1600 = \$5400
Save 3 days	0.2	\$(2000 + 1200) + 1400 = \$4600
Save 4 days	0.1	\$(2000 + 600) + 1200 = \$3800

Example: Decision to Crash a Project

The decision tree is finally completed by drawing branches to represent ***possible outcomes*** of ***secondary decisions & their costs*** at terminal nodes



(d) Complete decision tree

Assignment #1-1: The S.S. Kuniang

Case Study: The S.S. Kuniang

In the early 1980s, the New England Electric System (NEES) in the U.S. was deciding how much to bid for the salvage rights to a grounded ship, the S.S. Kuniang. If the bid were successful, the ship could be repaired and fitted out to haul coal for the company's power stations. But the value of doing so depended on the outcome of a court judgement about the salvage value of the ship.

The court's judgement involved an obscure law regarding domestic shipping in coastal waters. If the judgement indicated a low salvage value, then NEES would be able to use the ship for its shipping needs. If the judgement were high, the ship would be considered ineligible for use in domestic shipping unless a considerable amount of money was spent on fitting her with fancy equipment.

The court's judgement would not be known until after the winning bid was chosen, and so there was considerable risk associated with actually buying the ship by submission of the winning bid. If the bid failed, NEES's alternatives included buying a new ship or a tug-and-barge combination, both of which were relatively expensive alternatives. One of the major issues was that the higher the bid, the more likely NEES to win. NEES reckoned that a bid of $3 million would definitely not win, whereas a bid of $10 million definitely would win. Any bid in between was possible.

Assignment #1-1: The S.S. Kuniang

a. Draw an influence diagram for NEES's decision

b. How would you go about finding the optimal amount to bid?

Assignment #1-2: General Products Company

The executives of the General Products Company (GPC) have to decide which of three products to introduce, A, B, or C. Product C is risk-free, from which the company will obtain a net profit of 1 million (all units are assumed to be US dollars). Product B is more risky: sales may be high, with resulting net profit of 8 million, medium with net profit of 4 million, or low, in which case the company just breaks even. The probabilities for these outcomes are

$$P(Sales\ High\ for\ B) = 0.38$$
$$P(Sales\ Medium\ for\ B) = 0.12$$
$$P(Sales\ Low\ for\ B) = 0.50$$

Product A poses something of a difficulty; a problem with the production system has not yet been solved. The engineering division has indicated its confidence in solving the problem, but there is a slight (5%) chance that devising a workable solution may take a long time. In this event, there will be a delay in introducing the product, and that delay will result in lower sales and profits. Another issue is the price for Product A. The options are to introduce it at either high or low price; the price would not be set until just before the product is to be introduced. Both of these issues have an impact on the ultimate net profit.

Assignment #1-2: General Products Company

Finally, once the product (A) is introduced, sales can be either high or low. If the company decides to set a low price, then low sales are just as likely as high sales. If the company sets a high price, the likelihood of low sales depends on whether the product was delayed by the production problem. If there was no delay and the company sets a high price, the probability is 0.4 that sales will be high. However, if there is a delay and the price is set high, the probability is only 0.3 that sales will be high. The following table shows the possible net profit figures (in millions) for Product A:

	Price	High Sales	Low Sales
Time delay	High	5.0	-0.5
	Low	3.5	1.0
No delay	High	8.0	0.0
	Low	4.5	1.5

Assignment #1-2: General Products Company

a. Draw an influence diagram for GPC's problem. Specify the possible outcomes and the probability distributions for each chance node. Specify the possible alternatives for each decision node. Write out the complete table for the consequence node.

b. Draw a complete decision tree for GPC. Solve the decision tree. Represent every step in solving the decision tree within the influence diagram (from part (a)), by removing the appropriate nodes and show its effect on the table for the consequence node. What should GPC do?

c. One of the executives of GPC is less optimistic about Product B and assesses the probability of medium sales as 0.3 and the probability of low sales as 0.4. Based on expected value, what decision would this executive make? Should this executive argue about the probabilities (why or why not)?

PART II

SENSITIVITY ANALYSIS

Purposes of Sensitivity Analysis

- The focus is on STATE (Uncertain) VARIABLES

- Purposes
  - Identify the ***real*** decision drivers (Understand the relative degree of influence)
  - ***Simplify*** the analysis by eliminating non-sensitive variables from analysis
  - Know where to ***expand*** the analysis (Where to focus data acquisition efforts)

- Basic Approach
  - Develop a Data Attribute Table
  - Study 1 state variable at a time, while holding all others to their most likely value
  - Compute the range of outcomes from varying the study variable over its range of possible values
  - Summarize with a graphical plot
  - Interpret the results: what variables are "sensitive"?

Purposes of Sensitivity Analysis

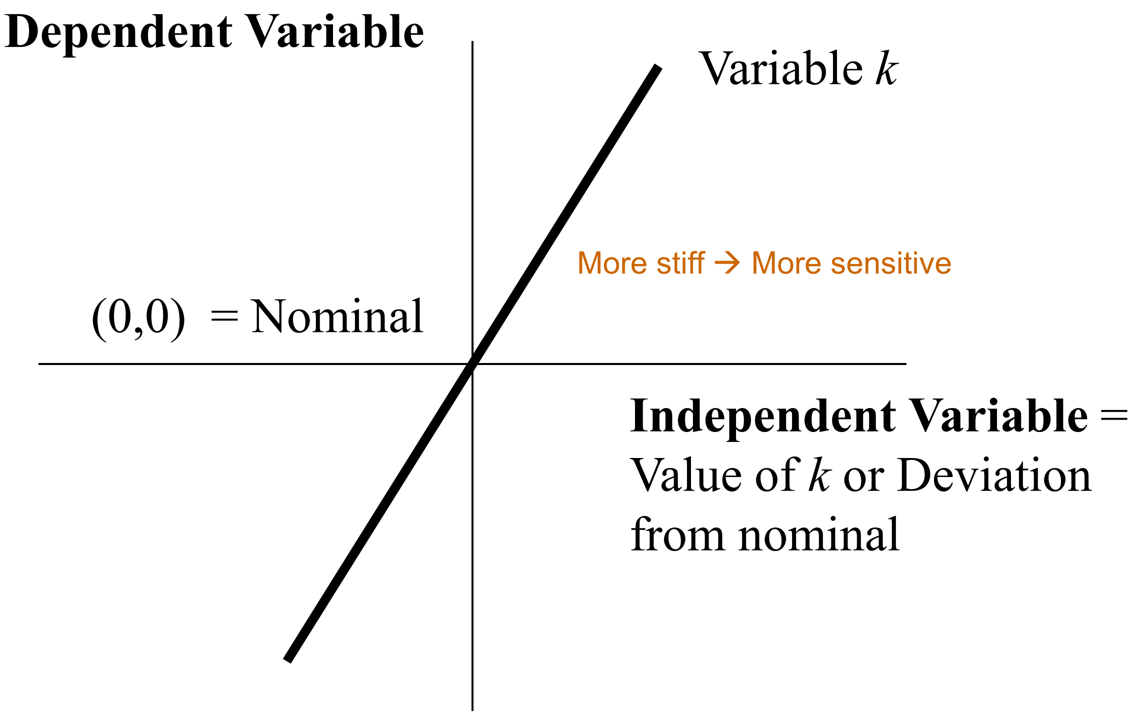
Data Attribute Table for Decision Analysis

DATE:

Ref. #	**Variable or Data Element**	**Variable Type**	**Best Unit of Measure**	**Variable Value(s) or Range**	**Best Source(s) of Information**	**Current Reliability of Information/ Source**	**Need to Modify Data?**
		Decision State Nominal Calculated Quantity					

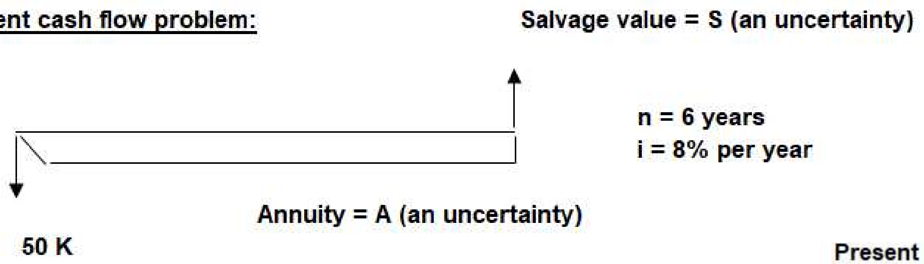
Sensitivity Plot

- A *slight* variation in the study variable yields a *significant* variation in the outcome

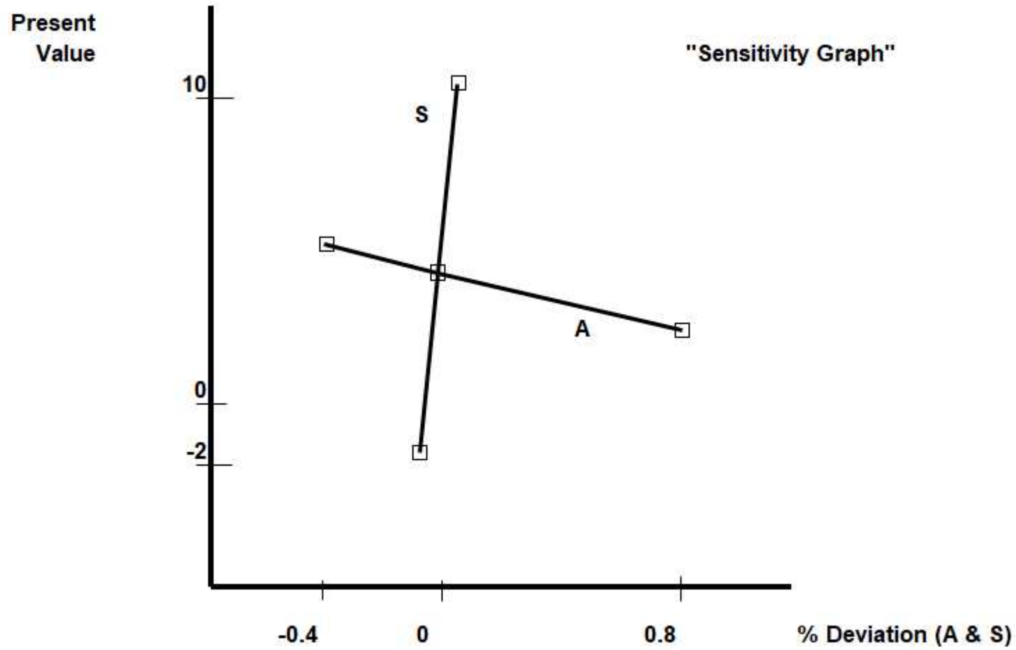


Sensitivity Plot

Investment cash flow problem:



Var.	Value	% Dev.	Pres. Value
A	0.3	-0.4	5.31
	0.5	0	4.39
	0.9	0.8	2.54
S	80	-0.11	-1.91
	90	0	4.39
	100	0.11	10.69



NPV = - 50 – A[P/A, 8%, 6yrs] + S[P/F, 8%, 6yrs]

NPV More sensitive at S than at A

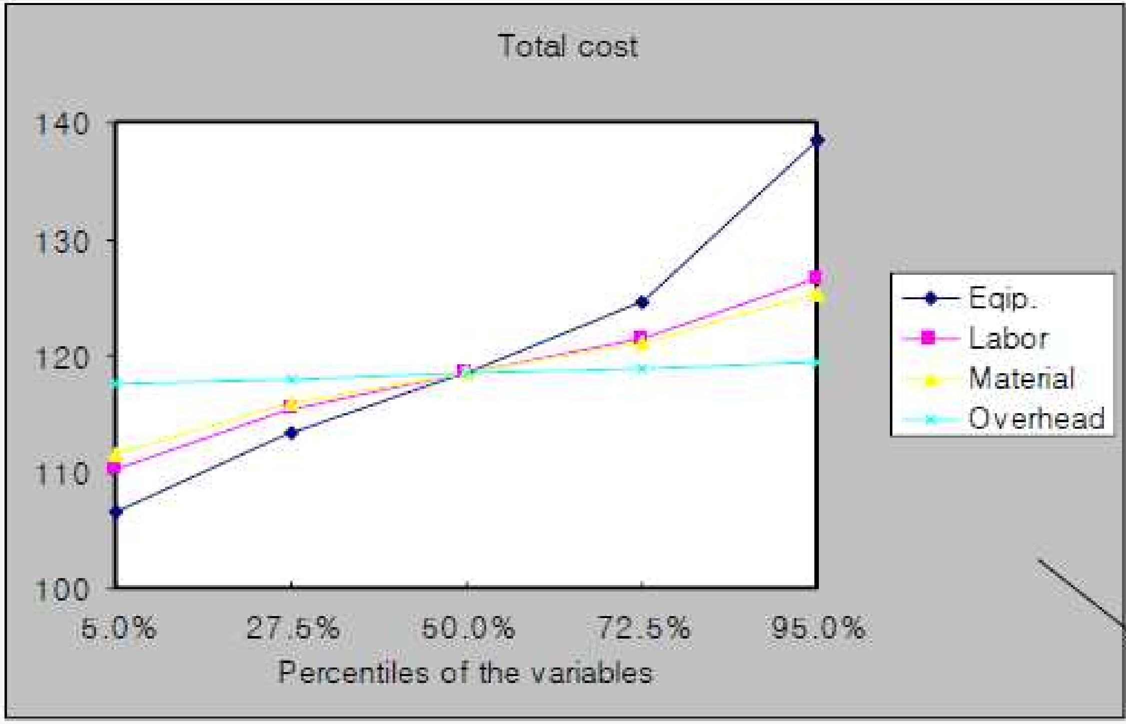
Sensitivity Plot

- Sensitivity: Tornado diagram

	Total cost			Input		
Variable	Downside	Upside	Range	Downside	Upside	Base Case
Eqip.	106.69	138.54	31.86	16.69	48.54	28.46
Labor	110.24	126.68	16.45	41.78	58.22	50
Material	111.62	125.30	13.68	23.16	36.84	30
Overhead	117.56	119.36	1.8	9.1	10.9	10

Sensitivity Plot

- Sensitivity: spider diagram



	Total cost				
Variable	5.0%	27.5%	50.0%	72.5%	95.0%
Eqip.	106.6866567	113.441043	118.4604989	124.5547764	138.5417789
Labor	110.2362307	115.4716983	118.4604989	121.4492996	126.6847671
Material	111.6227766	115.8766974	118.4604989	121.0443005	125.2982213
Overhead	117.5604989	118.0104989	118.4604989	118.9104989	119.3604989

Q & A

Street Calculus
Risk factors
black
male
aggressive body language
baseball cap on backwards
short hair
baggy jacket
wrong neighborhood
RF = 3
Mitigating Factors
female
over 40
loafers
tie and coat
whistling Sondheim
Fed Ex envelope
polo shirt
MF = 4
4 > 3
Risk: Acceptable.
Risk Factors
black
white
male
long hair
wrong neighborhood
police officer
baseball cap
Rf = 3
Mitigating factors
female
white
briefcase
groceries
humming Motown
tie + coat
over 40
MF = 4
4 > 3
Risk: Acceptable.
Good evening.
Good evening.