Modeling Decisions - 1

Decision Supports Systems 2017/18, Lecture 02

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Introduction to Decision Analysis

- we all have to make decisions

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We will learn *Decision Analysis*:

- provides *structure* and *guidance* for thinking systematically about hard decisions
- decision analysis provides analytical tools that make hard decisions easier
- hence, the decision maker is more confident about the decisions

Gypsy moth and the ODA

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  - use BT, a bacterial insecticide that is
    - target specific
    - ecologically safe
    - reasonably effective
  - use a chemical insecticide (Orthene) in three specific areas near city of Eugene
    - potential ecological threat
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    - potential ecological threat
    - potentially dangerous to humans
- forestry: chemical insecticide is more powerful than BT and is necessary!
- environmentalists: potential danger of Orthene is too big!
- some individuals: Orthene would not help because the infestation too advanced (nothing could help)!
- other individuals: Orthene would be useful but only if used immediately!

ODA has a complex problem at hand.

Why are decisions hard?

1. Because of their complexity

- many issues to take into account
- hard to keep in mind all of them
- decision analysis helps breaking down complex decisions to a manageable form
  - influence diagrams
  - decision trees

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- progress in one direction impedes progress in another
  - economic interest vs. ecological disaster

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4. Because different perspectives lead to different conclusions

- more people involved in the decision-making process
- different people have different opinions about uncertainties or values of outcomes

Decision analysis helps making good decisions

What is a good decision?

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A good outcome happens because:

- lucky outcome vs. good decision?
  - buy stocks in 1929 (just before the stock market crash)
  - buy stocks in 1980 (general economic growth in 1980s)
  - was the decision good?
    - yes, if careful consideration of the available information and thorough deliberation about the goals and possible outcomes.
  - was the outcome good?
    - 1929: no
    - 1980: yes
- you can make a **good decison** but have an **unlucky outcome**

Decision Analysis

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- Decision Analysis is a tool that **helps** and **works alongside** the decision maker
  - provides insight
  - information source

Subjective Judgment and Decision Making

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  - uncertainties
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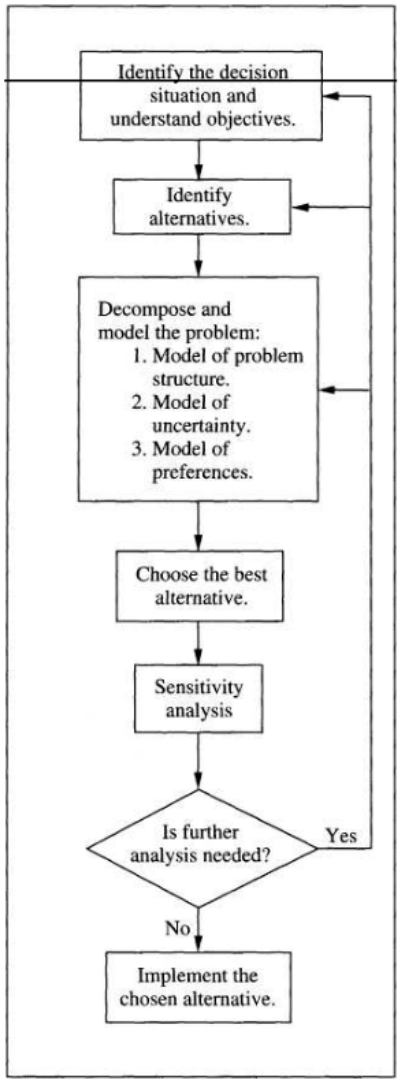
- personal judgments can be limited and misleading
  - we need to be aware of this
  - ignoring this can amplify their impact

The Decision Analysis Process

Figure 1.1
A decision-analysis process flowchart.



1. Problem identification
   - sometimes we treat the wrong problem
   - type III problem (right answer to the wrong question)
   - "I have a headache"
     - headache only?
     - symptom of another illness?

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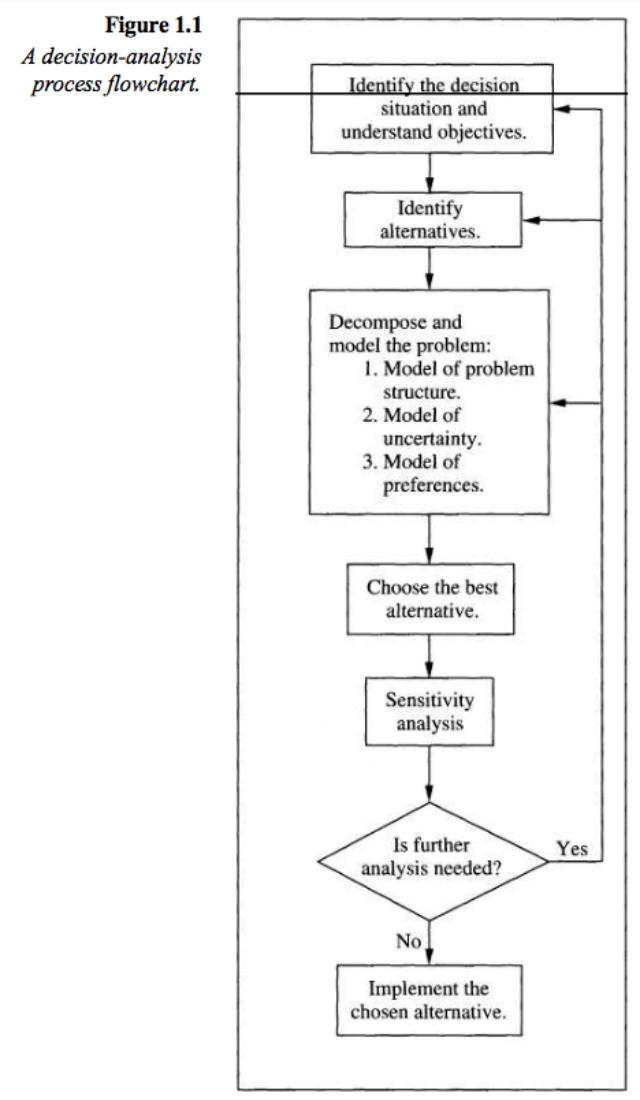

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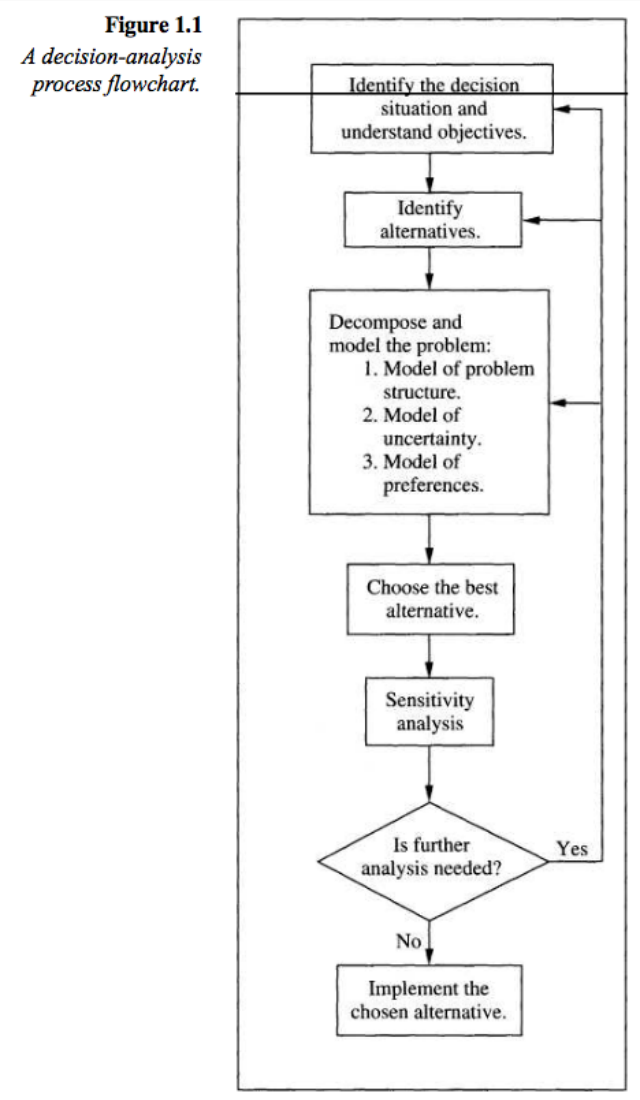
2. Identify objectives and alternatives
   - minimizing costs?
   - maximizing profit?
   - minimizing risk?
     - Money loss? Health?
   - consideration of many aspects (objectives) leads to unforseen alternatives

The Decision Analysis Process



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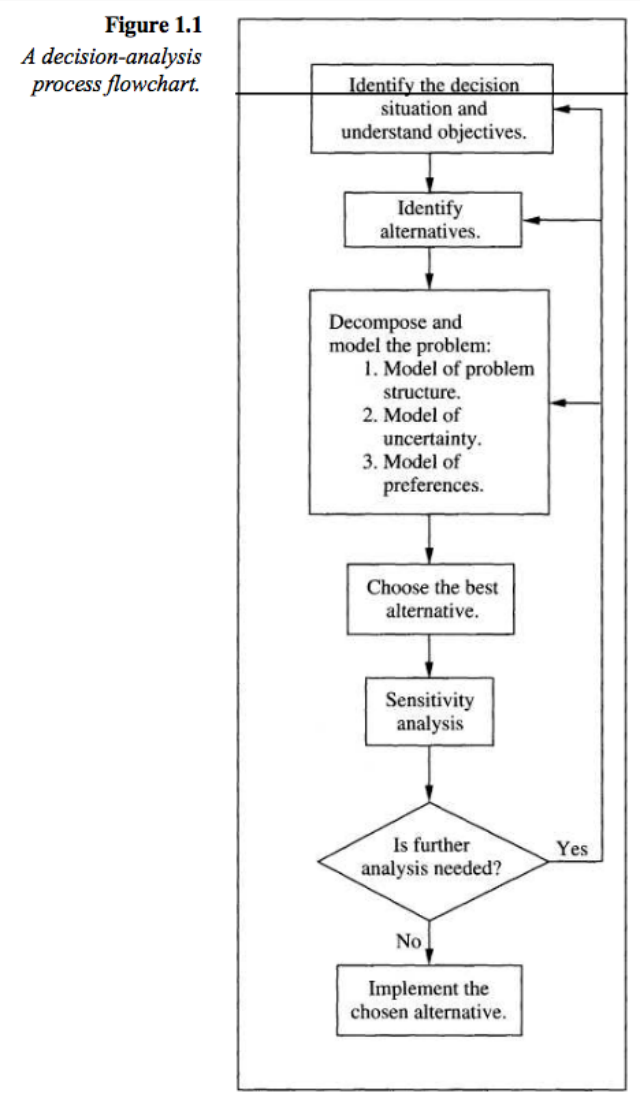
3. Modeling and Solutions

- divide and conquer = decompose problems in order to understand their structures and measure uncertainty and value
  - Modeling decisions (structuring)
    - influence diagrams
    - decision trees
  - Modeling uncertainty
    - probability
  - Models of outcome value (preferences)
    - utility functions

The Decision Analysis Process



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4. Sensitivity Analysis

- after a model has been chosen ->
- *if we make a slight change to the model parameters, does the optimal decision change?*
  - yes: the decision is **sensible** to small changes
    - adjust/reconsider the model (iterative process)
  - no: the decision is **not sensible** to small changes

Requisite Model

A requisite decision model is defined as a model whose form and content are sufficient to solve a particular problem. The model is constructed through an interactive and consultative process between problem owners and specialists

- we aim at getting to a requisite model of decisions

Lawrence D. Phillips, A theory of requisite decision models, In Acta Psychologica, Volume 56, Issues 1–3, 1984, Pages 29-48, ISSN 0001-6918, https://doi.org/10.1016/0001-6918(84)90005-2. (http://www.sciencedirect.com/science/article/pii/0001691884900052)

Where is Decision Analysis Used?

- business and government decision making
  - managing R&D programs
  - negotiations for oil and gas leases
  - forecasting sales
  - public utilities
    - where to put a power plant
    - where to have waste cleanup facilities . . .
- medicine
  - diagnoses
  - assessing risks of different treatments

Quiz

Give an example of a good decision that you made in the face of some uncertainty. Was the outcome lucky or unlucky? Can you give an example of a poorly made decision whose outcome was lucky?

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Identify the basic elements of the situation!

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When having a complicated problem to make, what to do first?

Identify the basic elements of the situation!

1. Decisions to make
2. Uncertain Events
3. Value of specific outcomes

Decisions to Make

Imagine a farmer whose trees are laden with fruit that is nearly ripe. If the weather forecast reports good weather, there is nothing to worry about. If it reports freezing weather, it might be appropriate to spend money on protective measures.

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- there are always at least two alternatives
  - leave as is
  - take protective measures
    - several strategies

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  - e.g.: wait for the evening weather report
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- alternative: insurance/hedging
  - e.g.: pay workers a small amount for night availability

Decisions to Make

- First critical step: **identify the immediate decision to be made**
  - no decision model can be made without knowing the decision problem
  - think of possible alternatives
- Always consider:
  - doing nothing
  - waiting to get more information
  - insurance/hedging

Sequential Decisions

- in many cases there is not one single decision but **several sequential decisions**

Farmer example: *Several weeks of the growing season remain. Each day there is a weather forecast and each day the farmer needs to take a decision about protecting the crops.*

- many decisions to make
- these are sequential
- this case: decisions are similar (mostly not the case)

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- harvest is tomorrow: DO PROTECT
- harvest is far in the future: WHAT TO DO?
  - policy, e.g. spend less on the protection than the value of the crop
    - don't protect in the early part of the growing season
    - wait until the harvest is closer and then protect
    - *if we are going to lose the crop, let's lose it early*

Sequential Decisions

- often a decision leads to another in a sequence
- mostly, these decisions are different
  - e.g. new product example
    1. decision: introduce/not introduce the new product
    2. decision: produce vs. subcontract
    3. decision: marketing decisions (distribution, promotion, pricing)

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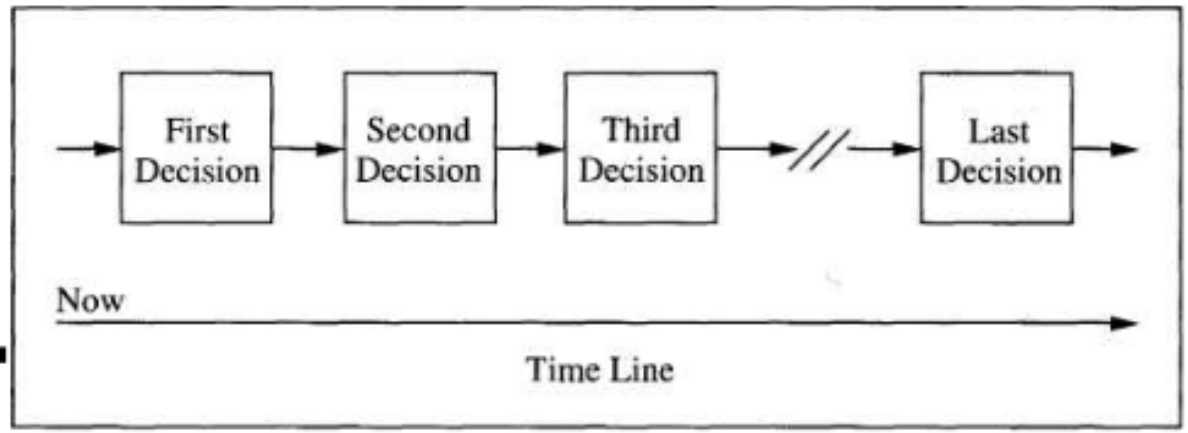
- we call *Dynamic Decision Problems*:
  - when making a decision, the decision-maker thinks of future decisions
  - future decisions depend on past decisions

Figure 2.2
Sequential decisions. A decision maker needs to consider decisions to be made now and later.



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- there can be more than one uncertain events affecting a single decision

Uncertain Events in Sequential Decisions

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  - which info is available
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- Example: investing in a company that is involved in a lawsuit
  1. decision (before lawsuit outcome is known):
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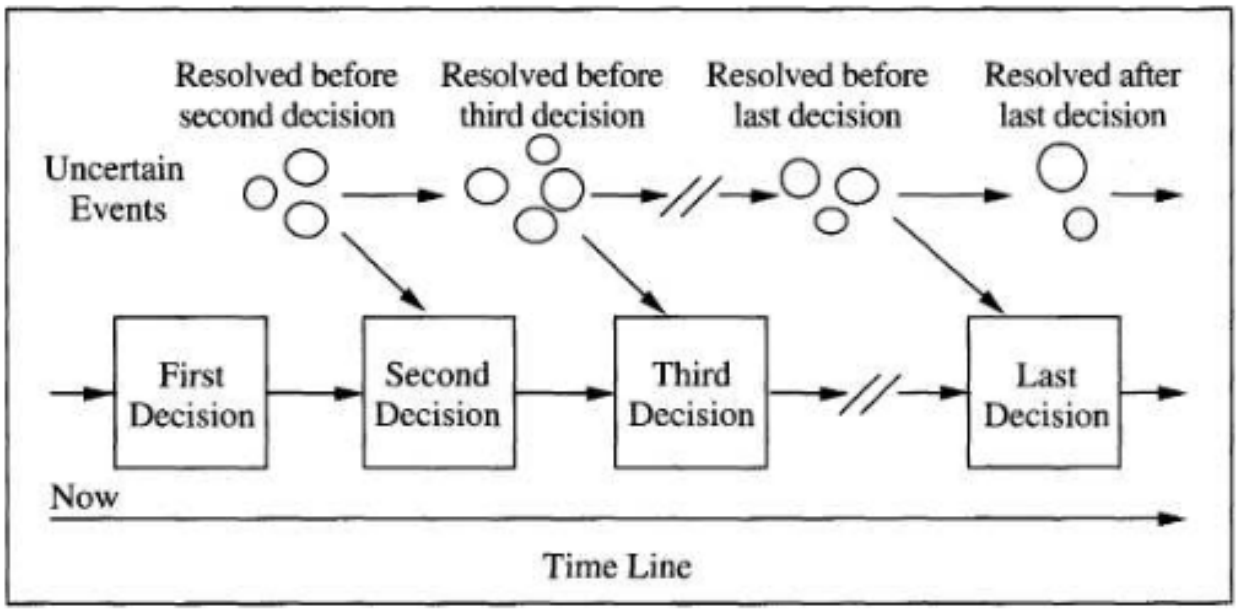
Figure 2.3
Dovetailing uncertain events and sequential decisions.



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- an outcome can have multiple values:
  - economical benefit
  - ecological loss
- e.g. general decision to attack a hill
  - hill taken
  - loss of soldiers

Planning Horizon

- we must think of the final outcome of a sequence
- farmer:
  - protect (decision), bad weather (resolved uncertainty): gain of 15k (value of outcome)
  - not protect (decision), bad weather (resolved uncertainty): loss of 4k (value of outcome)
- general:
  - attack: hill gained, 10 killed, 5 injured (value of outcome)
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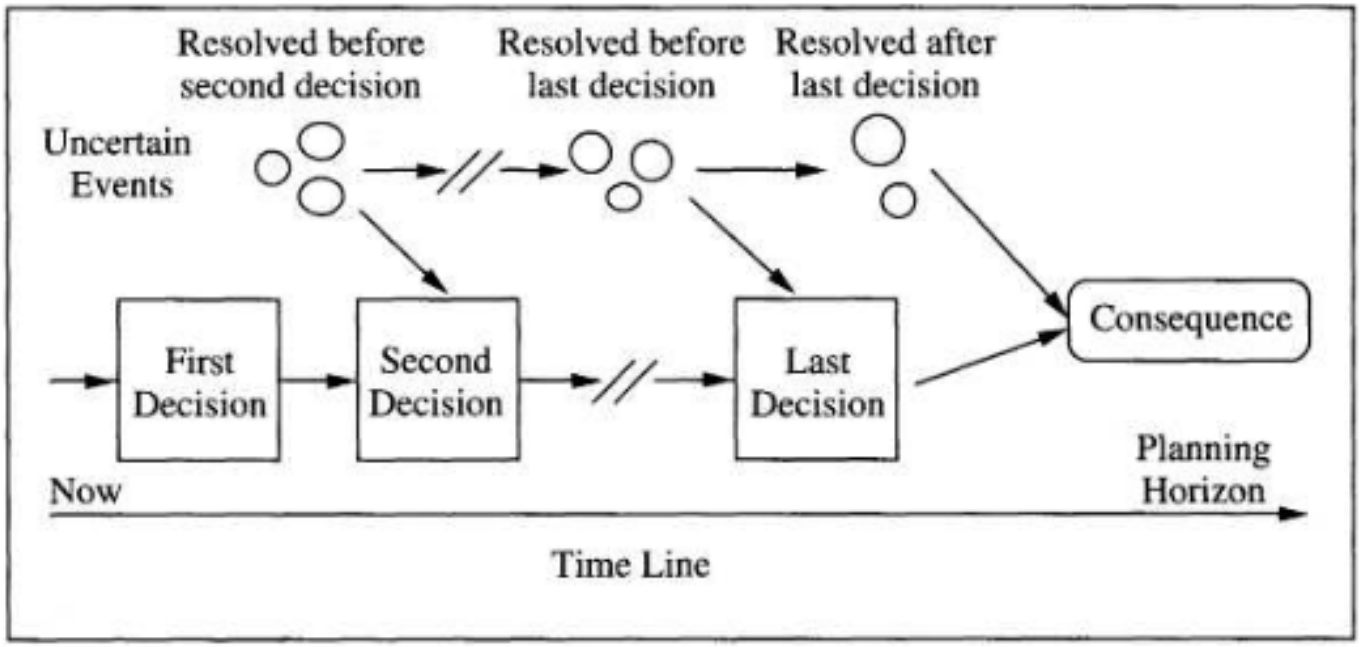
Figure 2.4
Including the consequence.



Planning Horizon

What is an appropriate planning horizon?

- farmer: time of the harvest
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  - more complicated
    - next day?
    - battle-wise?
    - war-wise?

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- important aspect: how far in the future to look?

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For the purpose of constructing a requisite model, the idea is to choose a planning horizon such that the events and decisions that would follow after **are not essential parts of the immediate decision problem**. To put it another way, choose a planning horizon that is consistent with your decision context and the relevant objectives.

Assigning Actual Values

- dimensions of the outcome are determined
- planning horizon is determined
- next step: what value has each possible outcome?

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- in many cases we can assign monetary values
- sometimes we have non-monetary objectives (some can be translated into money)
- e.g. manager decision to build a daycare center (kindergarten) for employees
- dimensions of the outcome:
  - goodwill between company and employees -> additional dimensions:
    - reduced absenteism
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- sometimes it is hard to determine how different objectives (dimensions) should be traded-off
  - how many lives should the general trade-off for conquering the hill
  - how much damage to the environment are we willing to accept in order to increase the U.S. supply of domestic oil?
  - how much in the way of health risks are we willing to accept in order to have blemish-free fruits and vegetables?

A Civil Action

A Civil Action, 1998 novel/film https://en.wikipedia.org/wiki/A_Civil_Action_(film)

On assigning monetary value to non-monetary outcomes from the perspective of personal injury law:

It's like this. A dead plaintiff is rarely worth more than a living severely-maimed plaintiff. However, if it's a long, slow, agonizing death as opposed to a quick drowning or car wreck, the value can rise considerably. A dead adult in his 20s is generally worth less than one who is middle aged. A dead woman less than a dead man. A single adult less than one who's married. Black less than white. Poor less than rich. The perfect victim is a white male professional, 40 years old, at the height of his earning power, struck down at his prime. And the most imperfect: well, in the calculus of personal injury law, a dead child is worth the least of all.

Table of Contents

Structuring Decisions

- we have identified the elements of the decision problem
- how do we structure problems?
  - influence diagrams
  - decision trees
- both approaches complement each other

Influence Diagram

- simple graphical representation of a decision problem
- the three elements are shown as different shapes
  - decision to make (rectangle)
  - uncertainty (oval)
    - deterministic - aggregated uncertainty (double oval)
  - values of outcomes (rounded rectangle or octagonal)
- they are connected with arrows/arcs
  - predecessor —> successor
  - tail -> head

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  - predecessor —> successor
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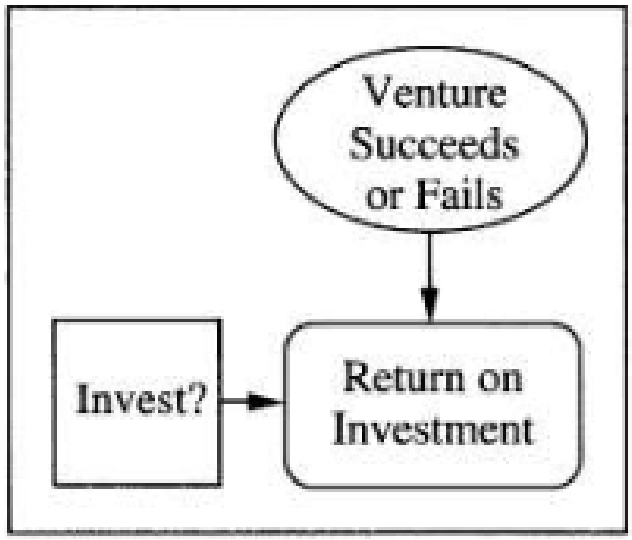
- mathematical model: **directed acyclic graph**
  - nodes (elements)
  - edges/arcs (connections)

Example: 1-1-1

Investment of the capitalist in a new venture

- one decision: invest or not?
- one uncertain event: will the company succeed?
- one outcome: value of the company

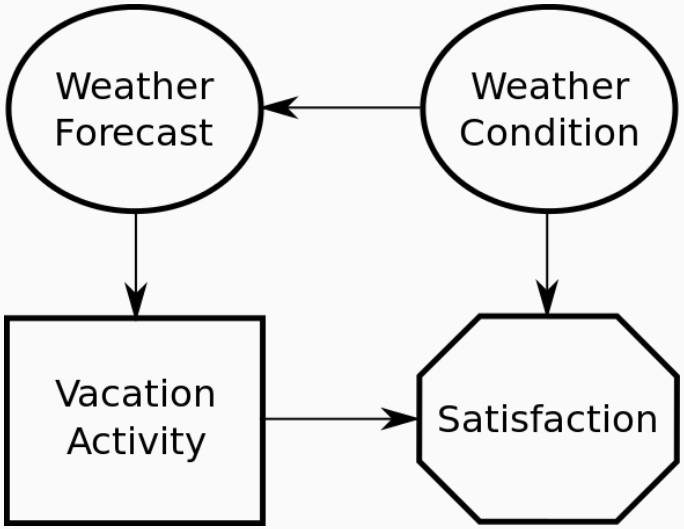
Figure 3.5
Influence diagram of venture capitalist's decision.



- decision influences value
- uncertain event influences value
- decision is not informed by the uncertain event (no arrow)
  - The absence of an arc indicates that when the decision is made, the venture capitalist does not know whether the project will succeed.
- decision does not affect the uncertain event (no arrow)

Types of arrows

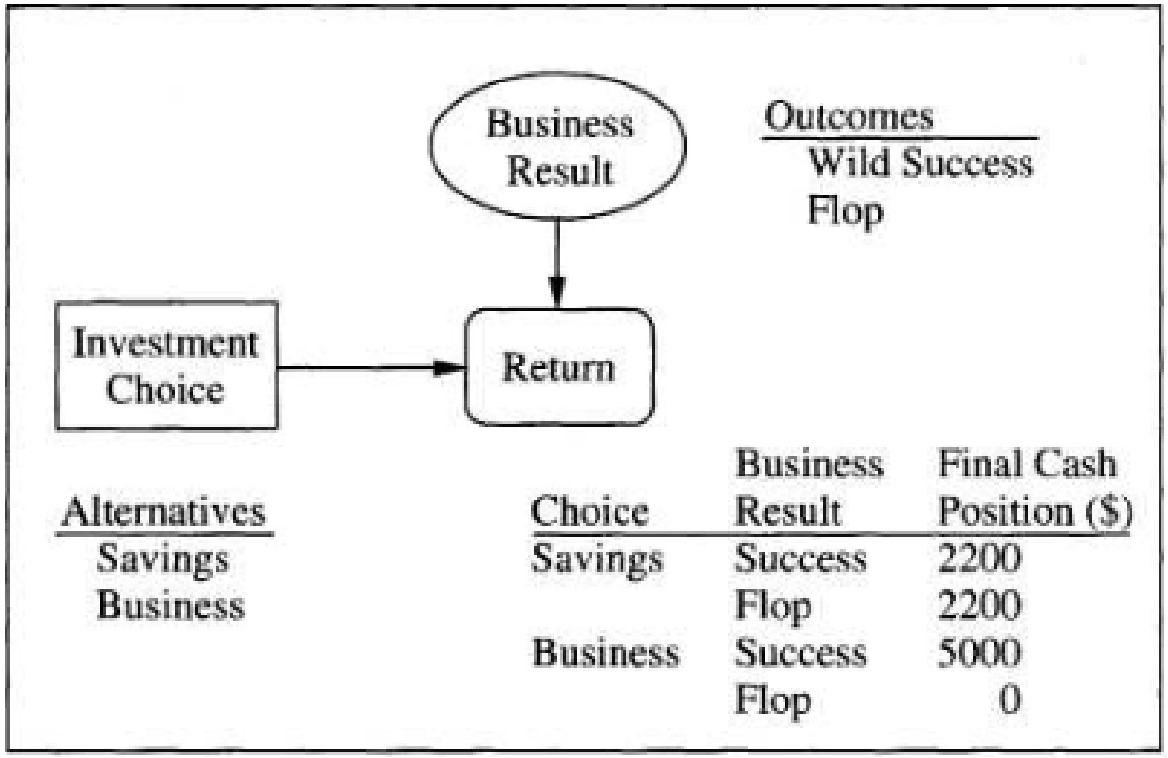
- **Functional arcs** (ending in value node) indicate that one of the components of additively separable utility function is a function of all the nodes at their tails.
- **Conditional arcs** (ending in uncertainty node) indicate that the uncertainty at their heads is probabilistically conditioned on all the nodes at their tails.
  - **Conditional arcs** (ending in deterministic node) indicate that the uncertainty at their heads is deterministically conditioned on all the nodes at their tails.
- **Informational arcs** (ending in decision node) indicate that the decision at their heads is made with the outcome of all the nodes at their tails known beforehand.



Basic Influence Diagrams: Basic Risky Decision

Figure 3.9

Basic risky decision with displayed choices, outcomes, and consequences.

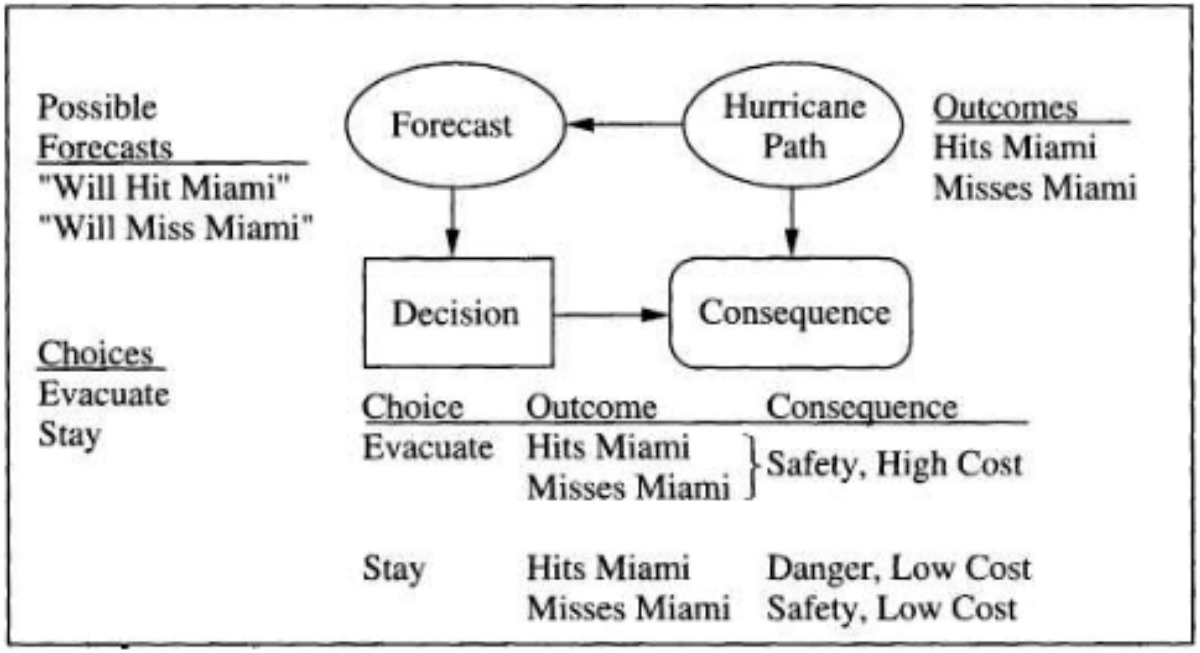


Alternatives
Savings
Business

Choice	Business Result	Final Cash Position ($)
Savings	Success	2200
	Flop	2200
Business	Success	5000
	Flop	0

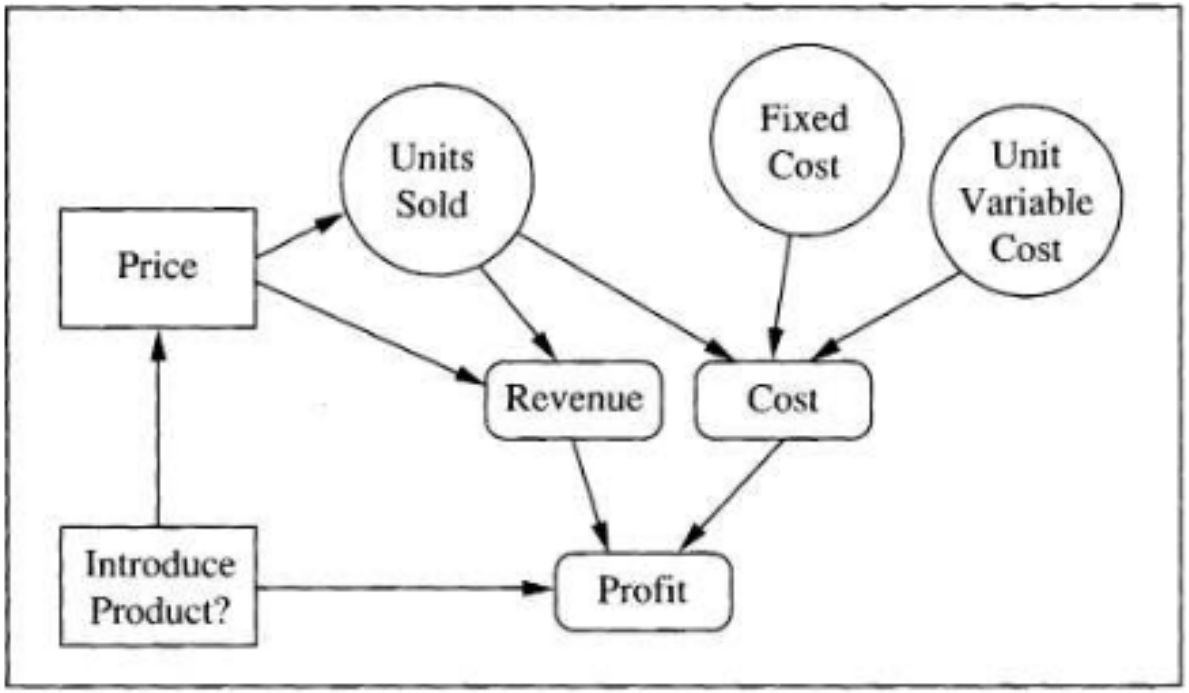
Basic Influence Diagrams: Imperfect Information

Figure 3.11
Influence diagram for the evacuation decision.



Basic Influence Diagrams: Deterministic Nodes

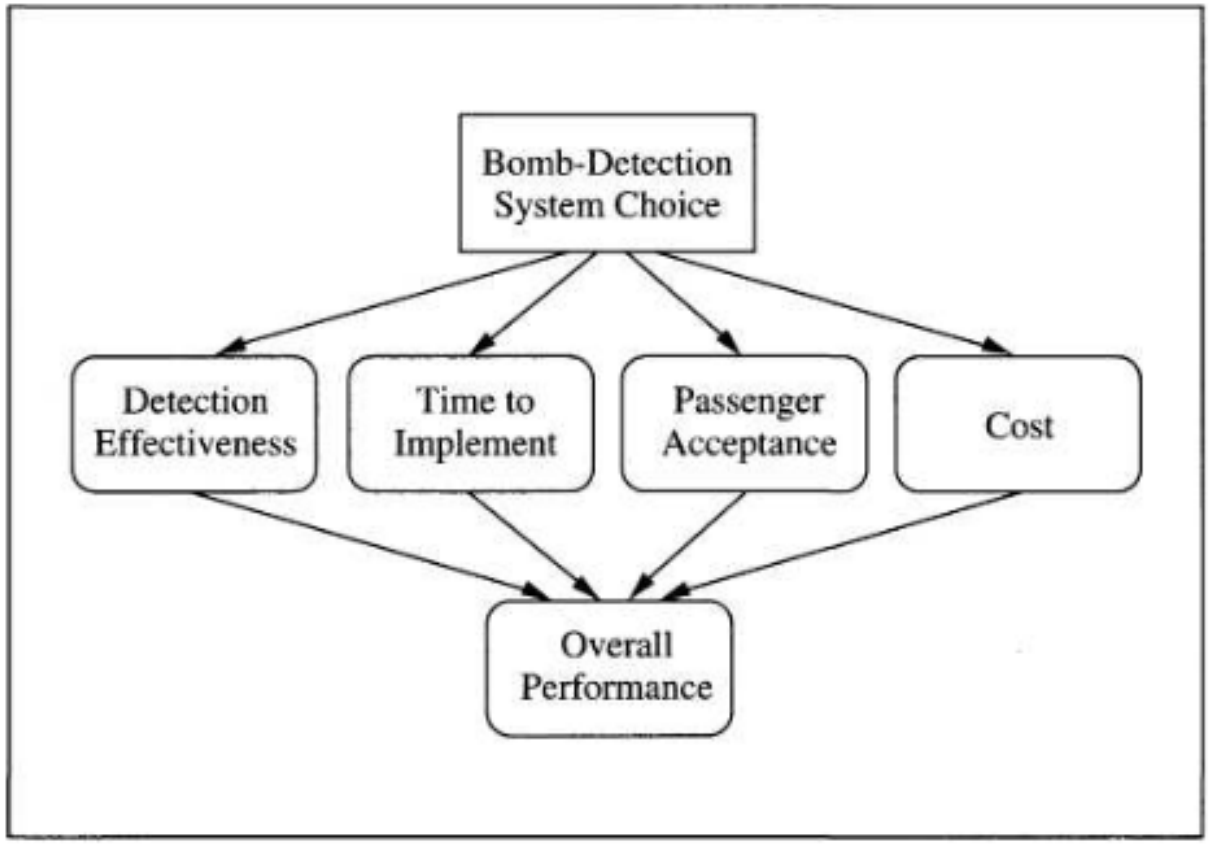
Figure 3.16
New product decision with calculation nodes for intermediate calculation of cost and revenue.



Basic Influence Diagrams: Multi-objectives

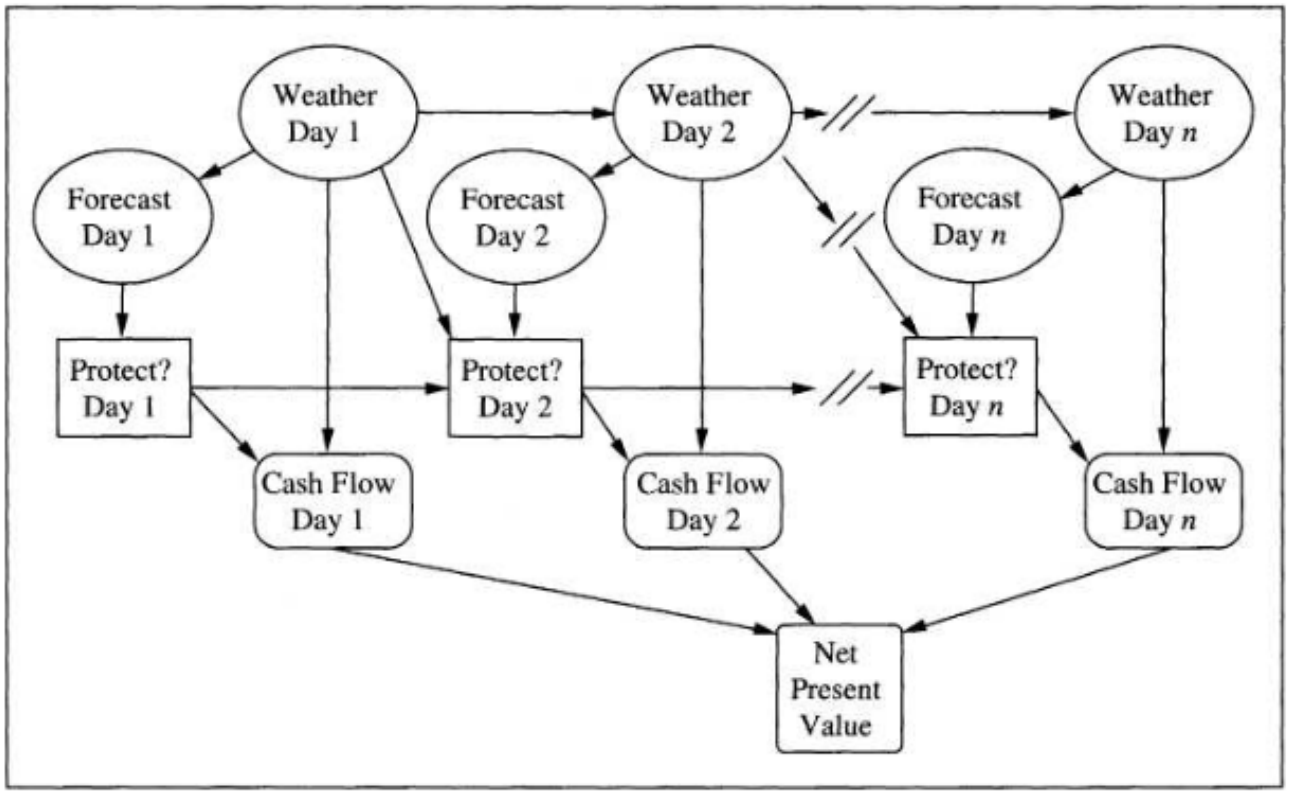
Figure 3.7

Multiple objectives in selecting a bomb-detection system.



Basic Influence Diagrams: Sequential Decisions

Figure 3.13
Influence diagram for farmer's sequential decision problem.



Decision Trees

- influence diagrams are good at showing the decision structure
- some details are missing
- decision trees show these details

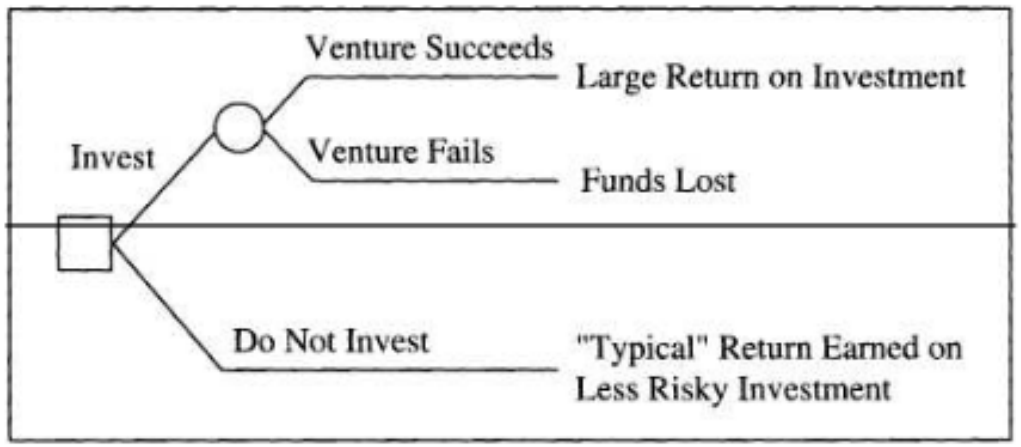
Decision Trees

- influence diagrams are good at showing the decision structure
- some details are missing
- decision trees show these details

- decisions . . . rectangles
- uncertain events . . . ovals
- branches from a rectangle . . . the possible choices
- branches from an oval . . . possible outcomes of the uncertain event
- the consequences are at the end of the branches

Decision Tree - Venture Capitalist

Figure 3.21
Decision-tree representation of venture-capital decision.



- the tree flows from left to right

Decision Tree - Venture Capitalist

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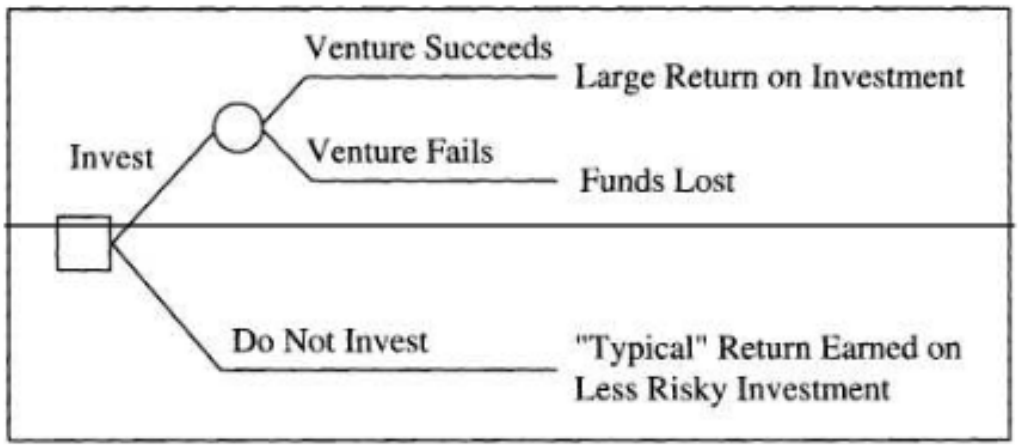

- the tree flows from left to right
- the decision-maker can choose only one branch(option)

Decision Tree - Venture Capitalist

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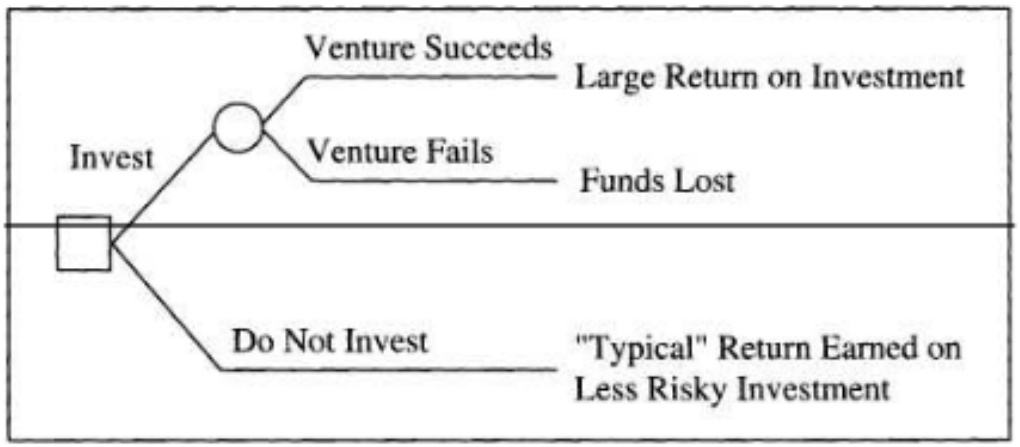

- the tree flows from left to right
- the decision-maker can choose only one branch(option)
- each chance node branches must be:
  - mutually exclusive
  - exhaustive

Decision Tree - Venture Capitalist

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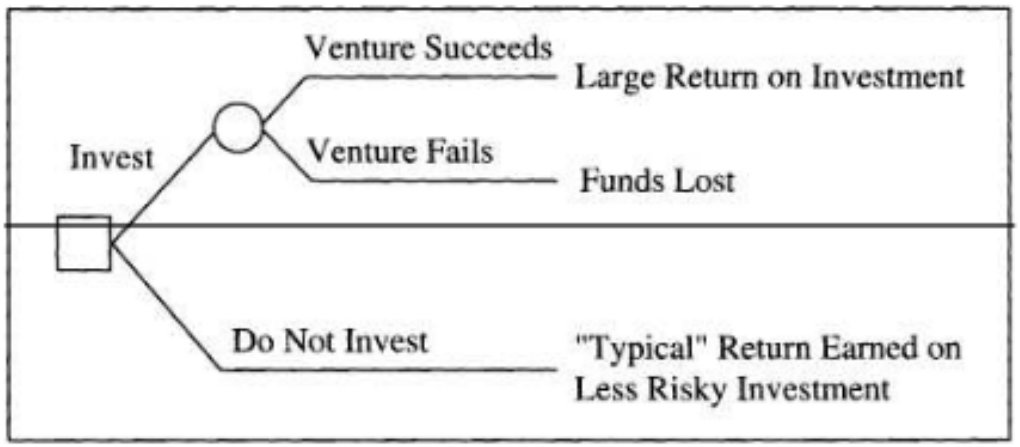

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Decision Tree - Venture Capitalist

Figure 3.21
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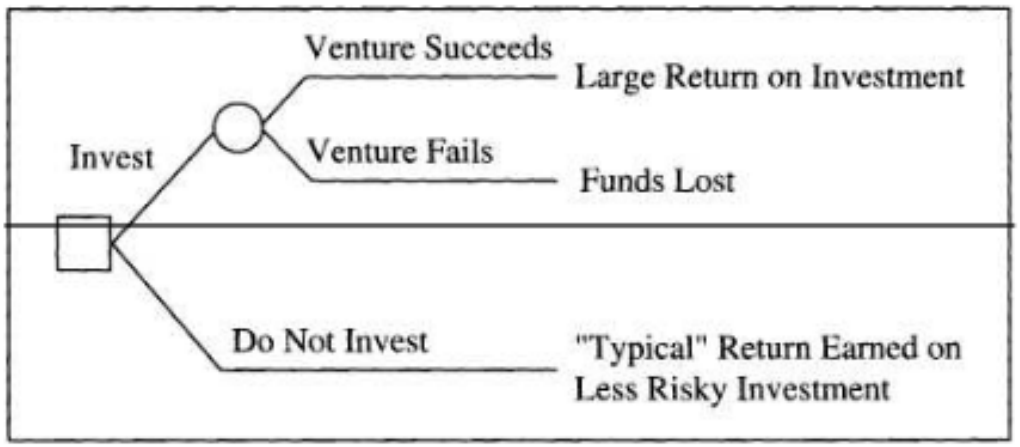
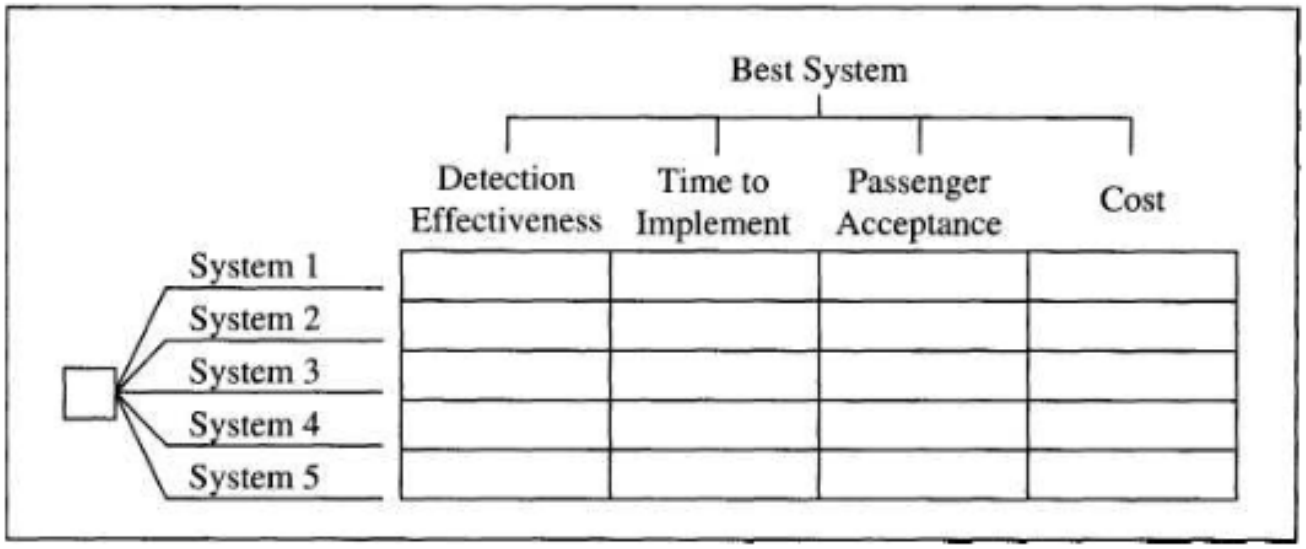


- the tree flows from left to right
- the decision-maker can choose only one branch(option)
- each chance node branches must be:
  - mutually exclusive
  - exhaustive
- a decision tree represents all of the possible paths that the decision maker might follow through time, including all possible decision alternatives and outcomes of chance events.
- think of nodes as occurring in a chronological order

Decision Trees and the Multiple Objectives

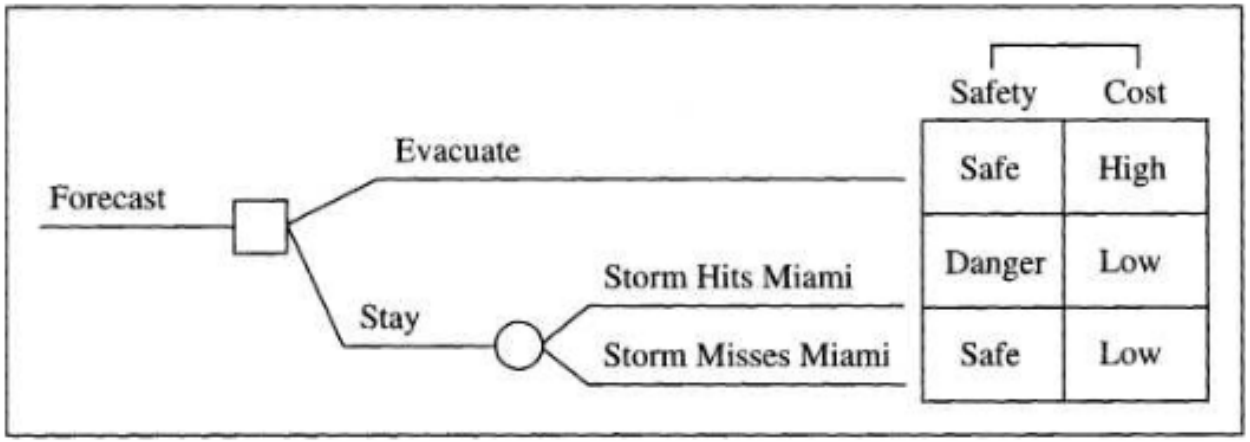
Figure 3.22
Decision-tree representation of FAA's multiple-objective bomb-detection decision.



- we can include multiple objectives using the *consequence matrix*
- each column = a fundamental objective
- each row = decision alternative

Decision Trees and the Multiple Objectives

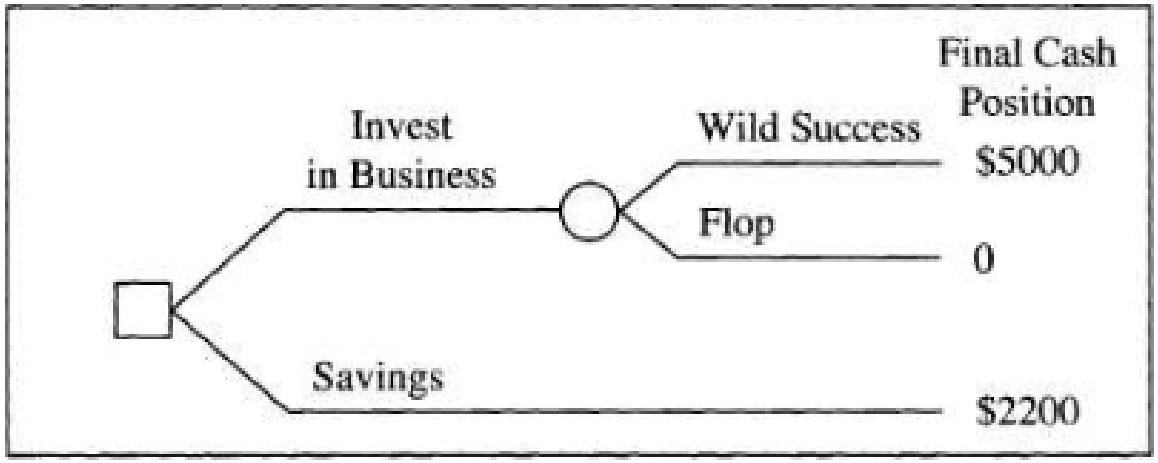
Figure 3.23
Decision-tree representation of evacuation decision.



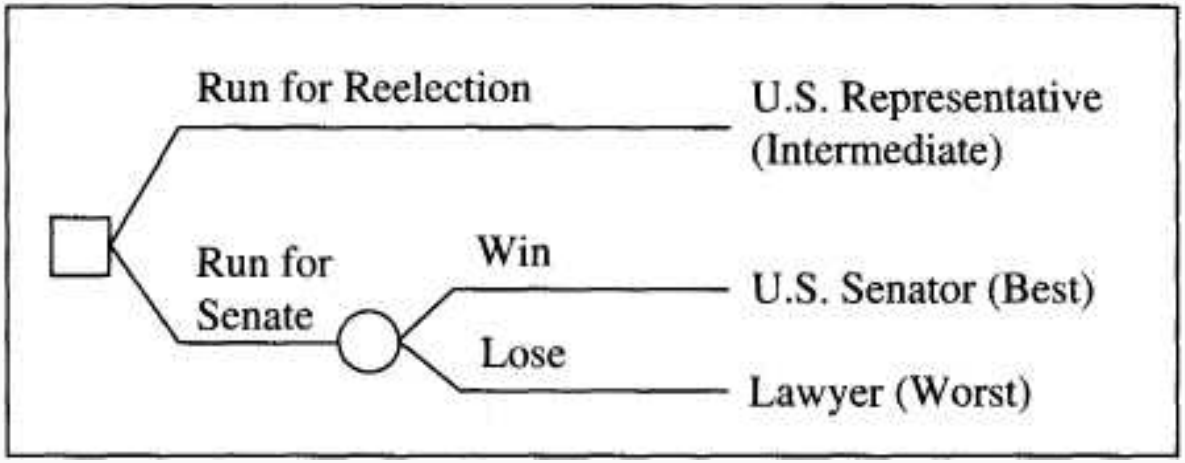
Decision Trees: Basic Risky Decision

Figure 3.24

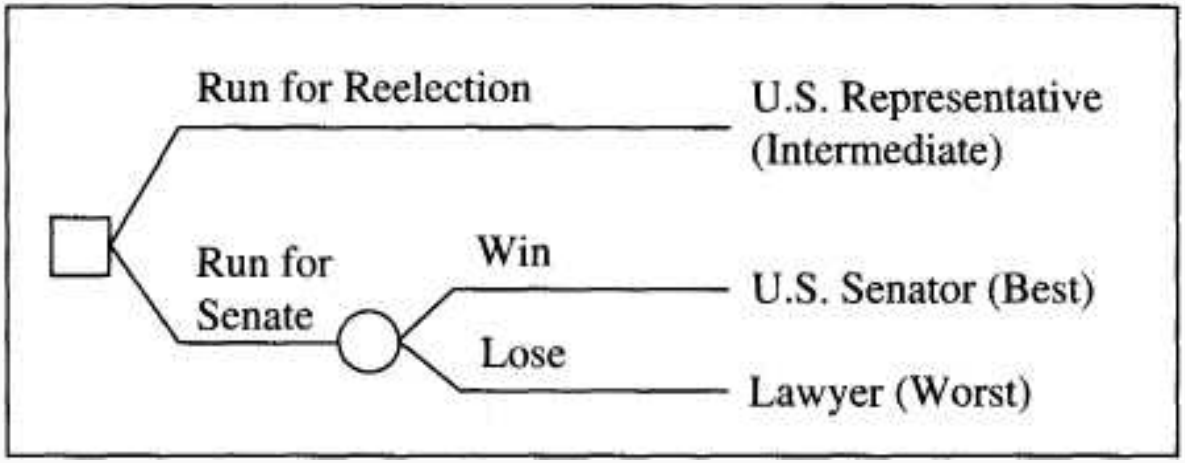
The investor's basic risky decision.

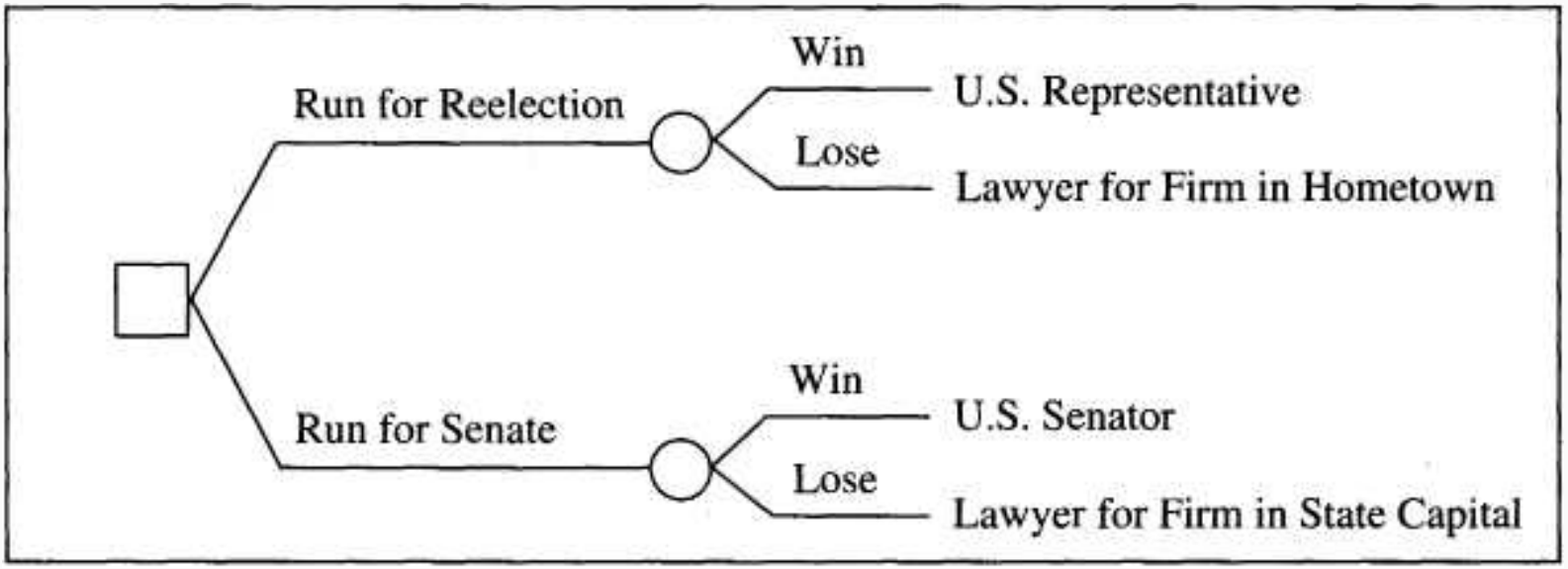


Decision Trees: Double Risk Decision

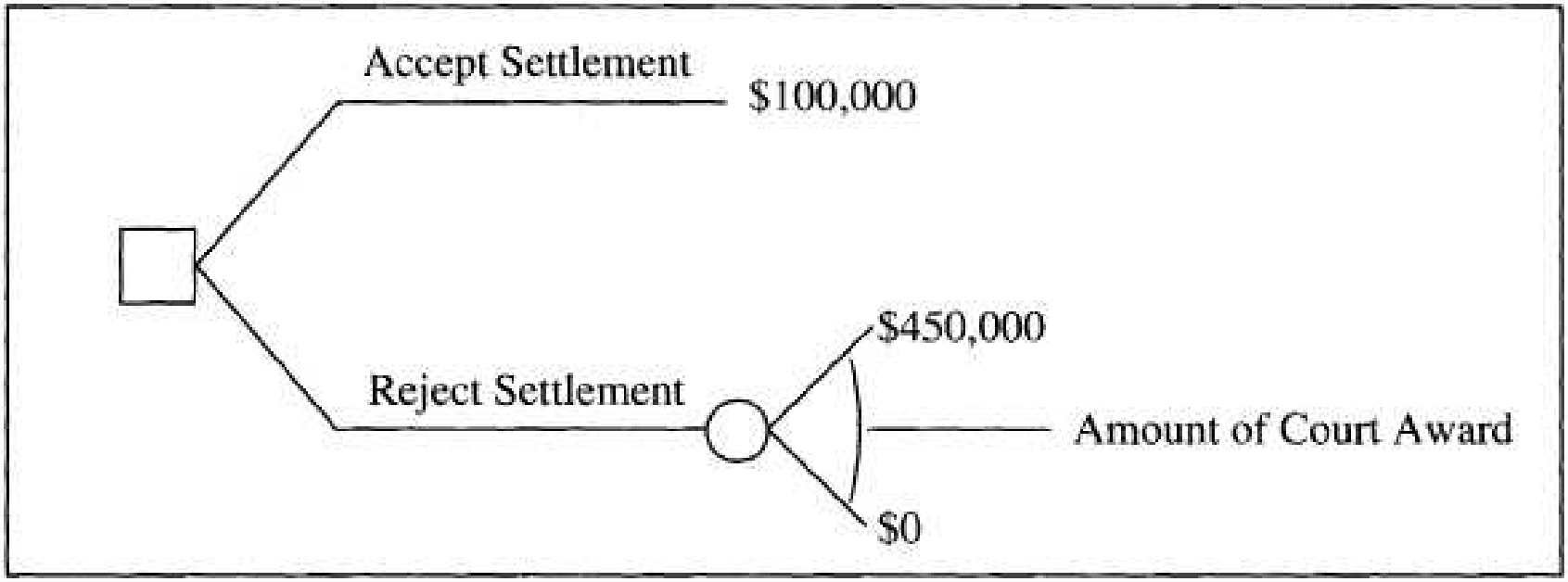


Decision Trees: Double Risk Decision

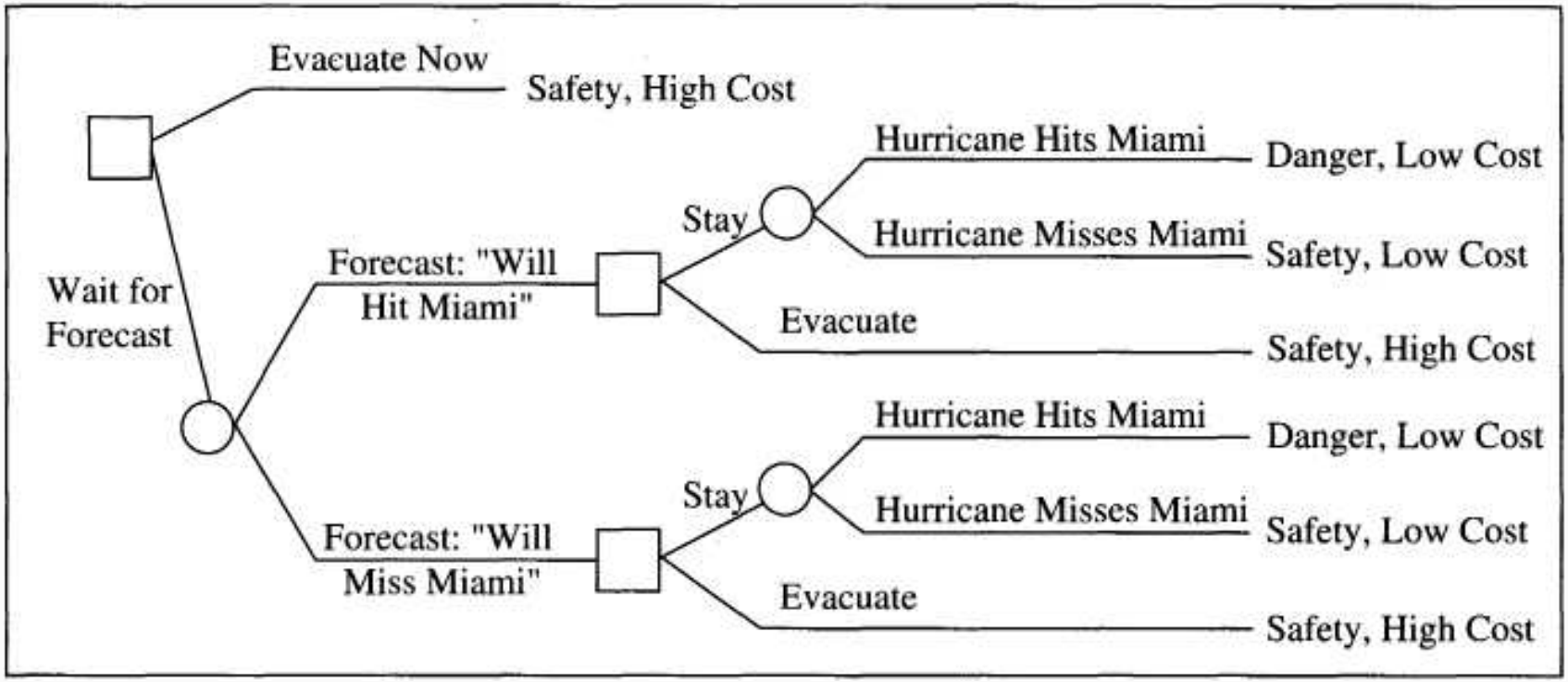




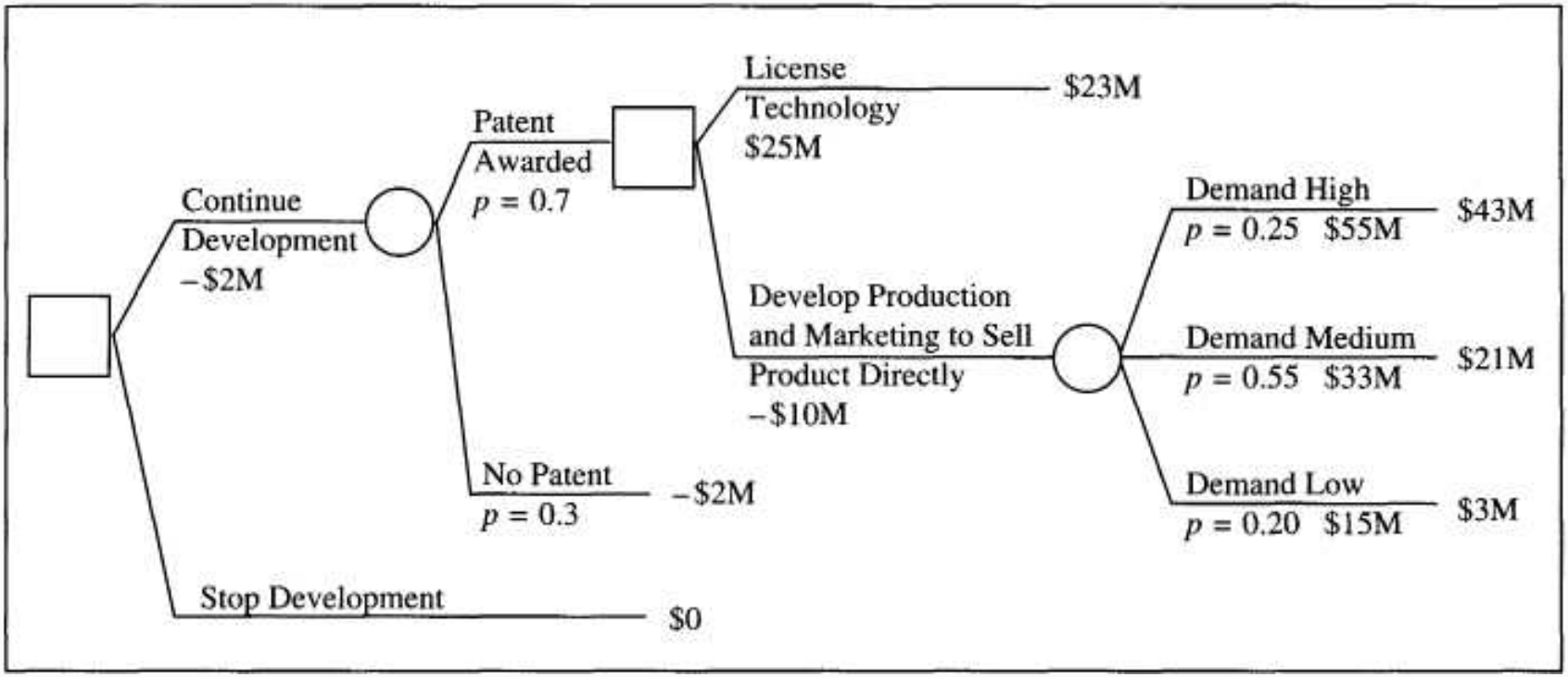
Decision Trees: Range-of-risk



Decision Trees: Sequential



Decision Trees: Probabilities



Quiz

On 26 September 1983, just three weeks after the Soviet military had shot down Korean Air Lines Flight 007, Stanislav Petrov was the duty officer at the command center for the Soviet nuclear early-warning system when the system reported that a missile had been launched from the United States, followed by up to five more. Petrov judged the reports to be a false alarm, and his decision is credited with having prevented an erroneous retaliatory nuclear attack on the United States and its NATO allies that could have resulted in large-scale nuclear war. Investigation later confirmed that the Soviet satellite warning system had indeed malfunctioned.

Draw the influence diagram and decision tree using multiple objectives.

References

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- Robert Clemen, Making Hard Decisions, 2nd Edition, 1996, Brooks Cole Publishing
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- https://en.wikipedia.org/wiki/Influence_diagram