

# Chapter 3

## Structuring Decisions

### ***Making Hard Decisions***

R. T. Clemen, T. Reilly

*Draft: Version 1*

# Introduction

**Suppose elements of Decision Problem (DP) are available, i.e.:**

- 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

**How does one proceed structuring the DP?**

**STEP 1: Filter & Operationalize the Objectives**

- Classify objectives as means or fundamental objectives
- Classify how to measure fundamental objectives

# Introduction

## STEP 2: 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**

## STEP 3: Fill in the Details, e.g.;

- Give precise (unambiguous) definitions of decisions & uncertain events
- Specify probability distributions for the uncertain events through a combination of data analysis & expert judgment.
- Specify precisely (unambiguous) how consequences are measured and formalize trade off between objectives.

# Introduction

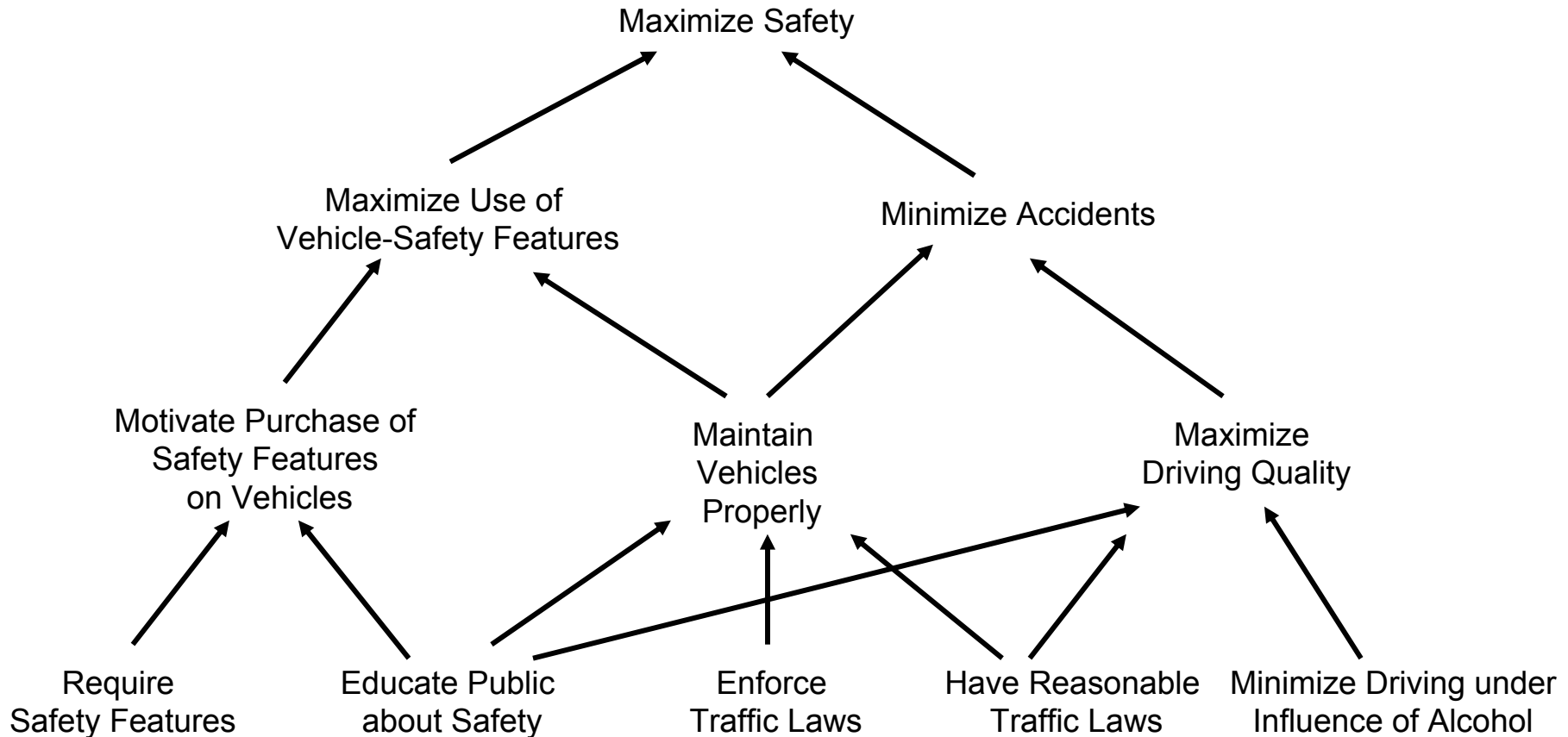
## Comment with Respect to STEP 1: Identifying objectives is Creative Process

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?
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?

Source: Keeny, R.L. (1994) " Creativity in Decision Making with Value-Focused Thinking,"  
Sloan Management Review, Summer, 33-41

# STEP 1: Filter & Operationalize Objectives

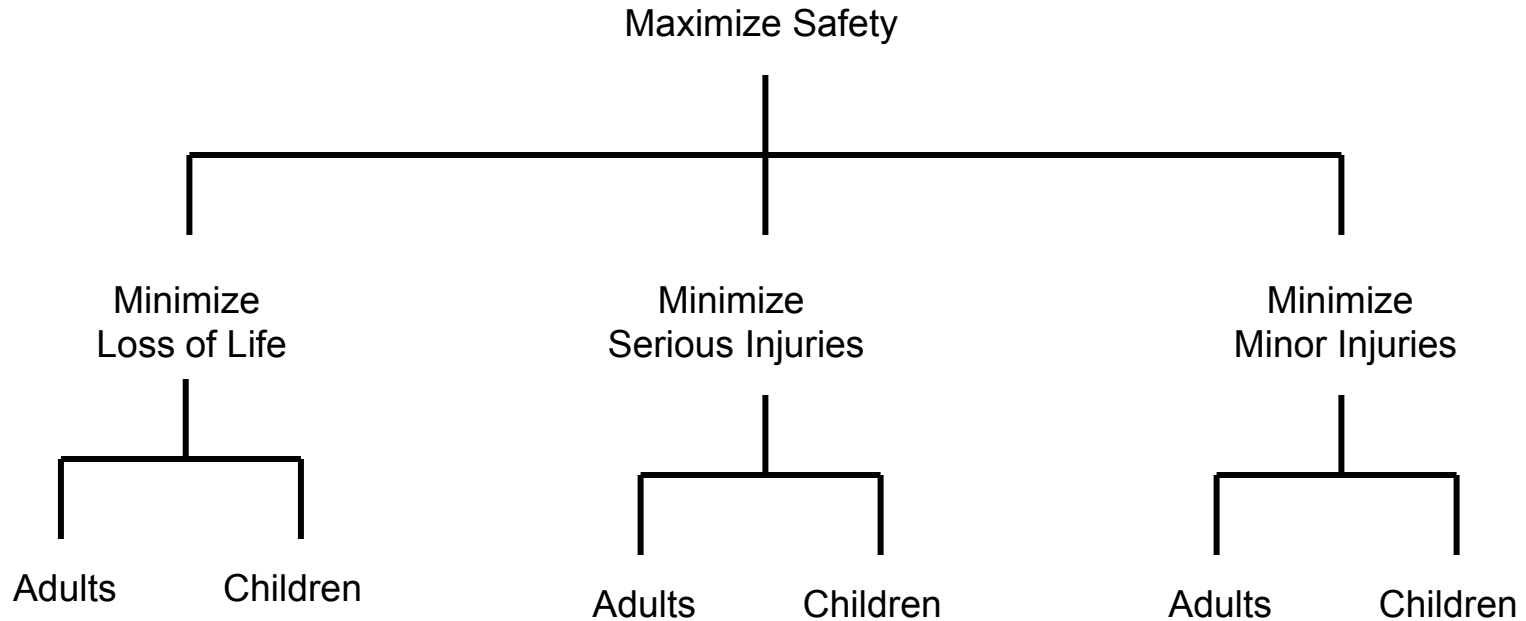
Classify objectives as means or fundamental objectives



Example of **Means Objective Network**

# STEP 1: Filter & Operationalize Objectives

Classify objectives as means or fundamental objectives



Example of **Fundamental Objective Hierarchy**

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# STEP 1: Filter & Operationalize Objectives

## Questions to aid in classifying objectives

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

**Decision Problems** are evaluated using only the **Fundamental Objective Hierarchy**

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# STEP 1: Filter & Operationalize Objectives

## 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.

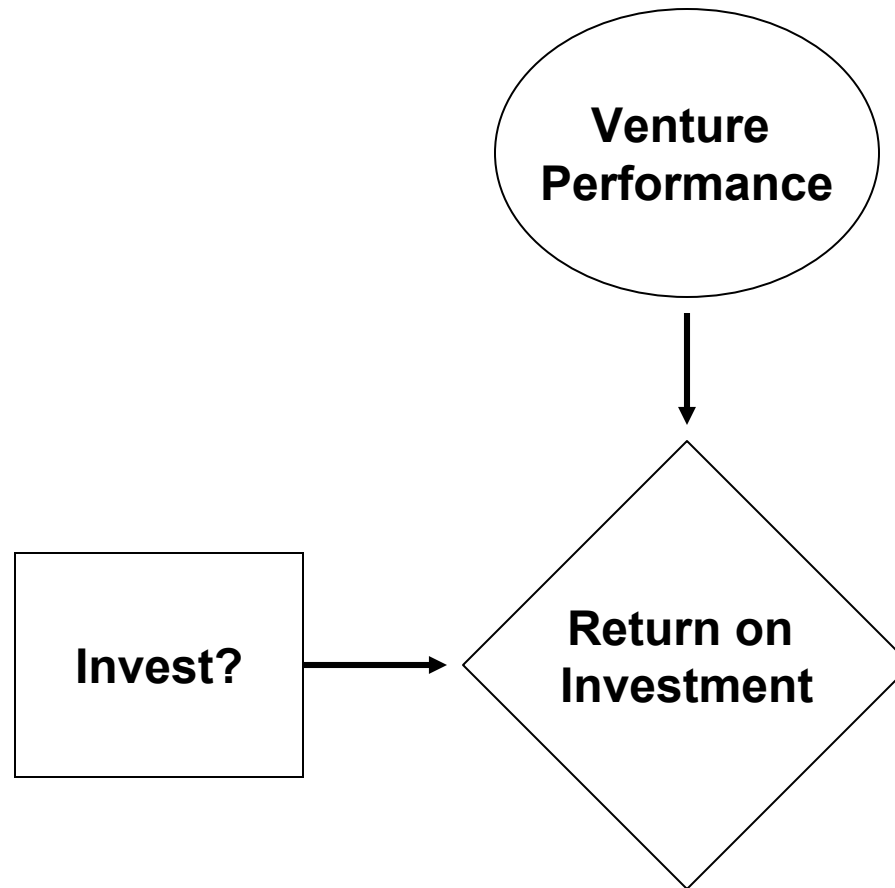
## Think of Example: Travel from A to B Comfortably

## 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 DP in the current decision context?

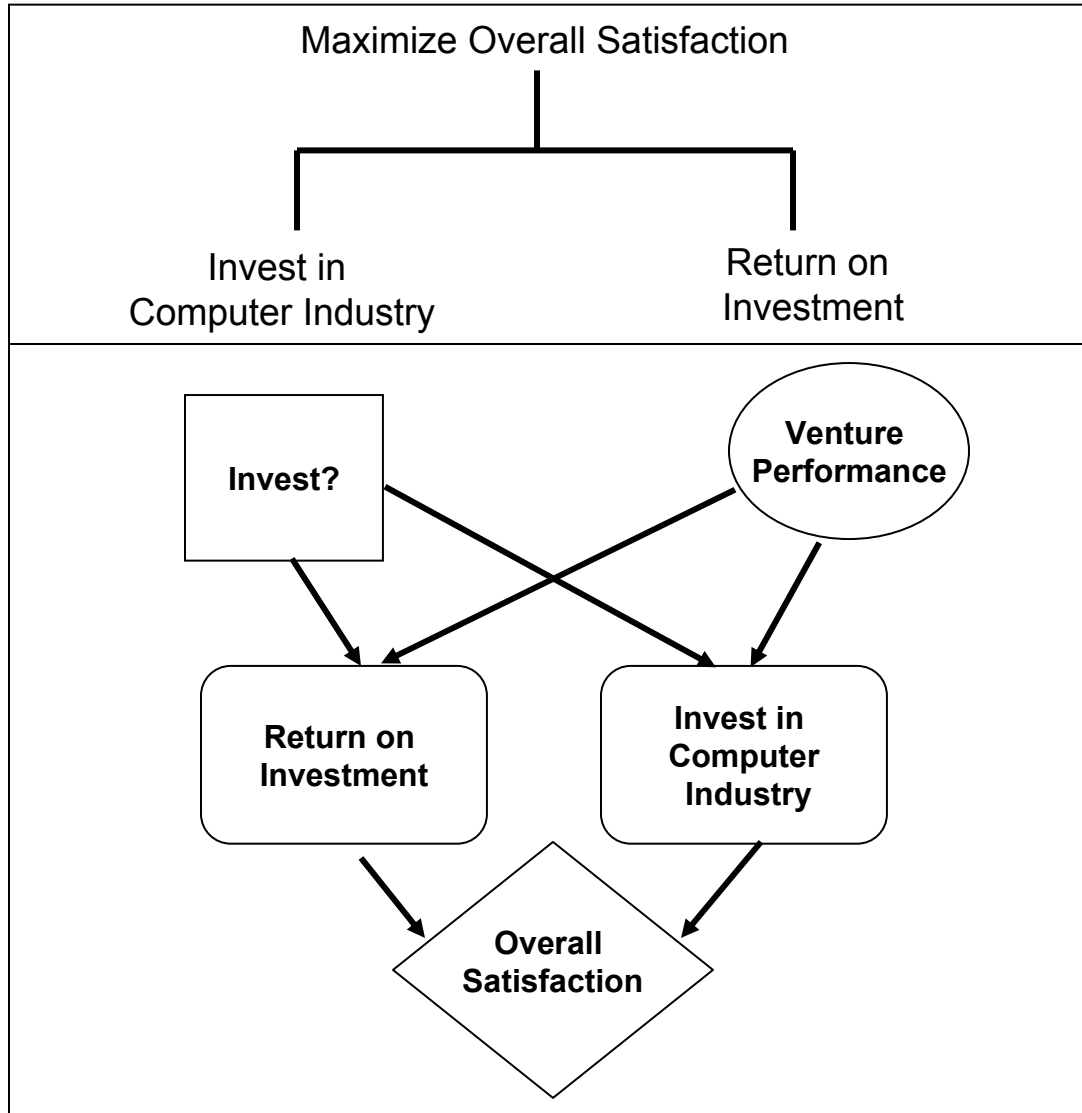
# Step 2: Structure Elements in a Logical Framework

## Investment example:



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# Step 2: Structure Elements in a Logical Framework



**Fundamental Objective Hierarchy**

**Influence Diagram**

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# Step 2: Structure Elements in a Logical Framework

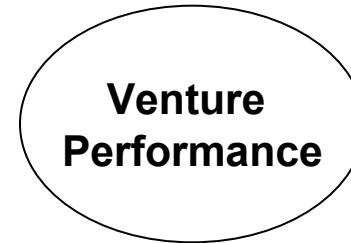
## Influence Diagrams

### 1. Elements are represented by:

Decision Nodes:



Chance Nodes:

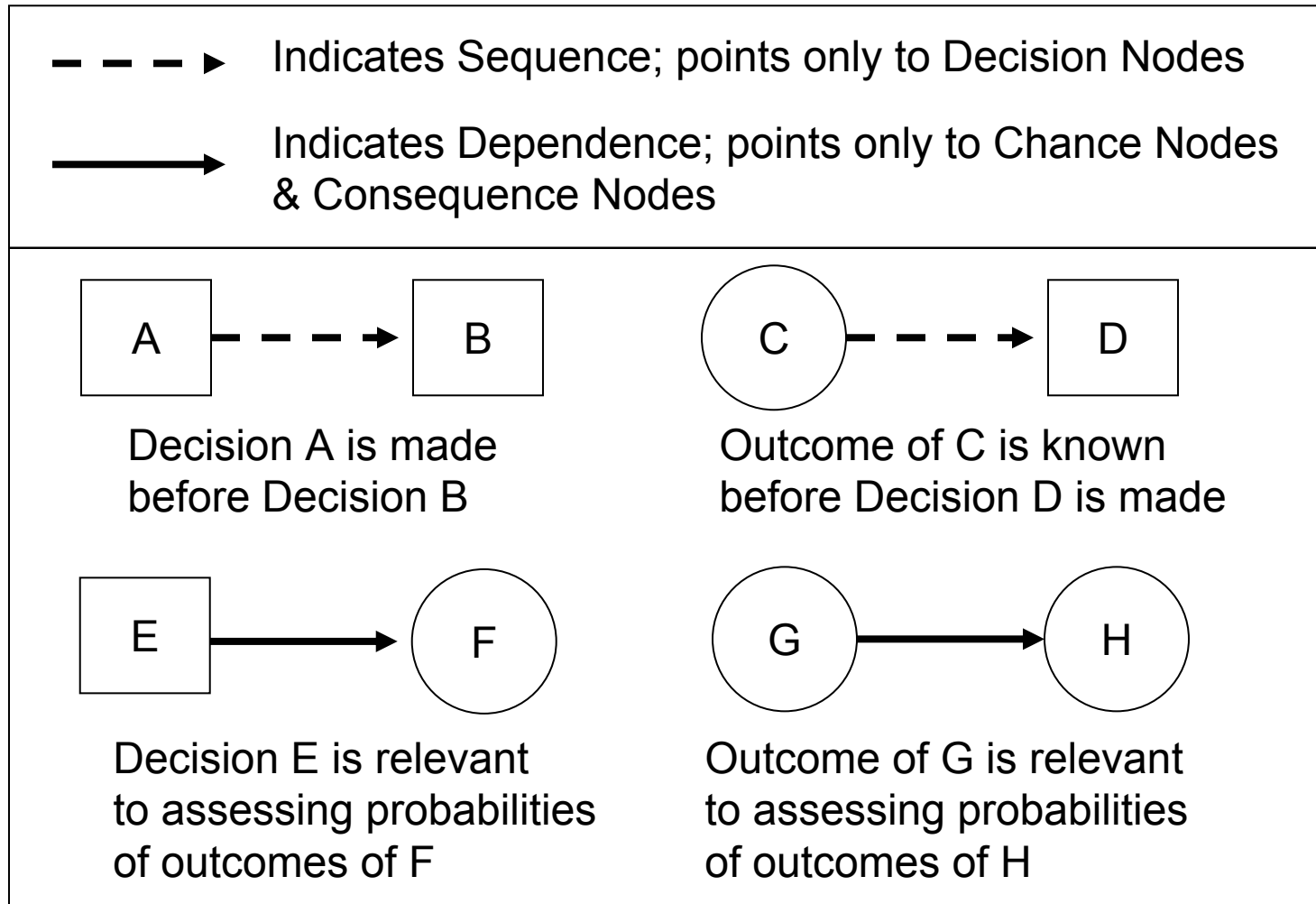


Consequence Nodes:



# Step 2: Structure Elements in a Logical Framework

## 2. Logical relationships are represented by arrows:



# Step 2: Structure Elements in a Logical Framework

- It is important to note here that we deviate from the convention in the book that does not distinguish between sequence arcs and influence arcs.
- This distinction is made here only for teaching purposes. Once one is comfortable with the differences between these arcs and their interpretations one could use solid arcs throughout the influence diagram

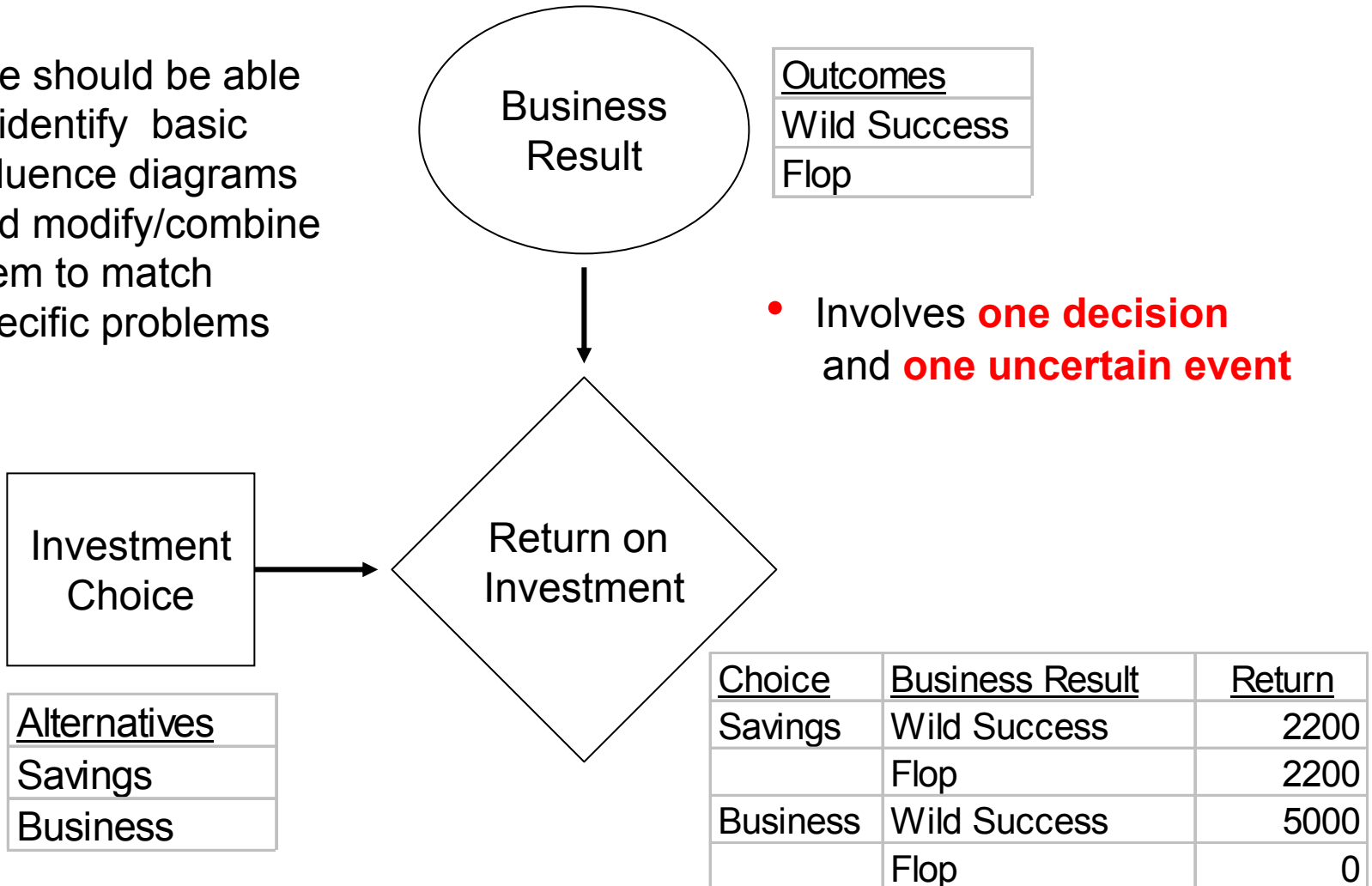
## Comments on Influence Diagrams:

- 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

# Step 2: Basic Influence Diagrams

## Basic Risky Decision

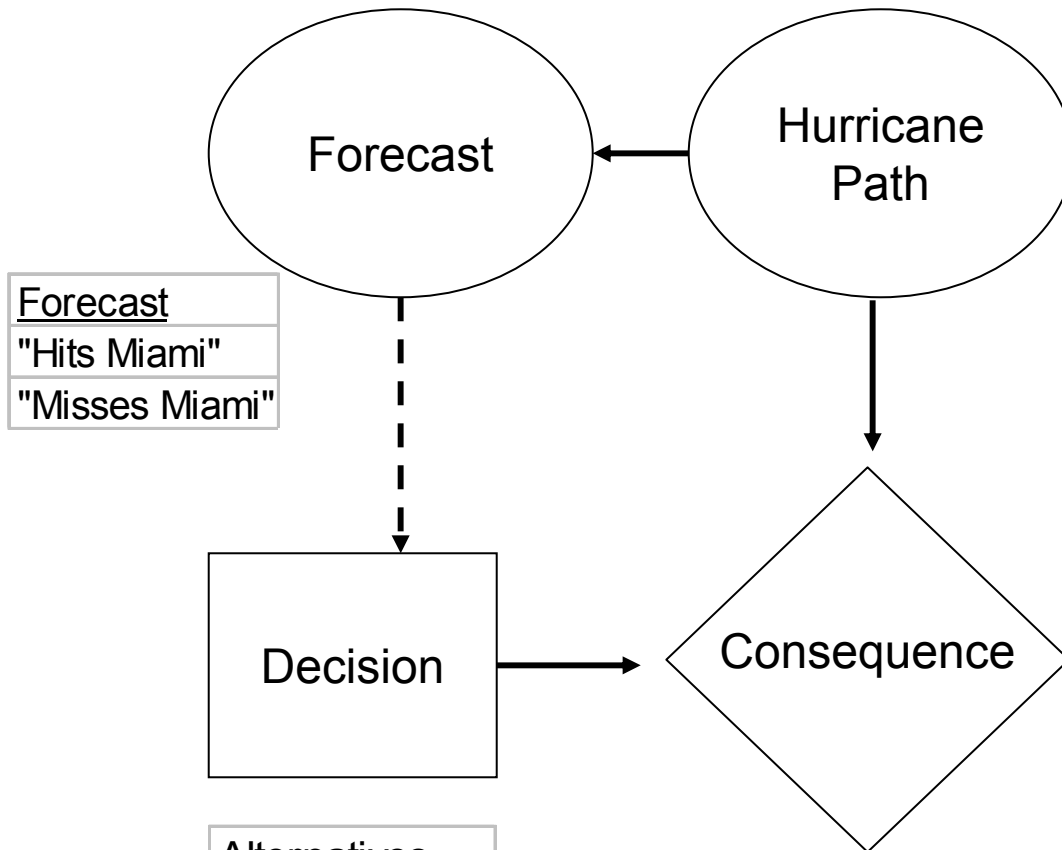
- One should be able to identify basic influence diagrams and modify/combine them to match specific problems



- Involves **one decision** and **one uncertain event**

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# Step 2: Basic Influence Diagrams



<u>Outcomes</u>
Hits Miami
Misses Miami

<u>Forecast</u>
"Hits Miami"
"Misses Miami"

<u>Alternatives</u>
Evacuate
Stay

## Imperfect Information:

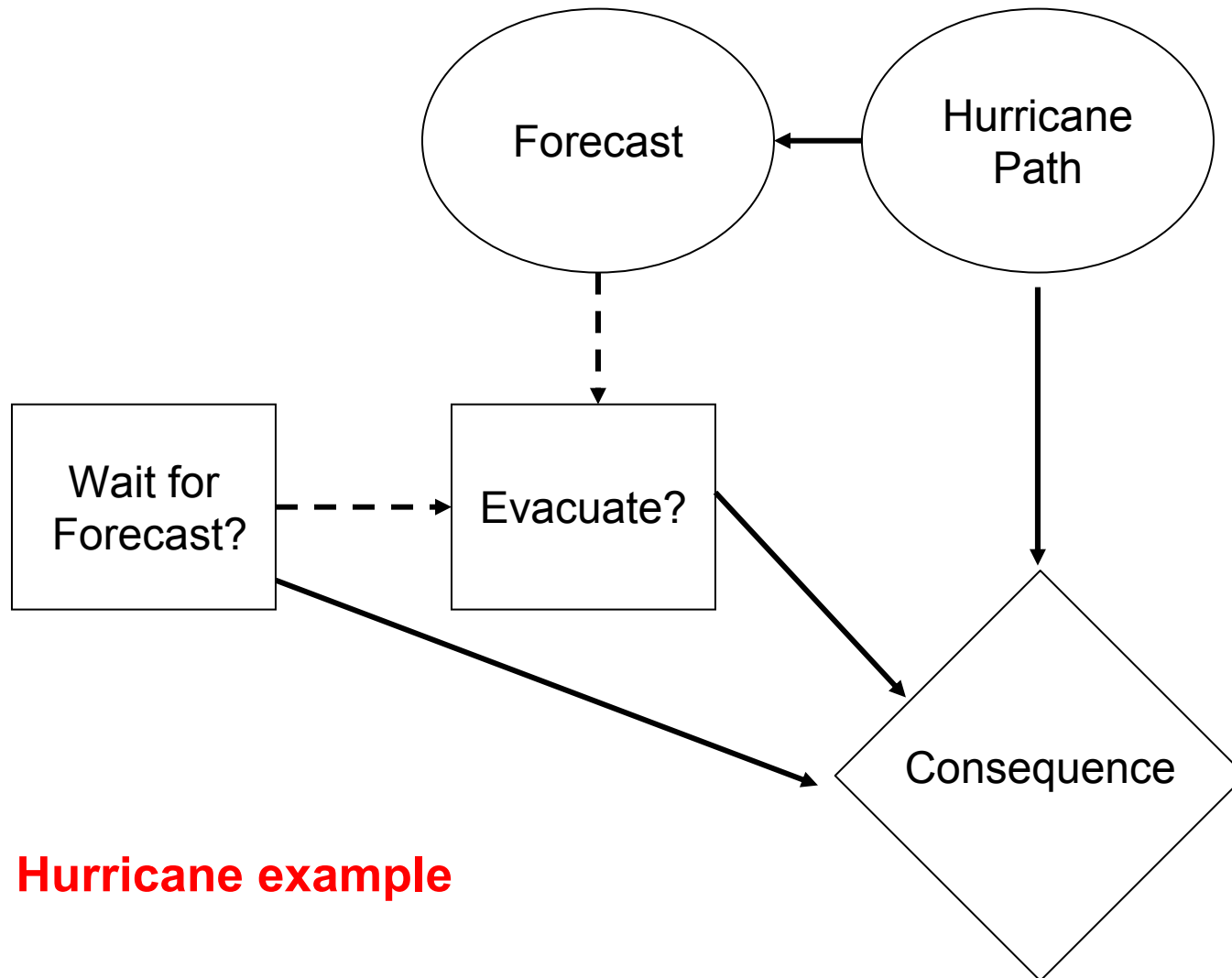
- Involves one decision and two uncertain events **at the time of the Decision Analysis**.
- One uncertain event is known **at the time that the immediate decision is made**.
- Solving the influence diagram results in **one** optimal decision for **each** possible outcome of the information source.

<u>Choice</u>	<u>Outcome</u>	<u>Consequence</u>	
		<u>Risk</u>	<u>Cost</u>
Evacuate	Hits Miami	Low Risk	High Cost
	Misses Miami	Low Risk	High Cost
Stay	Hits Miami	High Risk	High Cost
	Misses Miami	Low Risk	Low Cost

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# Step 2: Basic Influence Diagrams

## Sequential Decisions:

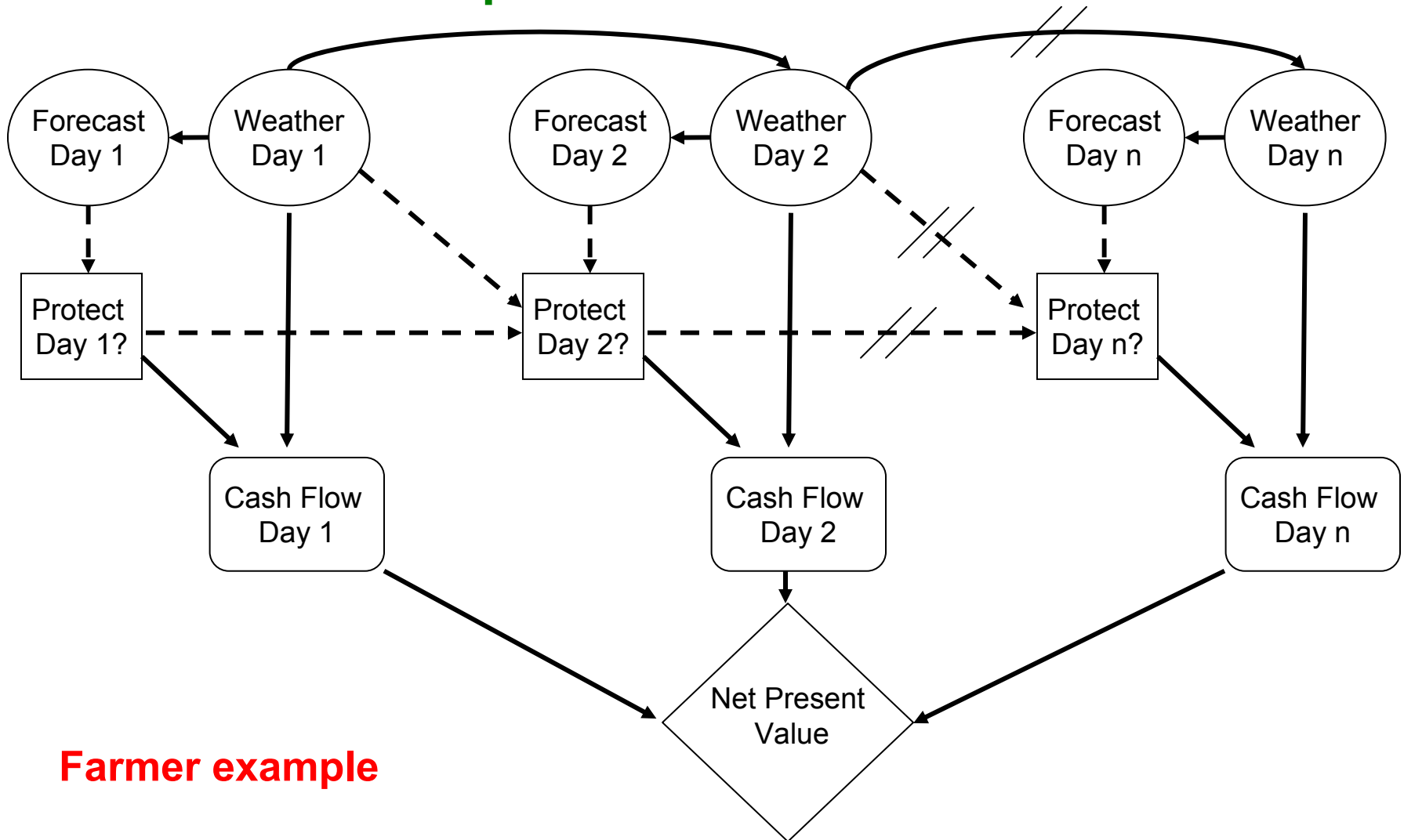


**Hurricane example**

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# Step 2: Basic Influence Diagrams

## Sequential Decisions:

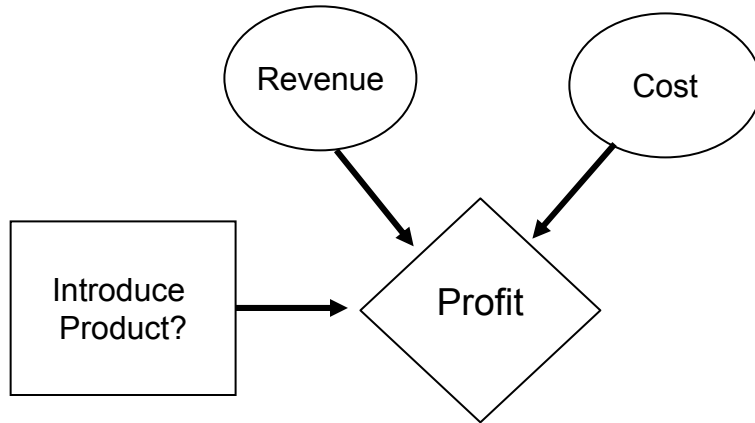


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**Farmer example**

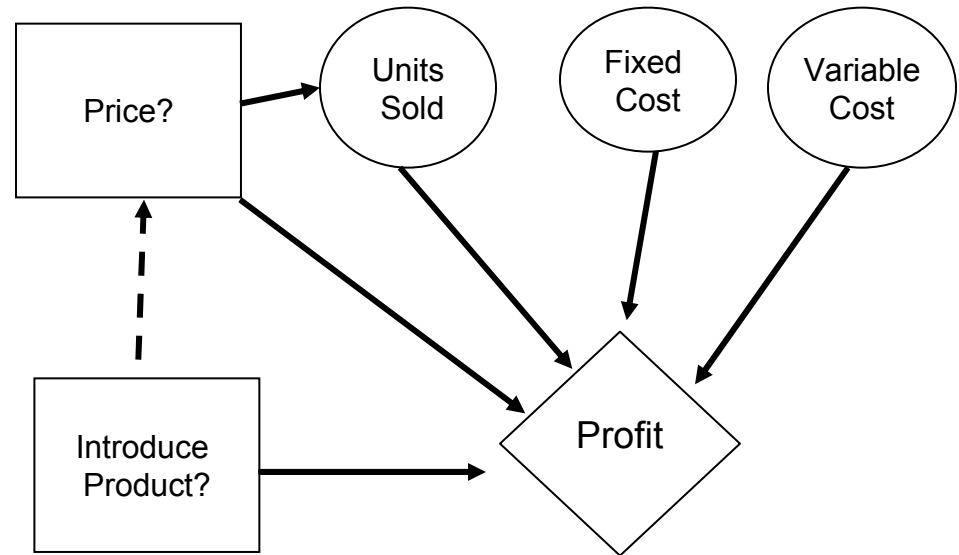
# Step 2: Basic Influence Diagrams

Intermediate calculations for additional clarity:



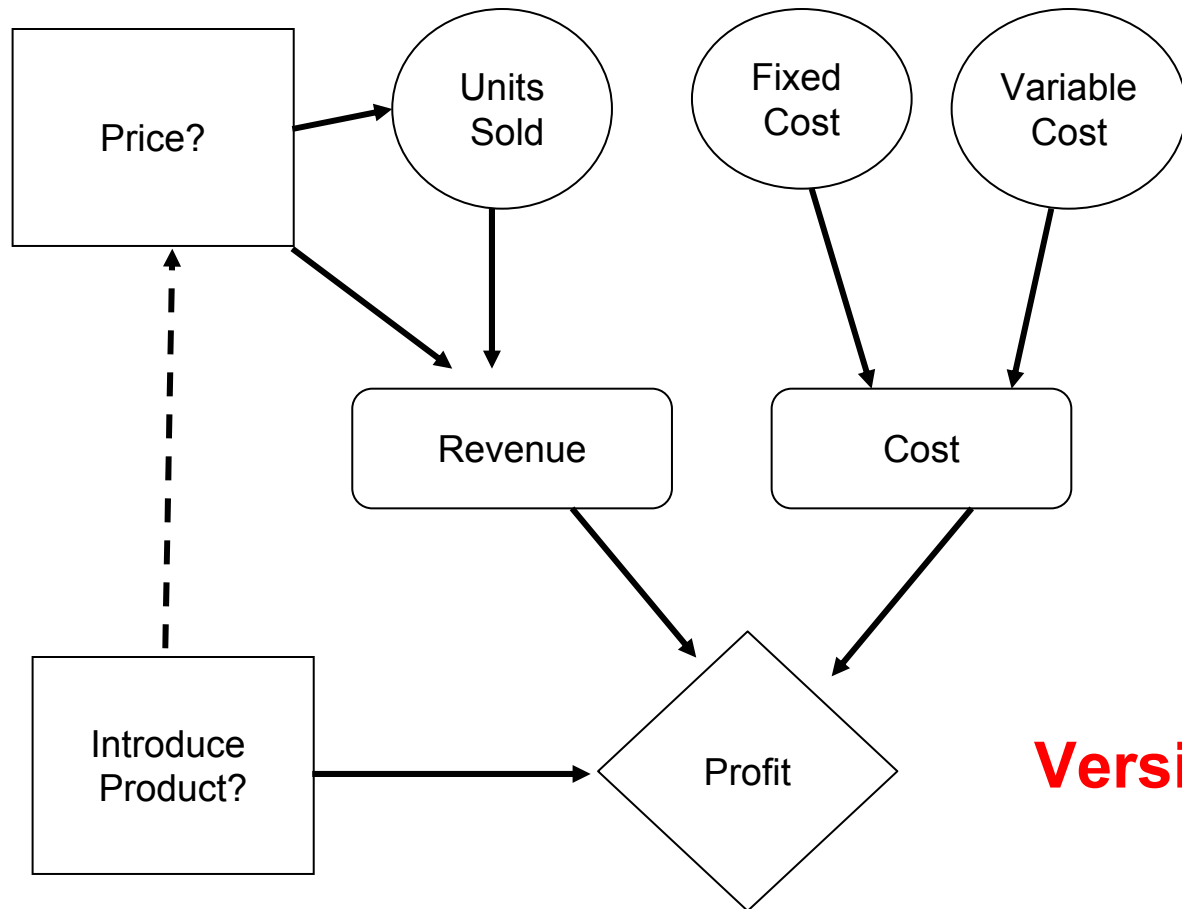
Version 1

Version 2



# Step 2: Basic Influence Diagrams

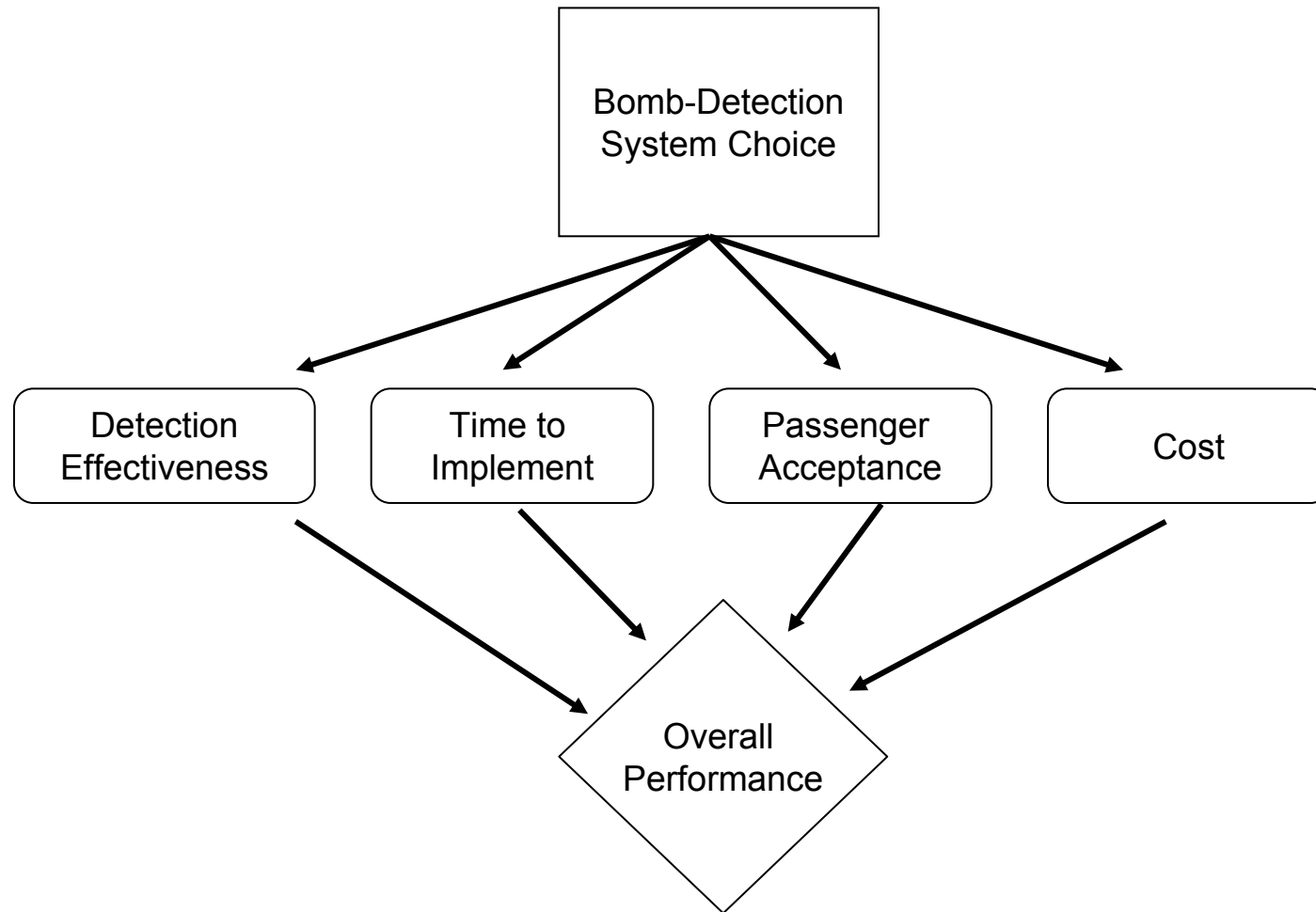
Intermediate calculations for additional clarity:



**Version 3**

# Step 2: Basic Influence Diagrams

Intermediate calculations reflecting Fundamental Objective Hierarchy:



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# Step 2: Building an Influence Diagrams

1. List all the decisions.
2. Draw **sequence arcs** between decisions. - - - - →
3. Identify the consequence node.
4. Breakdown the consequence node using the FOH.
5. Draw **relevance arcs** from decision nodes to the intermediate calculation nodes. —————→
6. List all the uncertainty nodes.
7. Draw the **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. —————→

# Step 2: Building an Influence Diagram

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

## Common Mistakes:

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

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# Building an Influence Diagram: Example

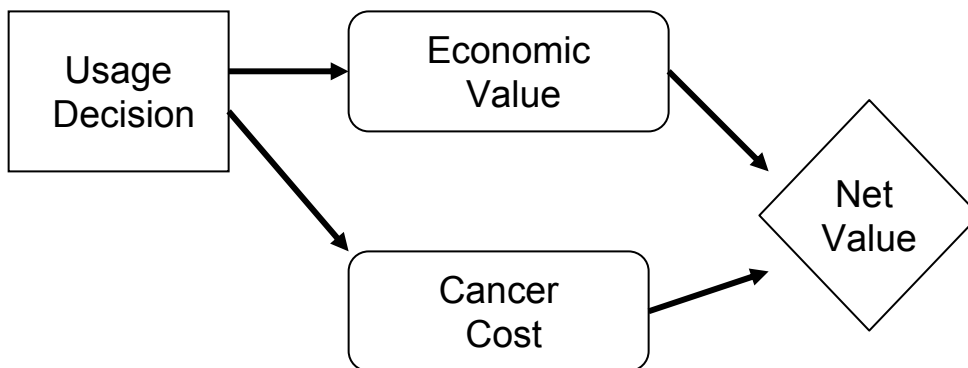
## Toxic Chemicals and the EPA

The Environmental Protection Agency often must decide **whether to permit the use** of an economically beneficial chemical that may be carcinogenic (cancer-causing). Furthermore, the decision often must be made **without perfect information** about either **the long-term benefits** or **health hazards**. Alternative courses of action are to permit the use of the chemical, restrict its use, or to ban it all together. **Tests can be run** to learn something about the **carcinogenic potential**, and **survey data** can give an indication of the extent to which people are exposed when they do use the chemical. These pieces of information are both important in making the decision. For example, if the chemical is only mildly toxic and the exposure rate is minimal, then restricted use may be reasonable. On the other hand, if the chemical is only mildly toxic but the exposure rate is high, then banning its use may be imperative.

# Building an Influence Diagram: Example

## Toxic Chemicals and the EPA

### STEPS 1 - 5

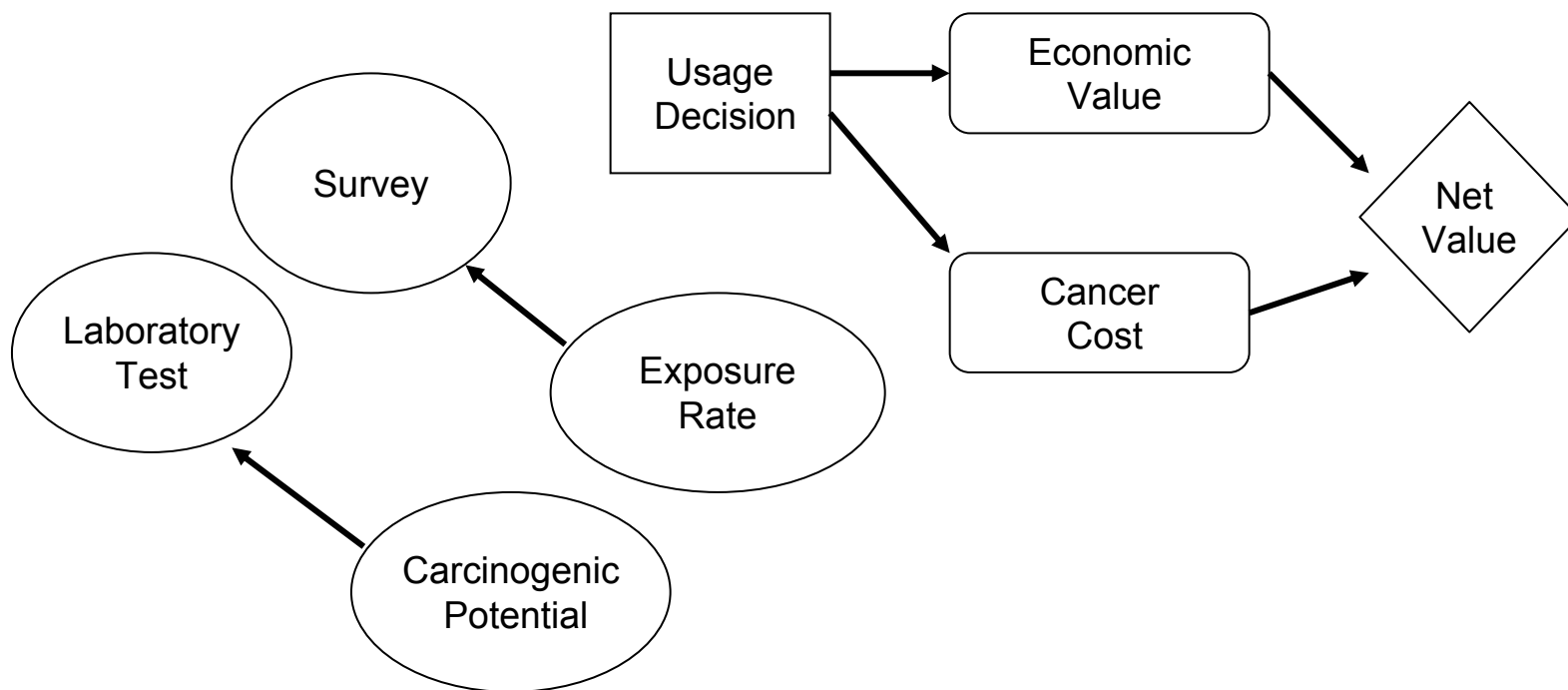


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# Building an Influence Diagram: Example

## Toxic Chemicals and the EPA

### STEPS 6 - 7

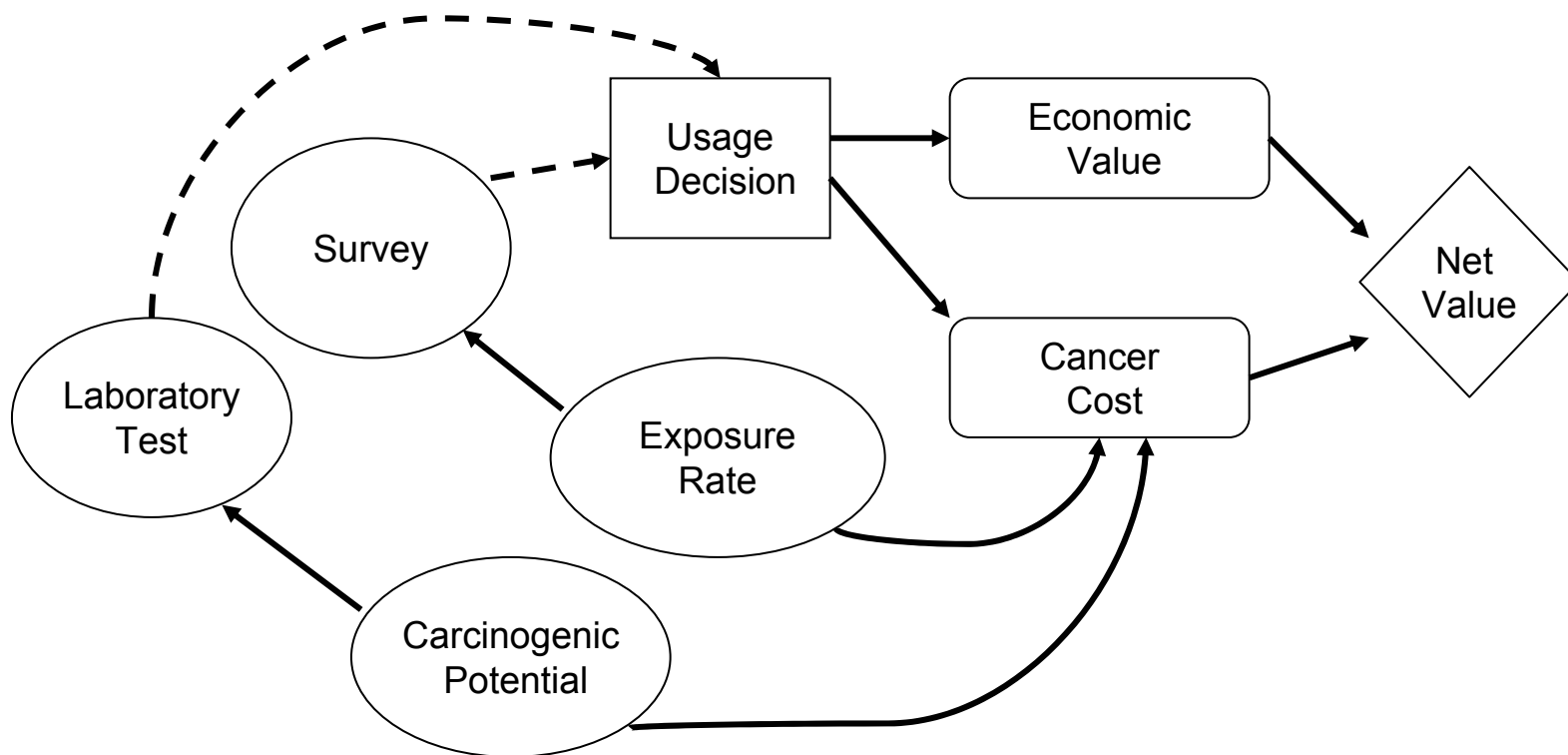


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# Building an Influence Diagram: Example

## Toxic Chemicals and the EPA

### STEPS 9 - 10



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# Building an Influence Diagram: Example

## Test Analyze and Fix (TAAF)

We are deciding on **whether or not to release** a new product. The product reliability, that is, the probability that the product functions satisfactorily, is a main driver in **profits** that may be derived from the product. We may decide to **release the product immediately** based on our best current assessment of the product reliability **or test the product**. A test consists of selecting a single product and seeing if it performs its required task. If it does not, the product is **redesigned** using the test results and a fixed cost for redesign is incurred. This redesign **may or may not improve** the product reliability. After the redesign we may decide to **release the redesigned product** or test the redesigned product. If the redesigned product does not perform its task, the redesigned product will be redesigned using the latest test results, etc. This **cycle** continues until the time has come that the **final decision** to release or not to release has to be made. The testing and re-design takes **one week** (regardless of the outcome of the test) and we have **two weeks** to make the **final decision**. Assume that the product reliability and the cost of testing affect the profits.

# Building an Influence Diagram: Example

## Test Analyze and Fix (TAAF)



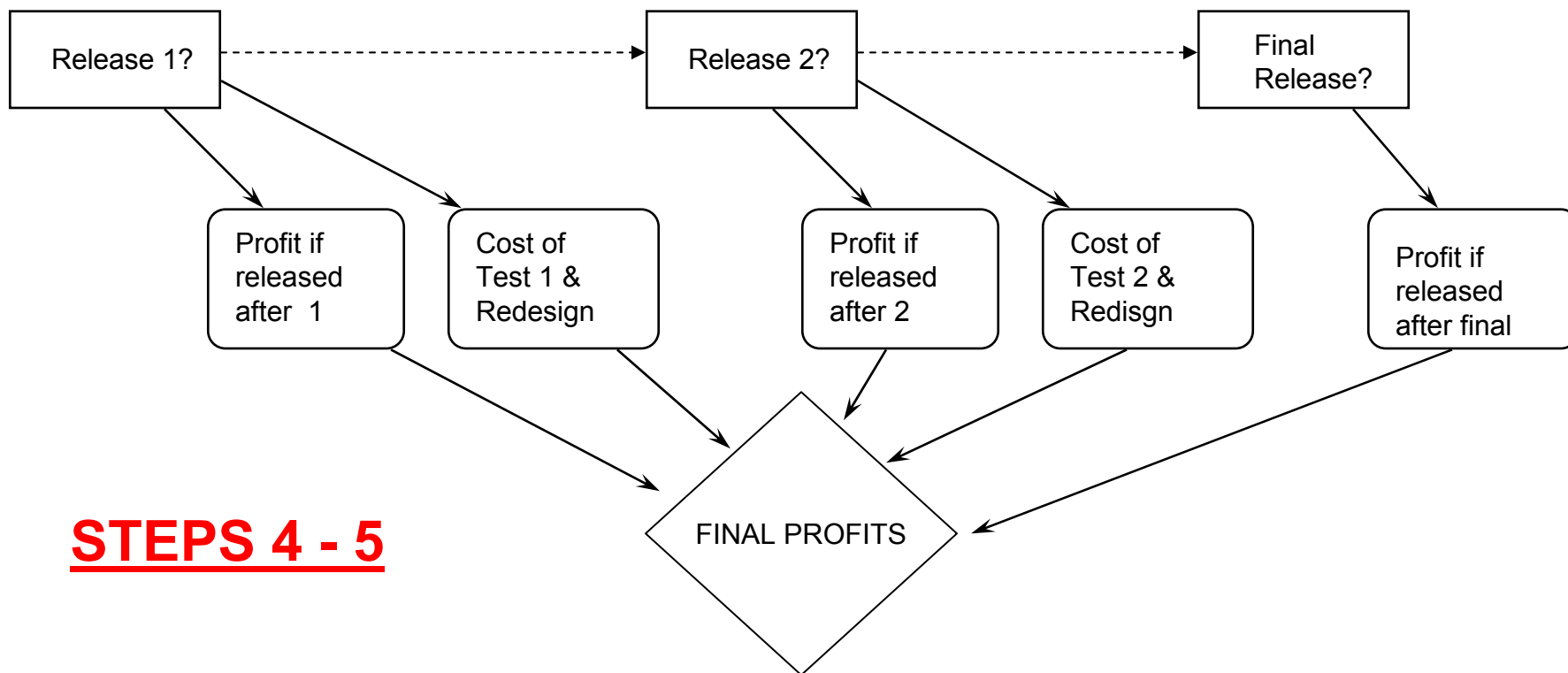
**STEPS 1 - 3**



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# Building an Influence Diagram: Example

## Test Analyze and Fix (TAAF)

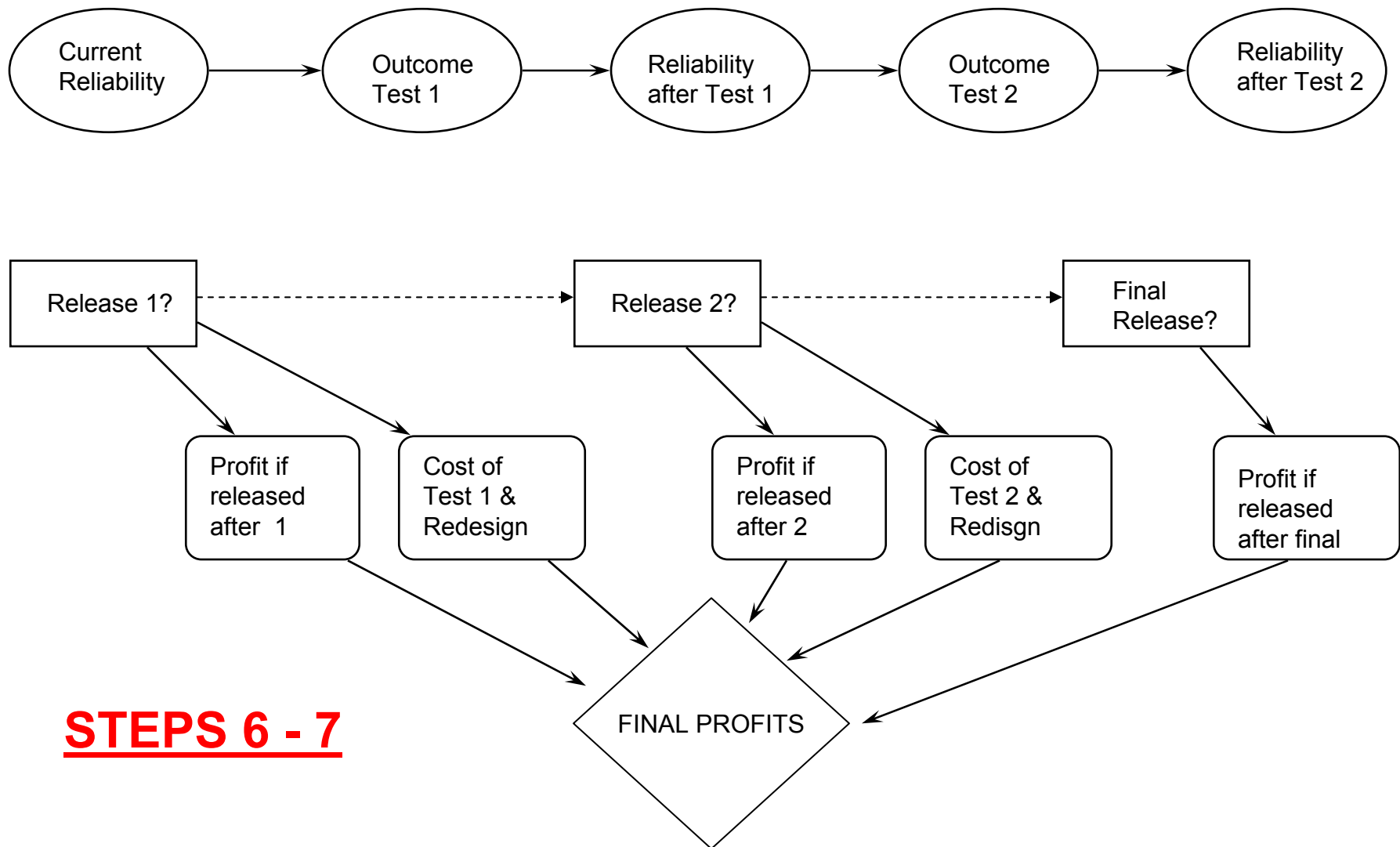


**STEPS 4 - 5**

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# Building an Influence Diagram: Example

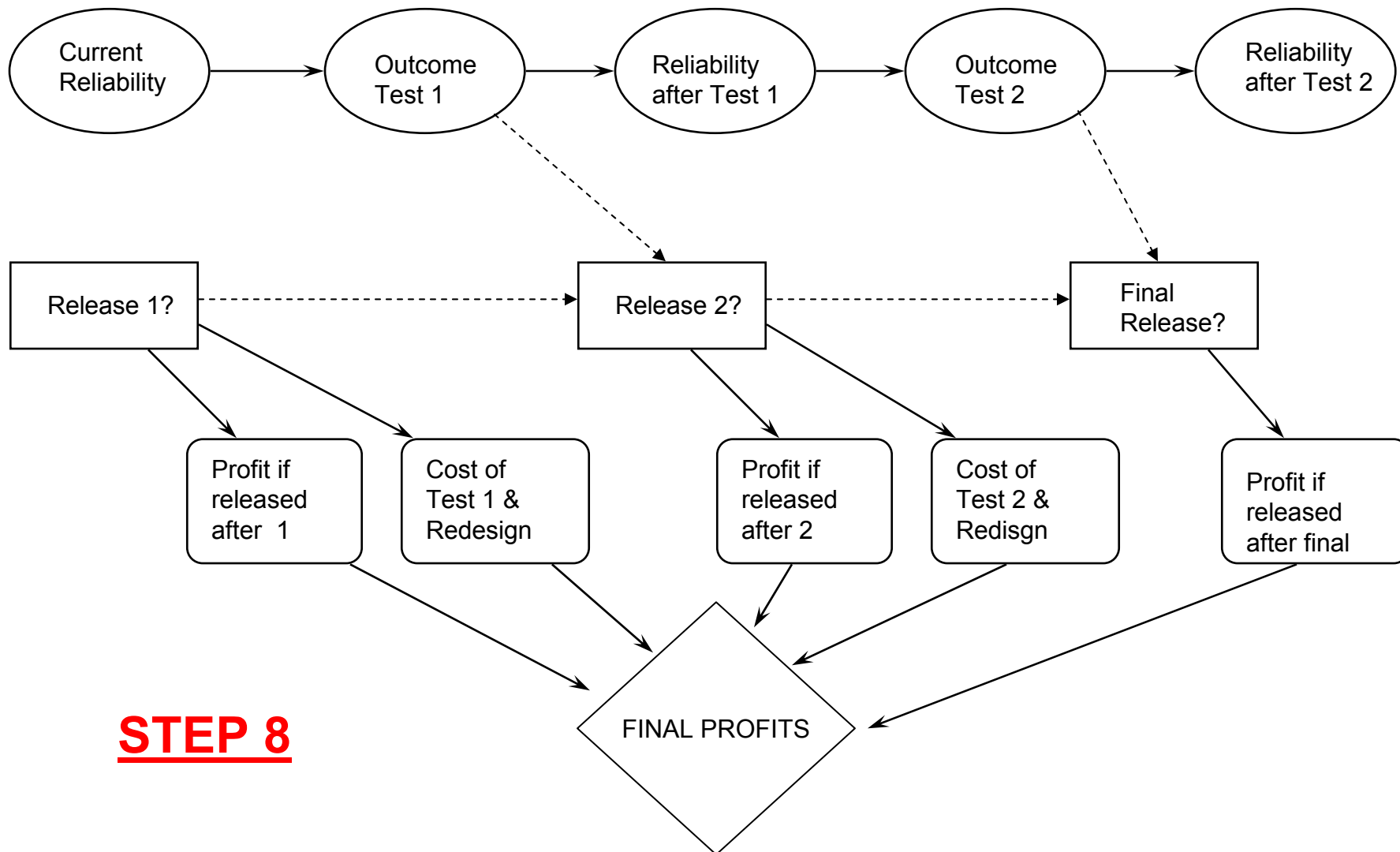
## Test Analyze and Fix (TAAF)



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# Building an Influence Diagram: Example

## Test Analyze and Fix (TAAF)

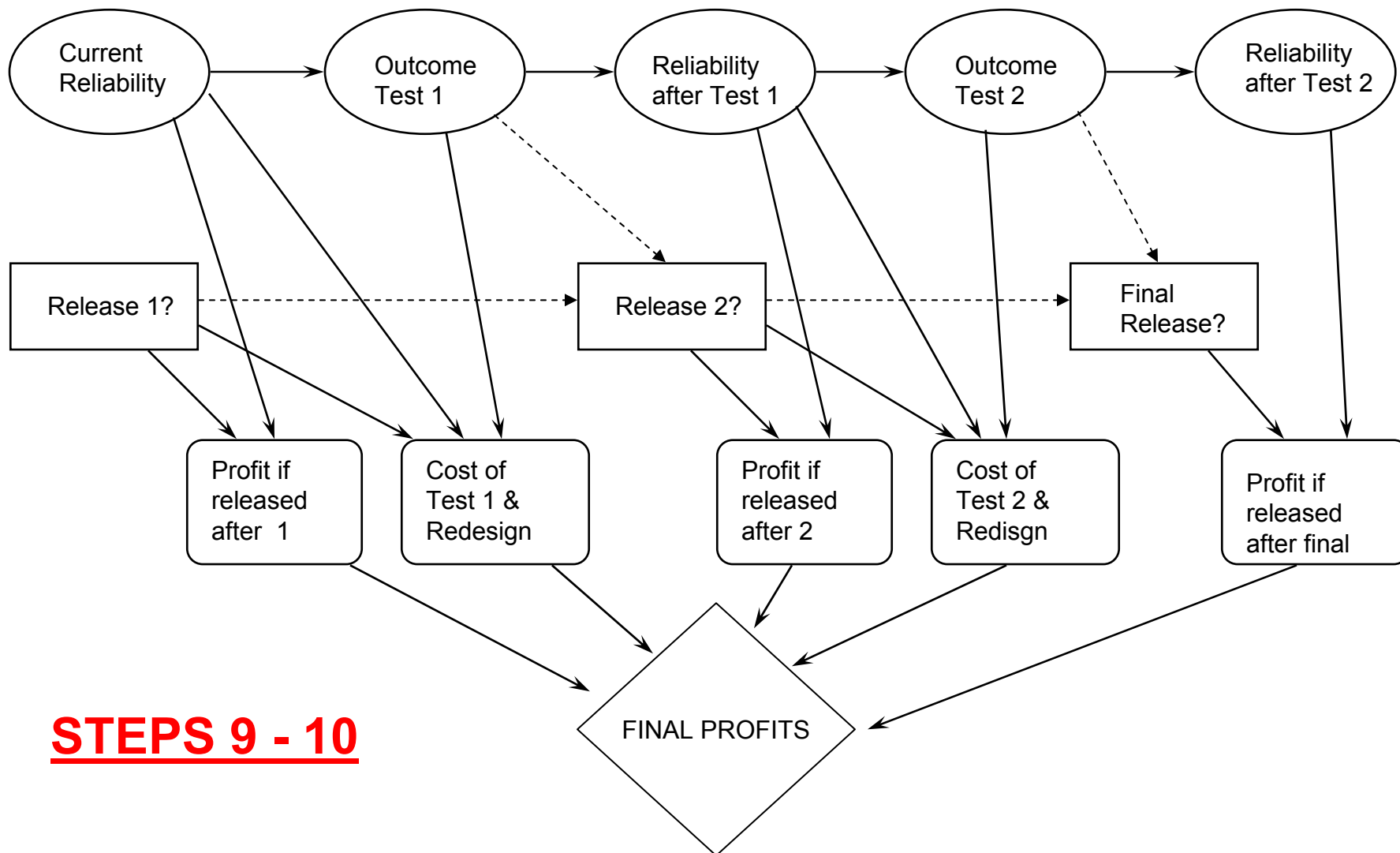


**STEP 8**

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# Building an Influence Diagram: Example

## Test Analyze and Fix (TAAF)

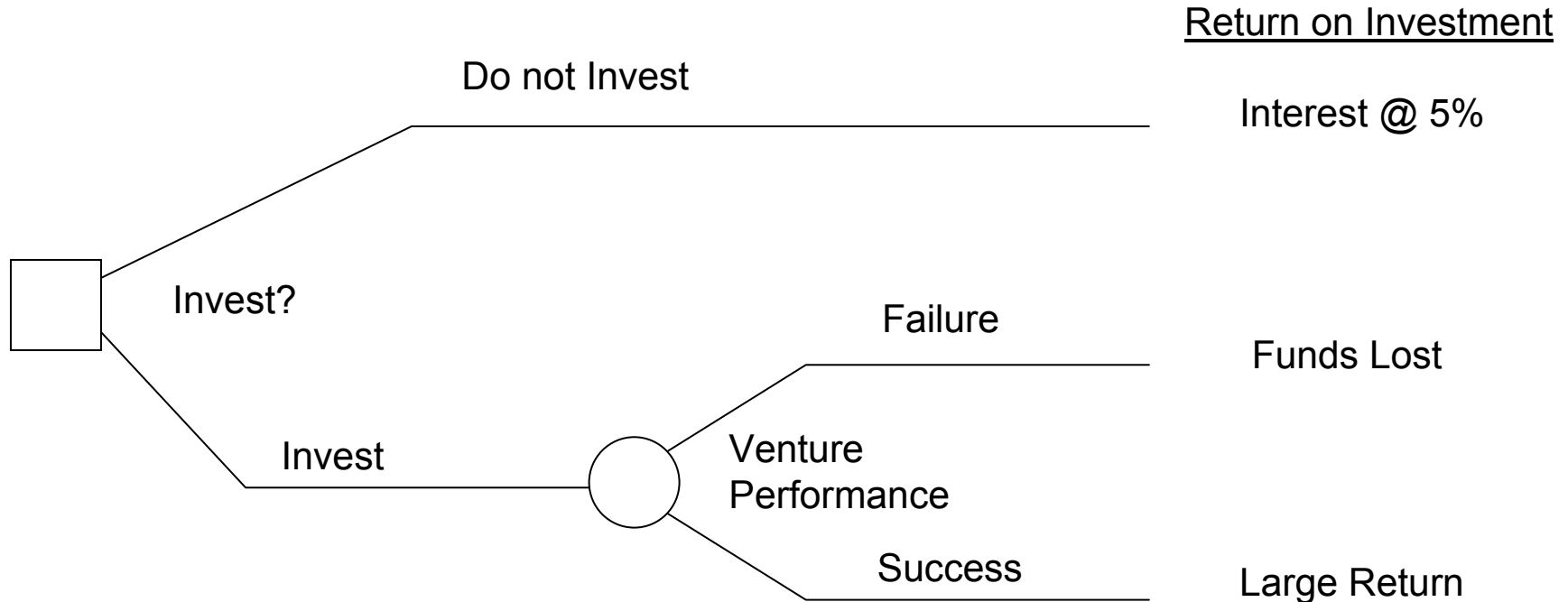


**STEPS 9 - 10**

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# Step 2: Structure Elements in a Logical Framework

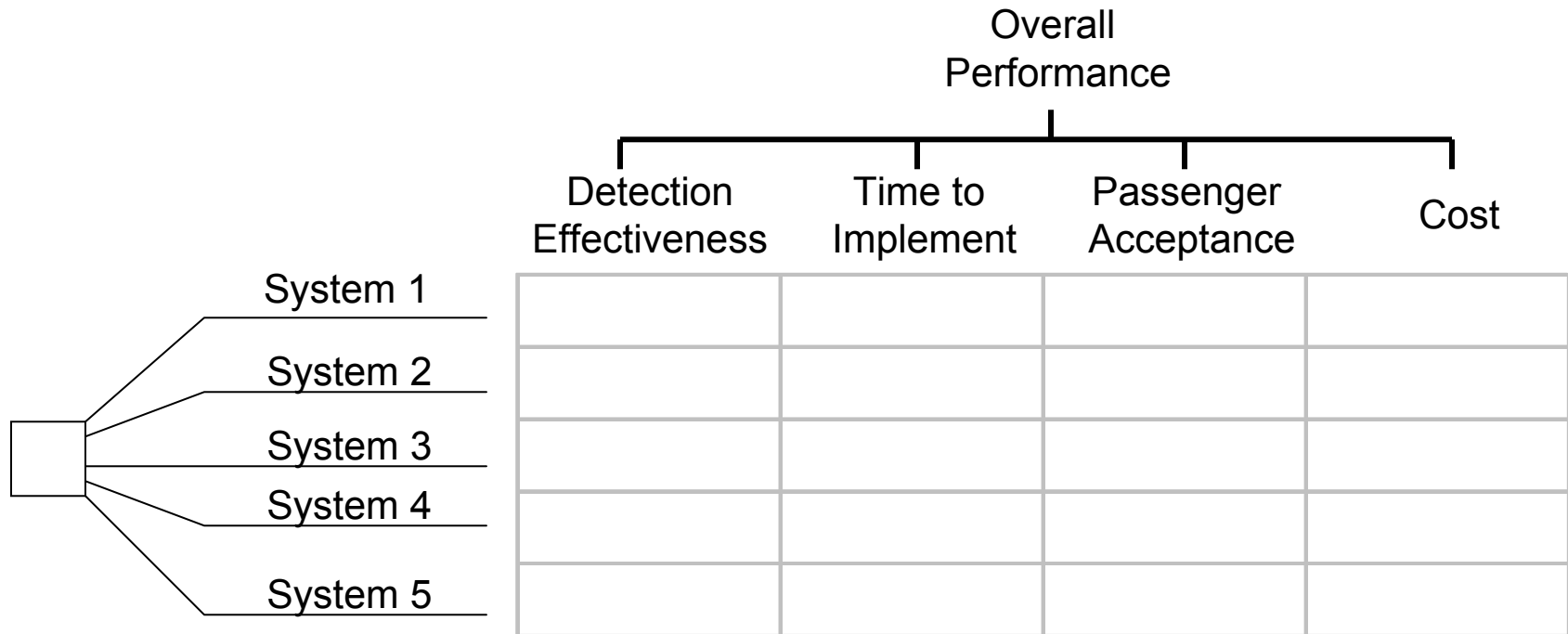
## Investment example:



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# Step 2: Structure Elements in a Logical Framework

## Decision trees and fundamentals-objective hierarchy:

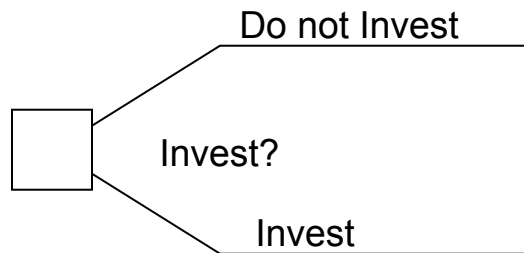


**Decision Trees reveal more detail  
than Influence Diagrams**

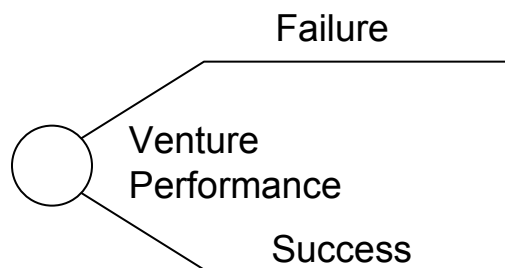
# Step 2: Structure Elements in a Logical Framework

Elements are represented by:

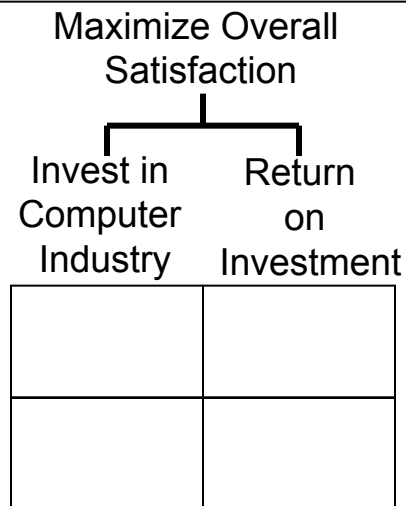
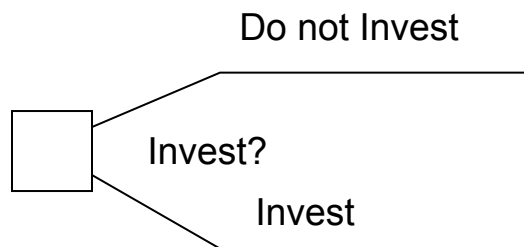
**Decision Nodes:**



**Chance Nodes:**



**Consequences:**



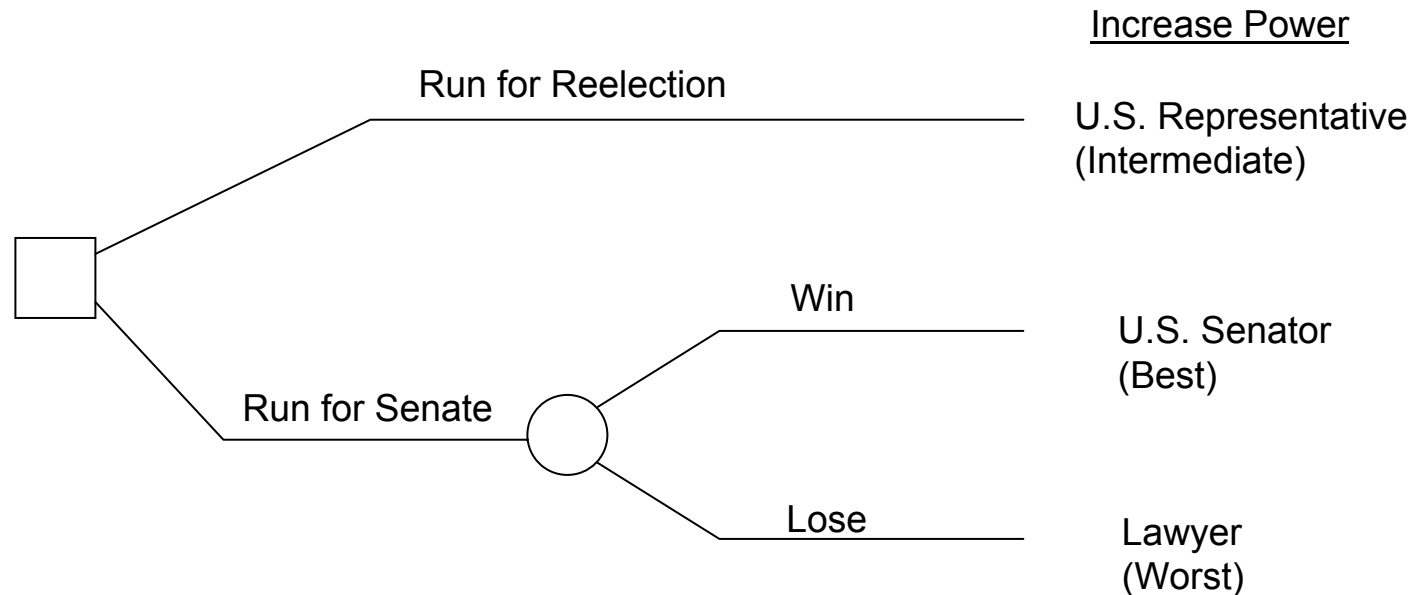
# Step 2: Structure Elements in a Logical Framework

1. Decision Trees are evaluated from left to right
2. Only one alternative can be chosen after each decision node
3. Outcome from a chance event need to be complete, i.e. not more than one outcome can happen at the same time and one outcome will happen.
4. Decision Trees represent all possible future scenarios
5. Think of nodes as occurring in time sequence
6. If for chance nodes the order is not important then use the easiest interpretation.

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# Step 2: Basic Decision Trees

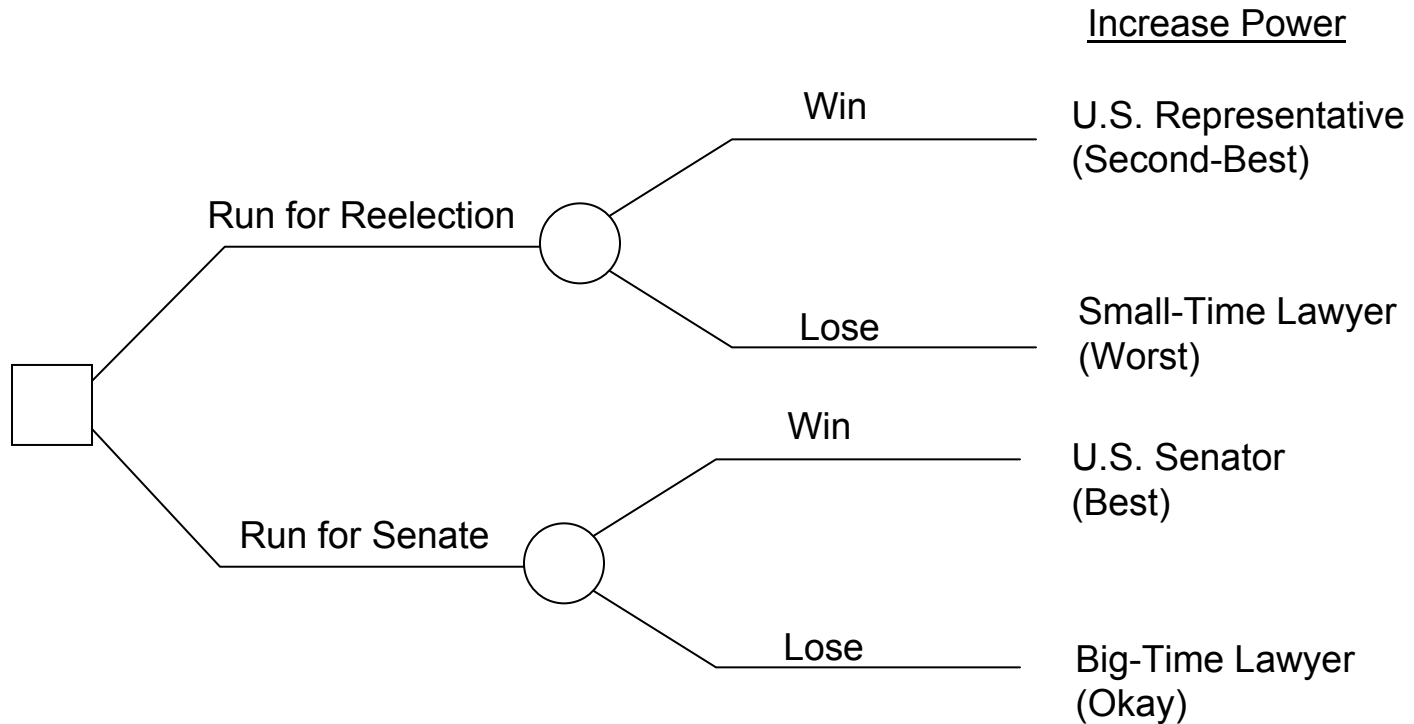
## The Basic Risk Decision



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# Step 2: Basic Decision Trees

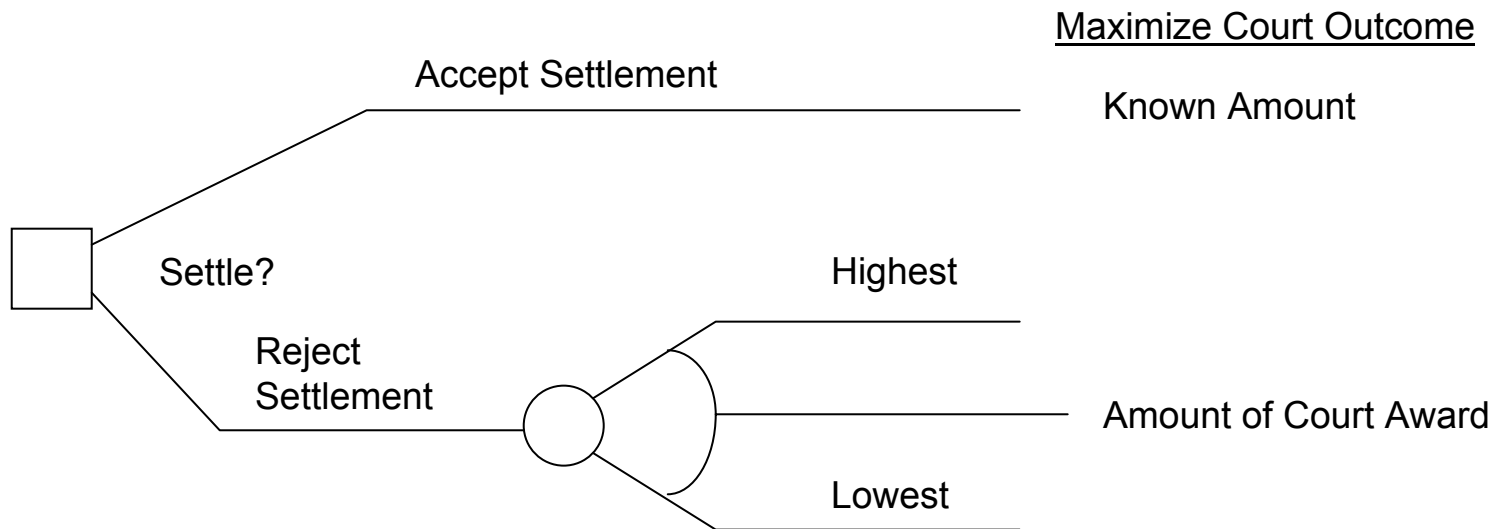
## The Double Risk Dilemma



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# Step 2: Basic Decision Trees

## Rang-of-Risk Dilemma

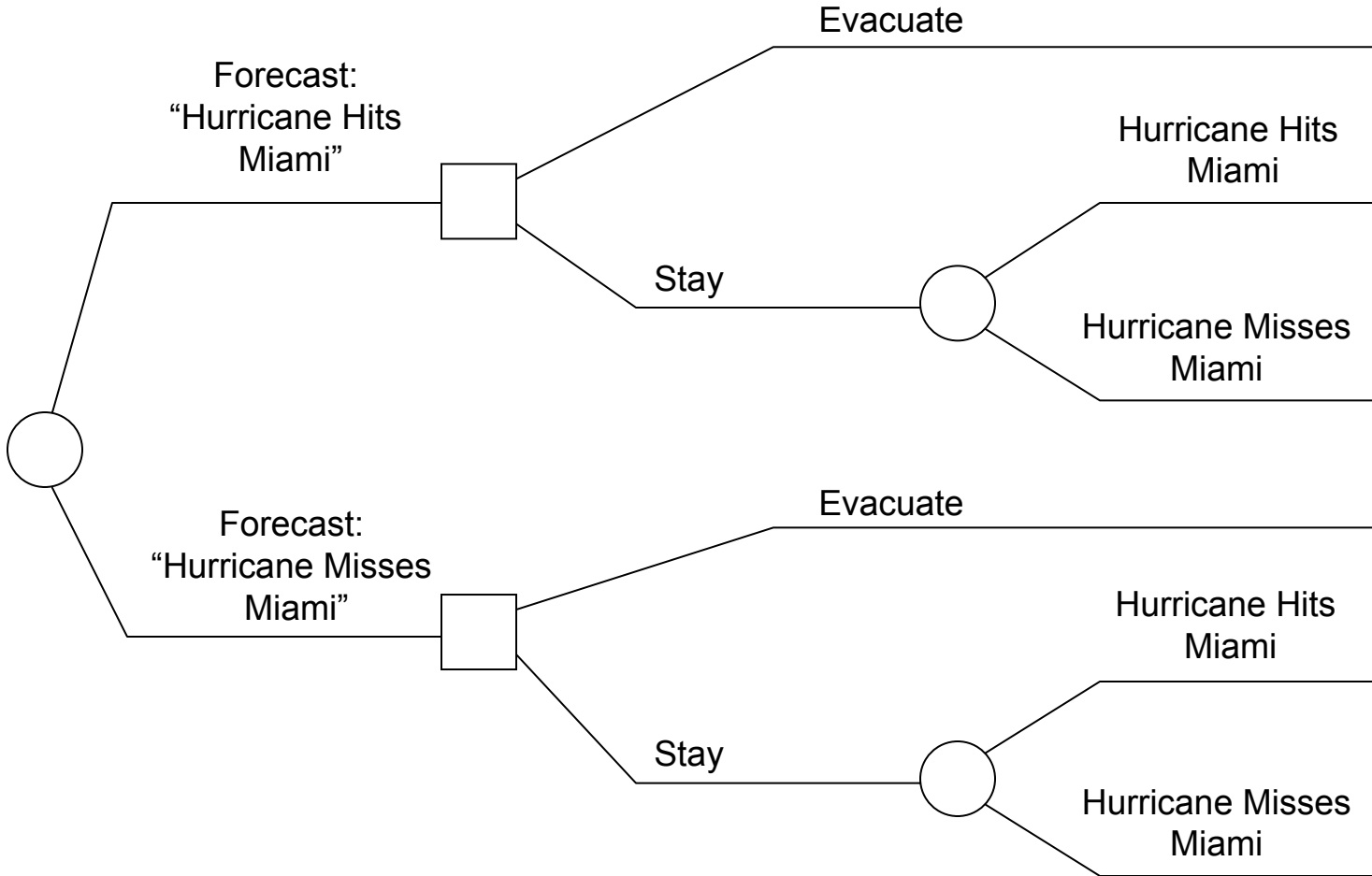
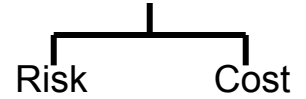


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# Step 2: Basic Decision Trees

## Imperfect Information

Maximize Overall Satisfaction



Safe	High
Danger	Low
Safe	Low

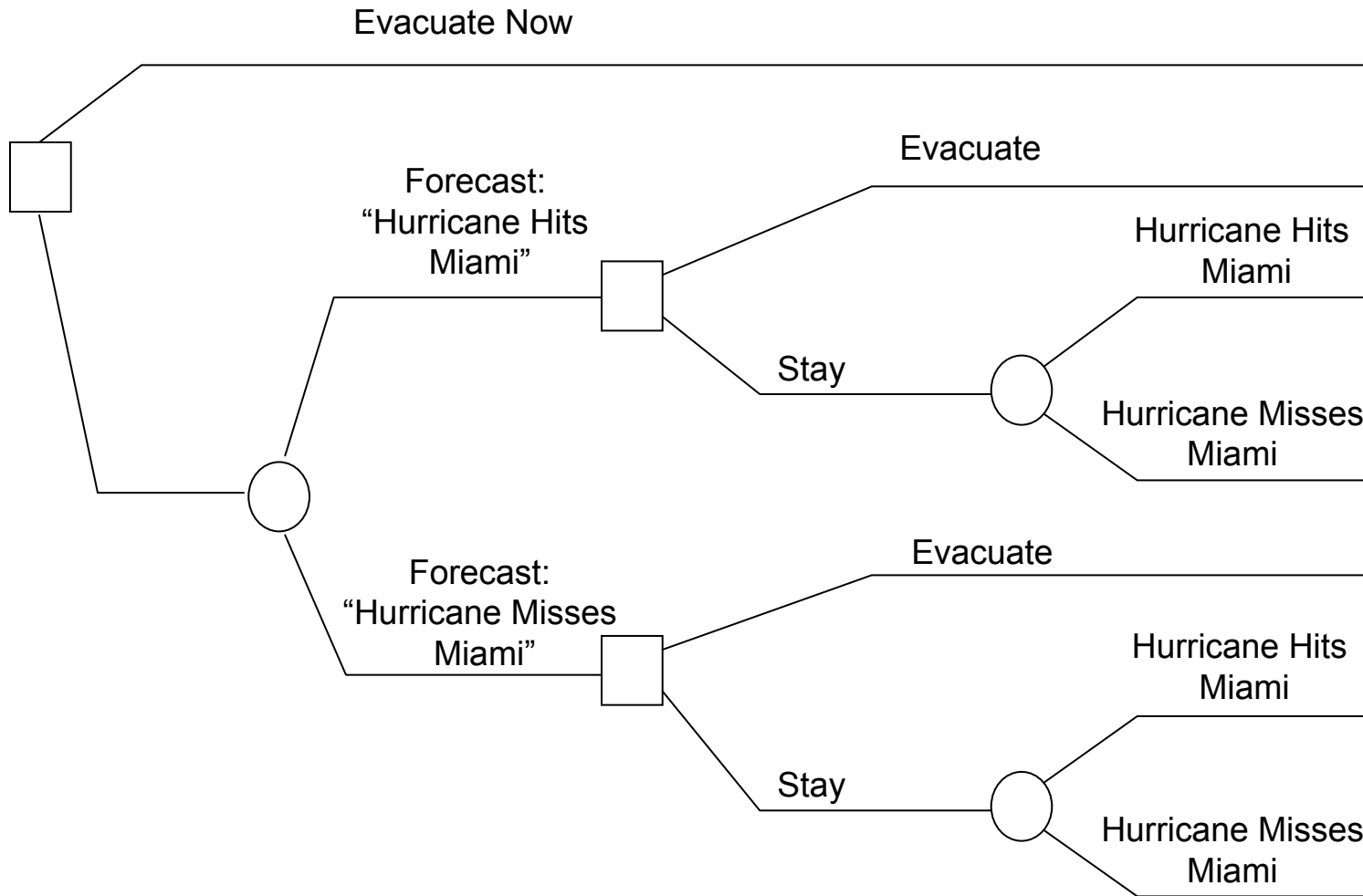
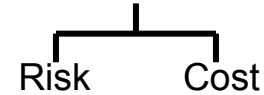
Safe	High
Danger	Low
Safe	Low

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# Step 2: Basic Decision Trees

## Sequential Decisions

Maximize Overall Satisfaction



Safe	High
------	------

Safe	High
------	------

Danger	Low
--------	-----

Safe	Low
------	-----

Safe	High
------	------

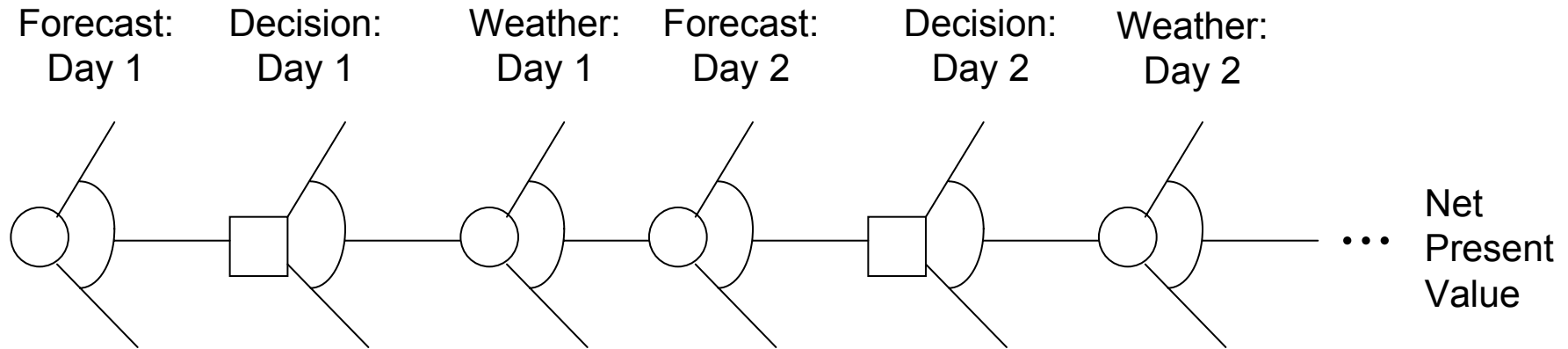
Danger	Low
--------	-----

Safe	Low
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# Step 2: Basic Decision Trees

## Sequential Decisions



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# Decision Trees and Influence Diagrams Compared

- When DP is **complex** decision trees, may get **too large** for presentation.
- For **presentation** a DP influence diagram are superior.
- Decision trees show more detail, hence are more useful for in-depth **understanding**.
- Influence diagrams are better in the **structuring phase**.
- For sensitivity analysis decision trees may be better.
- Influence diagram present the **relevance between uncertainty nodes**, decision trees do not.
- Influence diagrams and decision trees are **isomorphic**.
- Each technique has its strength and weakness. Using both may work **complementary**.
- Both must pass **the clarity test**. No misunderstanding should be possible about the basic key elements in the decision problem.

# Step 3: Fill in the Details

## 1. Define the elements in the decision model clearly

### Consider EPA Example:

Objective: Minimize the **social cost of cancer**. Definition?:

- Incremental Lives Lost ?
- Incremental cases of cancer ?
- Incremental cases of treatable cancer ?

Uncertain Event: **Rate of exposure**. Definition?:

- Number of people exposed to the chemical per day ?
- Ingesting a critical quantity ?
- Skin contact ?

# Step 3: Fill in the Details

## 1. Define the elements in the decision model clearly

### Consider EPA Example:

Objective: Minimize the **social cost of cancer**. Definition?:

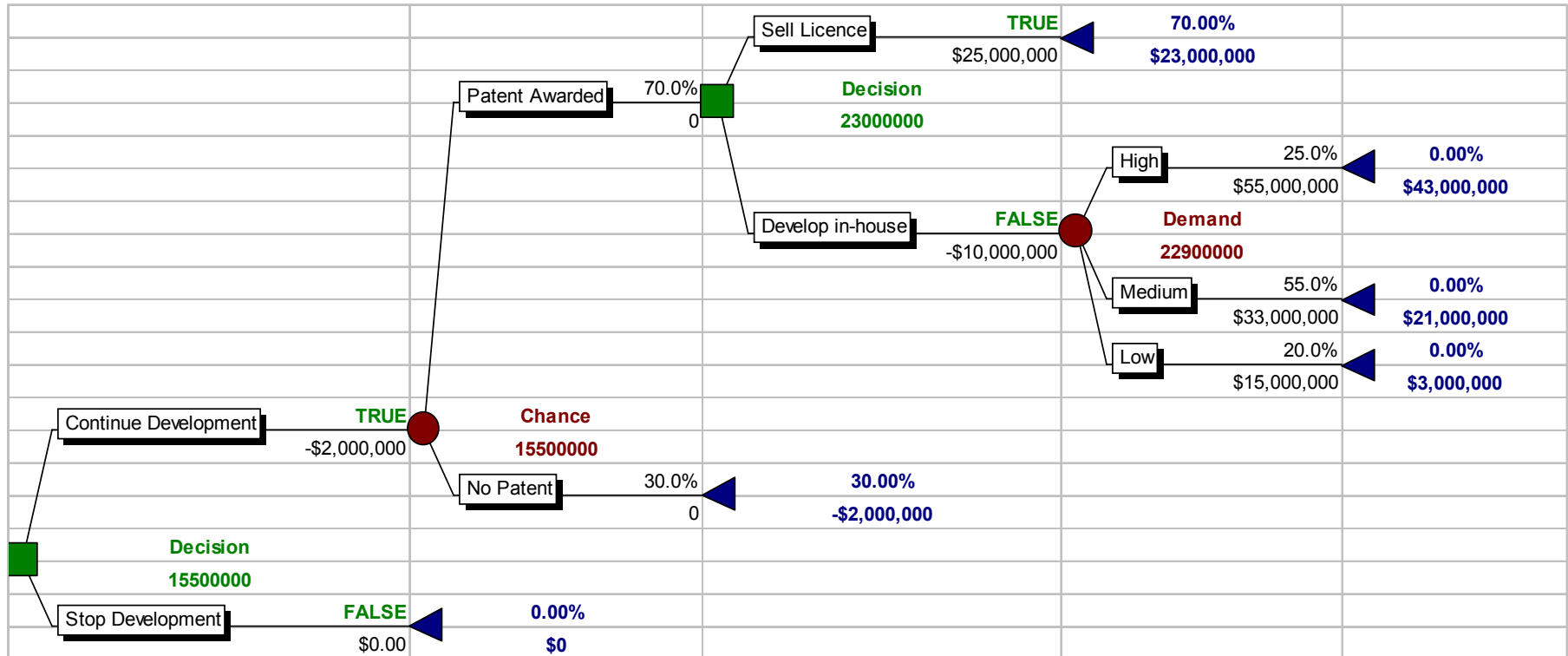
- Incremental Lives Lost ?
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Uncertain Event: **Rate of exposure**. Definition?:

- Number of people exposed to the chemical per day ?
- Ingesting a critical quantity ?
- Skin contact ?

# Step 3: Fill in the Details

## 2. Assess Cash Flows and Probabilities



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# Step 3: Fill in the Details

## 3. Defining Measurement Scales for Fundamental Objectives

Objectives are measured in attributes, e.g: Dollars, Hours, Percentage

### 1. Objectives with natural attribute scale

OBJECTIVE	ATTRIBUTE
Maximize profit	Money ( for example dollars)
Maximize Revenue	Money ( for example dollars)
Maximize Savings	Money ( for example dollars)
Minimize Cost	Money ( for example dollars)
Maximize Market Share	Percentage
Maximize Rate of Return	Percentage
Maximize proximity	Miles, minutes
Maximize Fuel Efficiency	Miles per gallon
Maximize time with friends	Days, Hours
Minimize hypertension	Inches Hg (Blood pressure)

# Step 3: Fill in the Details

## 2. Objectives with no natural attribute scale

Example: **Max Quality**. How does one measure it?

Solution: Define an attribute scale:

BEST, BETTER, SATISFACTORY, WORSE, WORST.

Each category needs to pass the **Clarity Test**:

- An attribute Scale passes the **Clarity Test** if an **outside candidate** using **your definition** can allocate specimens to the identified categories.

# Step 3: Fill in the Details

## Example: Measuring Survey Quality:

### Best Survey Quality:

State-of-the-art Survey. No apparent crucial issues left unaddressed. Has characteristics of the best survey projects presented at professional conferences.

### Worst Survey Quality:

Many issues left unanswered in designing survey. Members of the staff are aware of advances in survey design that could have been incorporated but were not. Not a presentable project.

See **additional category definitions** on Page 82.