CHAPTER

Risk Analysis in Engineering and Economics

RISK ANALYSIS METHODS

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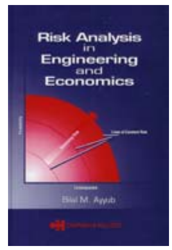
2



Risk Analysis for Engineering
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CHAPMAN
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Introduction

- Risk can be associated with all projects in our life.
- Risk is present in various forms and levels
  - Small domestic projects, such as adding a deck in a house
  - Large multibillion-dollar projects, such as developing and a producing a space shuttle.
- This chapter defines:
  - risk and its dimensions

Introduction (cont'd)

- Risk assessment processes, and
- Fundamental analytical tools needed for this purpose.

- The objective is to introduce needed terminology and methods for performing risk analysis, management and communication.

Risk Terminology

- Technical terms that are needed for presenting risk-based technology methods and analytical tools include:
  - Hazard
  - Reliability
  - Event Consequences
  - Risks
  - Performance
  - Risk-Based Technology

Risk Terminology

- **Hazard**
  - A hazard is an act or phenomenon posing potential harm to some person (s) or thing (s), i.e., a source of harm, and its potential consequences.
  - Hazards need to be identified and considered in projects' lifecycle analyses since they could pose threats and could lead to project failures.

Risk Terminology (cont'd)

- **Reliability**
  - Reliability of a system or a component is defined as the system or component ability to fulfill its design functions under designated operating or environmental conditions for a specified time period.
  - Reliability is, therefore, the occurrence probability of the complementary event to failure as provided in the following expression:

$$\text{Reliability} = 1 - \text{Failure Probability}$$

Risk Terminology (cont'd)

- **Event Consequences**
  - Event consequences can be defined as the degree of damage or loss from some failure.
  - Each failure of a system has some consequence (s).
  - A failure could cause economic damage, environmental damage, injury or loss of human life, or other possible events.
  - Consequences need to be quantified using relative or absolute measures for various consequence types to facilitate risk analysis.

Risk Terminology (cont'd)

- **Risks**
  - Risk can be defined as the potential of losses and rewards resulting from an exposure to a hazard or as a result of a risk event.
  - Risk can be viewed to be a multi-dimensional quantity that includes
    - event occurrence probability,
    - event occurrence consequences,
    - consequence significance, and
    - the population at risk.

Risk Terminology (cont'd)

- **Risks (cont'd)**
  - However, it is commonly measured as a pair of the probability of occurrence of an event, and the outcomes or consequences associated with the event's occurrence.
  - This pairing can be represented by the following equation:

$$Risk \equiv [(p_1, c_1), (p_2, c_2), \ldots, (p_i, c_i), \ldots, (p_n, c_n)] \qquad (1)$$

p_i = occurrence probability of an outcome or event i
c_i = occurrence consequences or outcomes of the event

Risk Terminology (cont'd)

- **Risks (cont'd)**
  - A generalized expression for risk is given as

$$Risk \equiv [(l_1, o_1, u_1, cs_1, po_1), (l_2, o_2, u_2, cs_2, po_2), \ldots, (l_n, o_n, u_n, cs_n, po_n)] \qquad (2)$$

l = likelihood
o = outcome,
u = utility (or significance)
cs = causal scenario
po = population affected by the outcome
n = number of outcomes

Risk Terminology (cont'd)

- **Risks (cont'd)**
  - Risk is commonly evaluated as the product of likelihood of occurrence and the impact severity of occurrence of the event:

$$RISK\left(\frac{Consequence}{Time}\right) = LIKELIHOOD\left(\frac{Event}{Time}\right) \times IMPACT\left(\frac{Consequence}{Event}\right) \qquad (3)$$

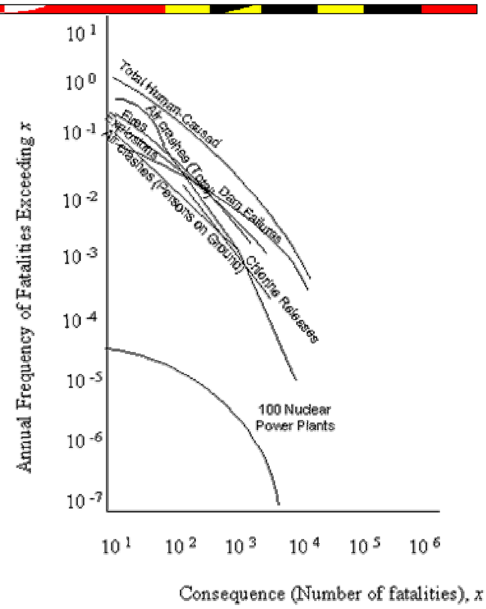
Risk Terminology (cont'd)

- **Risks (cont'd)**
  - The occurrence probability (p) of an outcome (o) can be decomposed into an occurrence probability of an event or threat (t), and the outcome-occurrence probability given the occurrence of the event ($o|t$).
  - The occurrence probability of an outcome can be expressed as follows:

$$p(o) = p(t)\,p(o\,|\,t) \qquad (4)$$

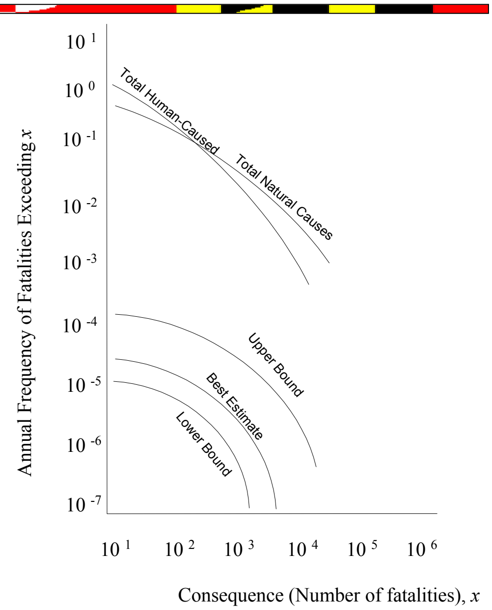
Risk Terminology (cont'd)

- **Risks (cont'd)**
  - A plot of occurrence probability and consequences is a *risk profile* or a *farmer curve*.



Risk Terminology (cont'd)

- **Risks (cont'd)**
  - Examples of curves with bands (meta-uncertainty).



Risk Terminology (cont'd)

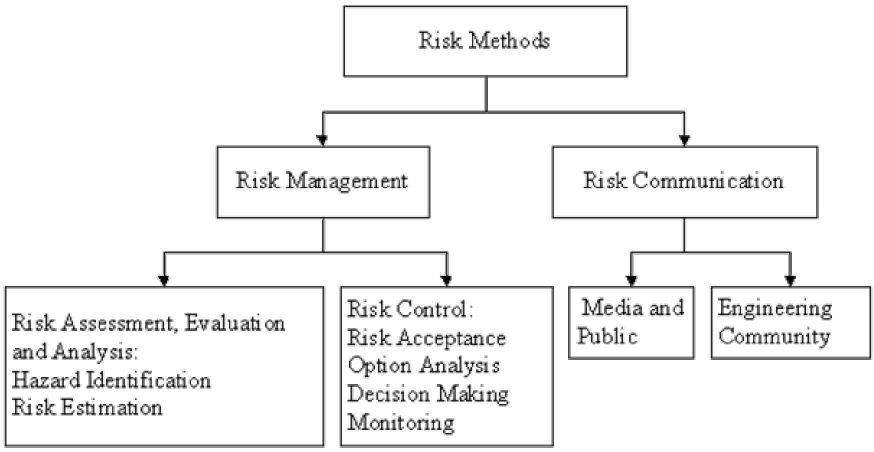
- **Performance**
  - The performance of a system or component can be defined as its ability to meet functional requirements.
  - The performance of an item can be described by various elements including such items as speed, power, reliability, capability, efficiency, and maintainability.
  - The design and operation of the product or system influence performance.

Risk Terminology (cont'd)

- **Risk-based Technology**
  - Risk-based technologies (RBT) are methods or tools and processes used to assess and manage the risks of a component or system.
  - RBT methods can be classified into risk management that includes risk assessment/risk analysis and risk control using failure prevention and consequence mitigation, and risk communication as shown in Figure 1 (next viewgraph).

Risk Terminology (cont'd)

- **Risk-based Technology (cont'd)**



Risk Terminology (cont'd)

- **Risk-based Technology (cont'd)**
  - *Risk assessment* consists of
    - Hazard identification
    - Event probability assessment
    - Consequence assessment
  - *Risk control* require the definition of acceptable risk and comparative evaluation of options and/or alternatives through monitoring and decision analysis. Risk control also includes failure prevention and consequence mitigation.

Risk Terminology (cont'd)

- **Risk-based Technology (cont'd)**
  - *Risk communication* involves perceptions of risk and depends on the audience targeted. Hence, it is classified into
    - Risk communication to the media;
    - To the public; and
    - To the engineering community

Risk Terminology (cont'd)

- **Safety**
  - Safety can be defined as the judgment of risk acceptability for the system.
  - Safety is a relative term.
  - Different people are willing to accept different risks as demonstrated by such factors as
    - Location
    - Method or system types
    - Occupation
    - Life style

Risk Terminology (cont'd)

■ Safety (cont'd)

Table 1. Relative Risk of Different Activities

Risk of Death	Occupation	Lifestyle	Accidents/ Recreation	Environmental Risk
1 in 100	Stunt-person			
1 in 1,000	Racecar driver	Smoking (one pack/day)	Skydiving Rock climbing Snowmobile	
1 in 10,000	Fire fighter Miner Farmer Police officer	Heavy drinking	Canoeing Automobile All home accidents Frequent air travel	

Risk Terminology (cont'd)

■ Safety (cont'd)

Table 1. Relative Risk of Different Activities

Risk of Death	Occupation	Lifestyle	Accidents/ Recreation	Environmental Risk
1 in 100,000	Truck driver Engineer Banker Insurance agent	Using contraceptive pills Light drinking	Skiing Home fire	Substance in drinking water Living downstream of a dam
1 in 1,000,000		Diagnostic X-rays Smallpox vaccination (per occasion)	Fishing Poisoning Occasional air travel (one flight per year)	Natural background radiation Living at the boundary of a nuclear power
1 in 10,000,000		Eating charcoal-broiled steak (once a week)		Hurricane Tornado Lightning Animal bite or insect sting

Risk Terminology (cont'd)

- **Safety (cont'd)**
  - Figure 1 (next slide) illustrates risk exposure during a typical day that starts by waking up in the morning and getting ready
    - to go to work,
    - then commuting and working during the morning hours,
    - a lunch break
    - additional work hours,
    - Commuting back home to have dinner, and
    - A round trip on motorcycle to a local pub.

Risk Terminology (cont'd)

- **Safety (cont'd)**

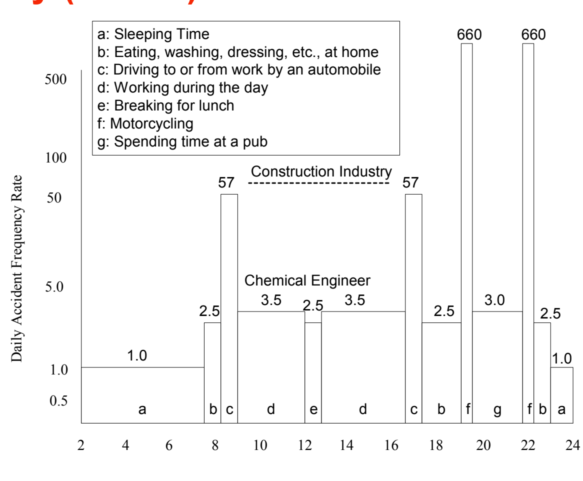


Figure 1. Daily Death Risk Exposure for a Working Healthy Adult

Risk Terminology (cont'd)

- **Safety (cont'd)**
  - The actual level of risk in some activities may not be reflected by risk perceptions of safety.
  - Table 2 shows the differences in risk perception for 29 risk items by
    - League of Women Voters,
    - college students
    - Experts

Risk Terminology (cont'd)

- **Safety (cont'd)**

Table 2. Risk Perception

Activity or Technology	League of Women Voters	College Students	Experts
Nuclear Power	1	1	20
Motor Vehicles	2	5	1
Hand Guns	3	2	4
Smoking	4	3	2
Motorcycles	5	6	6
Alcoholic Beverages	6	7	3
General Aviation	7	15	12

Risk Terminology (cont'd)

- **Safety (cont'd)**

Table 2. (cont'd) Risk Perception

Activity or Technology	League of Women Voters	College Students	Experts
Police Work	8	8	17
Pesticides	9	4	8
Surgery	10	11	5
Fire Fighting	11	10	18
Large Construction	12	14	13
Hunting	13	18	23
Spray Cans	14	13	25

Risk Terminology (cont'd)

- **Safety (cont'd)**

Table 2. (cont'd) Risk Perception

Activity or Technology	League of Women Voters	College Students	Experts
Mountain Climbing	15	22	28
Bicycles	16	24	15
Commercial Aviation	17	16	16
Electric (Non-nuclear) Power	18	19	9
Swimming	19	29	10
Contraceptives	20	9	11
Skiing	21	25	29

Risk Terminology (cont'd)

- **Safety (cont'd)**

Table 2. (cont'd) Risk Perception

Activity or Technology	League of Women Voters	College Students	Experts
X-rays	22	17	7
High School or College Sports	23	26	26
Railroads	24	23	19
Food Preservatives	25	12	14
Food Coloring	26	20	21
Power Mowers	27	28	27
Prescription antibiotics	28	21	24
Home Applications	29	27	22

Risk Terminology (cont'd)

- **Systems for Risk Analysis**
  - A system can be defined as a deterministic entity comprising an interacting collection of discrete elements and commonly defined using deterministic models.
  - "Deterministic" implies that the system is identifiable and not uncertain in its architecture.
  - The definition of the system is based on analyzing its functional and/or performance requirements.

Risk Terminology (cont'd)

- **Systems for Risk Analysis**
  - A description of a system may be a combination of functional and physical elements.
  - Usually functional descriptions are used to identify high information levels on a system.
  - A system may be divided into subsystems that interact.
  - Additional detail leads to a description of
    - the physical elements,
    - components, and
    - various aspects of the system.

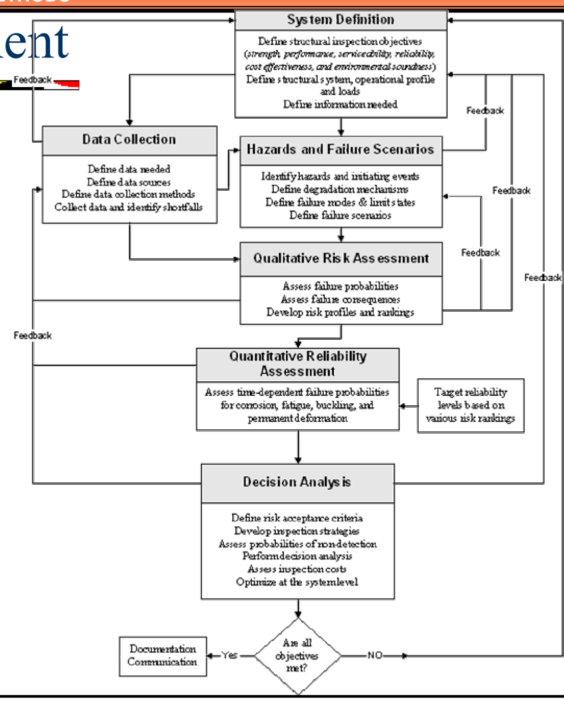
Risk Assessment

Definition: The scientific and engineering process of characterizing an adverse effect associated with an action or a situation.

- The risk assessment process is essentially the same for every anticipated effect.
- There is a great deal of confusion on the components of risk assessment, given differing methods historically developed for risk assessment by many groups in both public and commercial sectors.
- <u>There is a an obvious benefit for a common approach to risk assessment</u>.

Risk Assessment

- Risk Assessment Methodologies



Risk Assessment (cont’d)

- Risk Events and Scenarios
  - Risk events and scenarios can be categorized as follows:
    - Technical, technological, quality, or performance risks,
    - Project-management risks,
    - Organizational risks,
    - External risks, and
    - Natural hazards, such as earthquakes, floods, strong winds, etc.

Risk Assessment (cont'd)

Table 3. Risk Events and Scenarios

Risk Event Category or Scenario	Description
Unmanaged Assumptions	Unmanaged assumptions are neither visible nor apparent as recognizable risks. They are commonly introduced by organizational culture and that when unknowingly present in the project environment bring about incorrect perceptions and unrealistic optimism.
Technological Risk	A technological risk can arise from using unfamiliar or new technologies. At one end is the application of the state of art and familiar technology, where the technological risk can be quite low. At the other end, a new technology is used generating the greatest uncertainty and risk.
Economic Climate	For example, uncertain inflation rates, changing currency rates, etc., affect the implementation of a project in terms of cash flow. A forecast of the relative valuations of currencies can be relevant for industries with multinational competitors and project partners.

Risk Assessment (cont'd)

Table 3. (cont'd) Risk Events and Scenarios

Risk Event Category or Scenario	Description
Domestic Climate	Risk events in this category include tendencies among political parties, local governments, attitudes and policies toward trade and investment, and any recurring governmental crises.
Social Risks	Risks in this category are related to social values such as preservation of environment. Some projects had to be aborted after an investment decision had been made due to resistance from the local population.
Political Risks	Political risks are associated with political stability both at home and abroad. A large investment may require looking ahead several years from the time the investment is made.
Conflicts Among Individuals	Conflicts can affect the success of a project. These conflicts could arise from cognitive differences or biases including self-motivated bias.

Risk Assessment (cont'd)

Table 3. (cont'd) Risk Events and Scenarios

Risk Event Category or Scenario	Description
Large and Complex Project Risks	Large and complex projects usually call for multiple contracts, contractors, suppliers, outside agencies, and complex coordination systems and procedures. Complex coordination between the subprojects is itself a potential risk, as a delay in one area can cause a ripple effect in other areas.
Conceptual Difficulty	A project may fail if the basic premise from which it was conceived was faulty. For example, if an investment is planned to remove some of the operational or maintenance bottlenecks ignoring market requirements and forces, the risk of such a project not yielding desired financial benefits is extremely high.
Use of External Agencies	Appointing an external agency as project manager without creating a large project organization may not ensure the kind of ownership required for successful implementation or the liquidation of defects that the client can visualize through an earlier experience of operating the facilities.

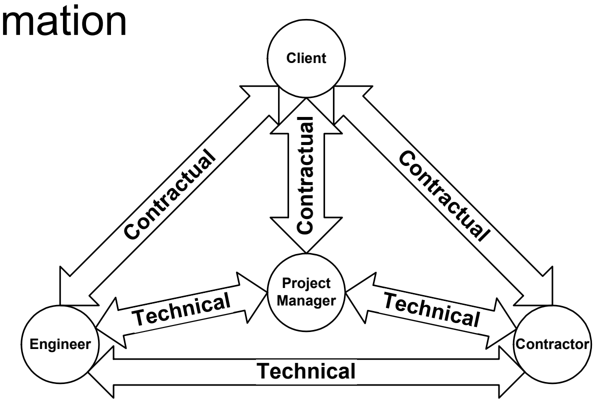
Risk Assessment (cont'd)

Table 3. (cont'd) Risk Events and Scenarios

Risk Event Category or Scenario	Description
Contract and Legal Risks	A contract as an instrument to transfer the risk from the owner to the contractor, the contractor risks only his fees, whereas the owner runs the risks of not having the plant at all. Although there are many modes available – like multiple split contracting, turnkey, engineering-procurement-construction-commissioning – , none of these come without risks.
Contractors	Contractor failure risk may originate from the lowest-cost syndrome, lack of ownership, financial soundness, inadequate experience, etc. In the face of immense competition, the contractor squeezes his profit margin to the maximum just to stay in the business. Contractors sometimes siphon mobilization advance to other projects in which they have greater business interest. If a contractor has difficulty with cash flow, then the project suffers.

Risk Assessment (cont'd)

- Example: Project Risks for Warehouse Automation



Relationships Among the Four Parties Involved in a Project

Risk Assessment (cont'd)

- Example: Project Risks for Warehouse Automation (cont'd)
  - ABC grocery and supermarket outlets desires to automate its warehouse by installing a computer-controlled order-packing system, along with a conveyor system for moving goods from storage to the warehouse shipping area.

Risk Assessment (cont'd)

- Example: Project Risks for Warehouse Automation (cont'd)
  - Four parties are involved in this project:
    - (1) client,
    - (2) project manager,
    - (3) engineer, and
    - (4) contractor
  - The risk events and scenarios associated with this project can be constructed based on the perspectives of the four parties as provided in Tables 2-4a, 2-4b, 2-4c, and 2-4d, respectively of your *textbook*.

Risk Assessment (cont'd)

- Identification of Risk Events and Scenarios
  - The risk assessment process starts with the question:

    "What can go wrong?"

  - The identification of *what can go wrong* entails defining:
    - *Hazards*
    - *Risk events*
    - *Risk scenarios*

Risk Assessment (cont'd)

- Identification of Risk Events and Scenarios
  - Risk identification can be a difficult task because it is often highly subjective, and no unerring procedures available that may be used to identify risk events and scenarios other than relaying heavily on the experience and insight of key project personnel.
  - Development of the scenarios for risk evaluation can be created
    - Deductively (e.g., fault tree)
    - Inductively (e.g., failure mode and effect analysis (FMEA)

Risk Assessment (cont'd)

Table 4. Risk Assessment Methods

Method	Scope
Safety/Review Audit	Identifies equipment conditions or operating procedures that could lead to a casualty or result in property damage or environmental impacts.
Checklist	Ensures that organizations are complying with standard practices.
What-If	Identifies hazards, hazardous situations, or specific accident events that could result in undesirable consequences.
Hazard and Operability Study (HAZOP)	Identifies system deviations and their causes that can lead to undesirable consequences and determine recommended actions to reduce the frequency and/or consequences of the deviations.
Preliminary Hazard Analysis (PrHA)	Identifies and prioritizes hazards leading to undesirable consequences early in the life of a system. It determines recommended actions to reduce the frequency and/or consequences of the prioritized hazards. This is an inductive modeling approach.

Risk Assessment (cont'd)

Table 4. (cont'd) Risk Assessment Methods

Method	Scope
Probabilistic Risk Analysis (PRA)	Methodology for quantitative risk assessment developed by the nuclear engineering community for risk assessment. This comprehensive process may use a combination of risk assessment methods.
Failure Modes and Effects Analysis (FMEA)	Identifies the components (equipment) failure modes and the impacts on the surrounding components and the system. This is an inductive modeling approach.
Fault Tree Analysis (FTA)	Identifies combinations of equipment failures and human errors that can result in an accident. This is an deductive modeling approach.
Event Tree Analysis (ETA)	Identifies various sequences of events, both failures and successes that can lead to an accident. This is an inductive modeling approach.

Risk Assessment (cont'd)

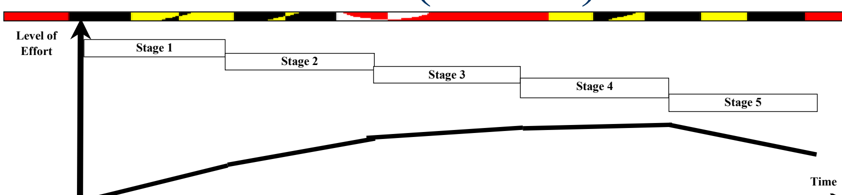
Table 4. (cont'd) Risk Assessment Methods

Method	Scope
The Delphi Technique	Assists to reach consensus of experts on a subject such as project risk while maintaining anonymity by soliciting ideas about the important project risks that are collected and circulated to the experts for further comment. Consensus on the main project risks may be reached in a few rounds of this process.
Interviewing	Identifies risk events by interviews of experienced project managers or subject-matter experts. The interviewees identify risk events based on experience and project information.
Experience-Based Identification	Identifies risk events based on experience including implicit assumptions.
Brain Storming	Identifies risk events using facilitated sessions with stakeholders, project team members, and infrastructure support staff.

Risk Assessment (cont'd)

- Example: Risk Assessment Methods for Warehouse Automation Project
  - This example identifies suitable risk assessment methods for various aspects of the warehouse automation project.
  - Risk assessment methods include checklist, what-if-then analysis, FMEA, FTA, and ETA, and qualitative and quantitative risk assessments.
  - The client risks identified in Example 2-1 (Text) are used herein to illustrate the use of checklists and what-if-then analysis.

Risk Assessment (cont'd)



Project stages	Feasibility study	Preliminary design	Detailed design	Execution and implementation	Termination
what if	Feasibility stage is delayed for some reason.	The preliminary design is not approved for various reasons caused by the architect, engineer, project planner, or project manager.	The detailed design performed by the architect/engineer is delayed.	The execution and implementation stage is delayed or disrupted for one reason or more as provided in Example 2-1.	The termination stage is delayed or not scheduled.
then	The four stages of the project will be delayed causing problems to the client's financial and investment obligations.	The detailed design will not be ready for zoning and planning approval, and for the selection process of contractors causing accumulated delays in finishing the project leading to additional financial burdens on the client.	The project management activities cannot be performed efficiently, and the contractor (if selected at this stage) cannot start work properly causing delays in the execution of the project.	Definitely, the project will not be finished on time and will be completed over budget causing serious financial problems to the client.	The whole automation system will become unreliable and hazardous causing customer complaints and the increasing client's contractual obligation problems.

Example: What-if-then Analysis and Results for Various Project Stages

Risk Assessment (cont'd)

- Risk Breakdown Structure

Level 0	Level 1	Level 2	Level 3
Project Risks	Management	Corporate	History, experiences, culture, personnel
			Organization structure, stability, communication
			Finances conditions
			Other projects
			:
		Customers & stakeholders	History, experiences, culture, personnel
			Contracts and agreements
			Requirement definition
			Finances and credit
			:
	External	Natural environment	Physical environment
			Facilities, site, equipment, materials
			Local services
			:
		Cultural	Political
			Legal, regulatory
			Interest groups
			Society and communities
			:
		Economic	Labor market, conditions, competition
			Financial markets
			:
	Technology	Requirements	Scope and objectives
			Conditions of use, users
			Complexity
			:
		Performance	Technology maturity
			Technology limitations
			New technologies
			New hazards or threats
			:
		Application	Organizational experience
			Personnel skill sets & experience
			Physical resources
			:

Risk Breakdown Structure (Enlarged)

Level 0	Level 1	Level 2	Level 3
Project Risks	Management	Corporate	History, experiences, culture, personnel
			Organization structure, stability, communication
			Finances conditions
			Other projects
			:
		Customers & stakeholders	History, experiences, culture, personnel
			Contracts and agreements
			Requirement definition
			Finances and credit
			:
	External	Natural environment	Physical environment
			Facilities, site, equipment, materials
			Local services
			:
		Cultural	Political
			Legal, regulatory
			Interest groups
			Society and communities
			:
		Economic	Labor market, conditions, competition
			Financial markets
			:
	Technology	Requirements	Scope and objectives
			Conditions of use, users
			Complexity
			:
		Performance	Technology maturity
			Technology limitations
			New technologies
			New hazards or threats
			:
		Application	Organizational experience
			Personnel skill sets & experience
			Physical resources
			:

Risk Assessment (cont'd)

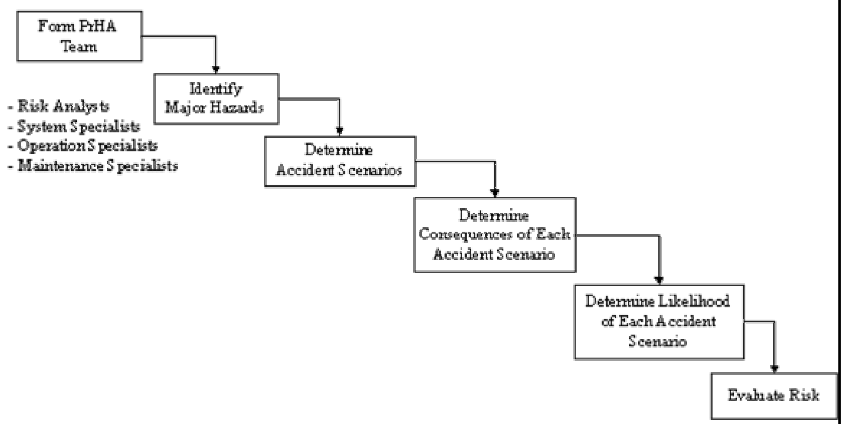
- System Definition for Risk Assessment
  - The system must be constructed in a well organized and repeatable fashion.
  - The formation of system boundaries is based upon the objectives of the risk analysis.
  - Delineating system boundaries can assist in developing the system definition.
  - Establishing the system boundary is partially based on what aspects of the system's performance are of concern.

Risk Assessment (cont'd)

- System Definition for Risk Assessment (cont'd)
  - Along with identifying the boundaries, it is important to establish a resolution limit for the system.
  - The system breakdown structure is the top-down division of a system into subsystems and components.

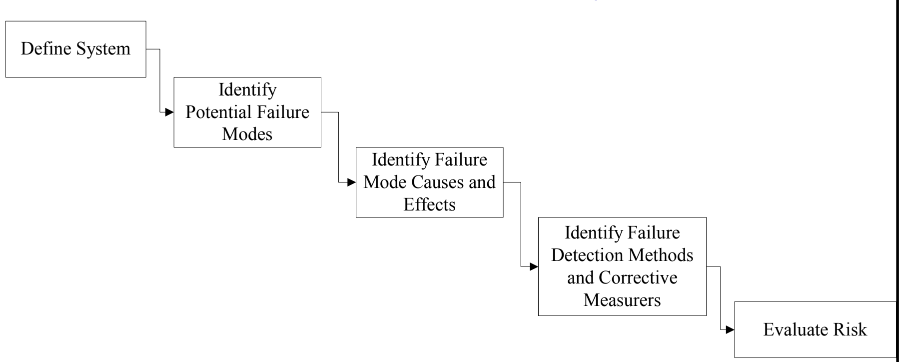
Risk Assessment (cont'd)

- Selected Risk Assessment Methods
  – Preliminary Hazard Analysis



Risk Assessment (cont'd)

- Selected Risk Assessment Methods (cont'd)
  – Failure Mode and Effects Analysis



Risk Assessment (cont'd)

- Selected Risk Assessment Methods (cont'd)
  - Failure Mode and Effects Analysis (cont'd)
    - **Failure Modes:** A failure mode is a way in which a specific process or product fails. It is a description of features that can be negatively affected by a process step or component
    - **Failure Effects:** Failure effects are the impact on end user or regulatory requirements. They are what the end user might experience or notice as a result of the failure mode. The effect is the outcome of the occurrence of the failure mode on the system.

Risk Assessment (cont'd)

- Selected Risk Assessment Methods (cont'd)
  - Failure Mode and Effects Analysis (cont'd)
    - **Severity Ratings:** The severity rating is the importance of the effect on end user requirements. It is concerned with safety and other risks if failure occurs. Severity rating is driven by failure effects and criticality and applies only to the effect. Severity rating should be the same each time the same failure effect occurs. A relative rating scale of 1 to 10 is commonly used (where 1 = not severe and 10 = extremely severe) as given in Table 5.

Risk Assessment (cont'd)

Table 5. Severity Rating Evaluation Criteria

Rating	Description
Minor:	
1	Not noticeable. No effect to the product and end user.
Low:	
2	Not noticeable. No effect.
3	Slightly noticeable, slight end user annoyance.
Moderate:	
4 – 6	End user will notice immediately upon receipt. Noticeable effects on sub-system, or product performance. Some end user dissatisfaction. End user is uncomfortable or annoyed by failure.
High:	
7 – 8	Effects on major system, but not on safety or government regulated compliance items. High degree of end user dissatisfaction due to nature of failure.
Extreme:	
9 – 10	Affects safety or involves noncompliance with government regulations. (9 with warning; 10 without warning)

Risk Assessment (cont'd)

- Selected Risk Assessment Methods (cont'd)
  - Failure Mode and Effects Analysis (cont'd)
    - **Failure Causes:** Causes of failure are sources of process variation that causes the failure mode to occur. Potential causes describe how the failure could occur in terms of something that can be corrected or controlled. Potential causes should be thought of as potential root causes of a problem and point the way toward preventive / corrective action. Identification of causes should start with failure modes associated with the highest severity ratings.

Risk Assessment (cont'd)

- Selected Risk Assessment Methods (cont'd)
  - Failure Mode and Effects Analysis (cont'd)
    - **Occurrence Rating:** The occurrence rating of a cause is the frequency with which a given cause occurs and creates the failure mode. Occurrence rating refers to the industry wide average likelihood or probability that the failure cause will occur. A rating scale of 1 to 10 is used as given in Table 6.
    - **Definition of Controls:** Current controls are those controls that either prevent the failure mode from occurring or detect the failure mode should it occur. Prevention controls consist of mistake-proofing and automated control. Controls also include inspections and tests which detect failures that may occur at a given process step or subsequently.

Risk Assessment (cont'd)

Table 6. Occurrence Rating Criteria

Rating	Failure Consequence Description	Failure Rate
Minor:		
1	Failure is unlikely. No failures ever associated with almost identical processes.	< 1 in 1,000,000
Low:		
2	Only isolated failures associated with almost identical processes.	1 in 20,000
3	Isolated failures associated with similar processes.	1 in 4,000
Moderate:		
4 5 6	Generally associated with similar processes that have experienced occasional failures, but not in major proportions.	1 in 1,000 1 in 400 1 in 80
High:		
7 8	Generally associated with similar processes that have often failed. Process is not in control.	1 in 40 1 in 20
Extreme:		
9 10	Failure is almost inevitable.	1 in 8 1 in 2

Risk Assessment (cont'd)

- Selected Risk Assessment Methods (cont'd)
  - Failure Mode and Effects Analysis (cont'd)
    - **Detection Ratings:** The detection rating is a measure of the capability of current controls. A detection rating indicates the ability of the current control scheme to detect the causes before creating failure mode and/or the failure modes before causing effect. Detection rating provides the probability that current controls will prevent a defect from reaching the end user given that a failure has occurred as given in Table 7.

Risk Assessment (cont'd)

Table 7. Detection Rating Criteria for Likelihood Defect is caught by Current Controls

Rating	Description
Certainty of non-detection:	
10	Controls will not or cannot detect the existence of a defect.
Very low:	
9	Controls probably will not detect the existence of a defect.
Low:	
7 – 8	Controls have a poor chance of detecting the existence of a defect.
Moderate:	
5 – 6	Controls may detect the existence of a defect.
High:	
3 – 4	Controls have a good chance of detecting the existence of a defect. The process automatically detects failure.
Very high:	
1 – 2	Controls will almost certainly detect the existence of a defect. The process automatically prevents further processing.

Risk Assessment (cont'd)

- Selected Risk Assessment Methods (cont'd)
  - Failure Mode and Effects Analysis (cont'd)
    - **Risk Priority Number (RPN):** The Risk Priority Number (RPN) can be introduced as a weighted assessment number used for prioritizing the highest risk items. The RPN focuses efforts on factors that provide opportunities to make the greatest improvement. The RPNs are sorted and actions are recommended for the top issues. Risk assessment should be performed to determine when a corrective action is required:

RPN = Risk Priority Number
= (Occurrence rating) (Severity rating) (Detection rating) (4)

Risk Assessment (cont'd)

- Risk Matrices
  - Risk can presented and assessed using matrices for preliminary screening by subjectively estimating probabilities and consequences in a qualitative manner.
  - A risk matrix is a two-dimensional presentation of likelihood and consequences using qualitative metrics for both dimensions.

Risk Assessment (cont'd)

- Risk Matrices (cont'd)

Table 8. Likelihood Categories for a Risk Matrix

Category	Description	Annual Probability Range
A	Likely	$\geq$ 0.1 (1 in 10)
B	Unlikely	$\geq$ 0.01 (1 in 100) but < 0.1
C	Very Unlikely	$\geq$ 0.001 (1 in 1,000) but < 0.01
D	Doubtful	$\geq$ 0.0001 (1 in 10,000) but < 0.001
E	Highly Unlikely	$\geq$ 0.00001 (1 in 100,000) but < 0.0001
F	Extremely Unlikely	< 0.00001 (1 in 100,000)

Risk Assessment (cont'd)

- Risk Matrices (cont'd)

Table 9. Consequence Categories for a Risk Matrix

Category	Description	Examples
I	Catastrophic	Large number of fatalities, and/or major long-term environmental impact.
II	Major	Fatalities, and/or major short-term environmental impact.
III	Serious	Serious injuries, and/or significant environmental impact.
IV	Significant	Minor injuries, and/or short-term environmental impact.
V	Minor	First aid injuries only, and/or minimal environmental impact.
VI	None	No significant consequence.

Risk Assessment (cont'd)

- Risk Matrices (cont'd)

Table 10. Example Consequence Categories for a Risk Matrix in 2003 Monetary Amounts (US$)

Category	Description	Cost
I	Catastrophic Loss	≥ $10,000,000,000
II	Major Loss	≥ $1,000,000,000 but < $10,000,000,000
III	Serious Loss	≥ $100,000,000 but < $1,000,000,000
IV	Significant Loss	≥ $10,000,000 but < $100,000,000
V	Minor Loss	≥ $1,000,000 but < $10,000,000
VI	Insignificant Loss	< $1,000,000

Risk Assessment (cont'd)

- Risk Matrices (cont'd)

– Example: Risk Matrix

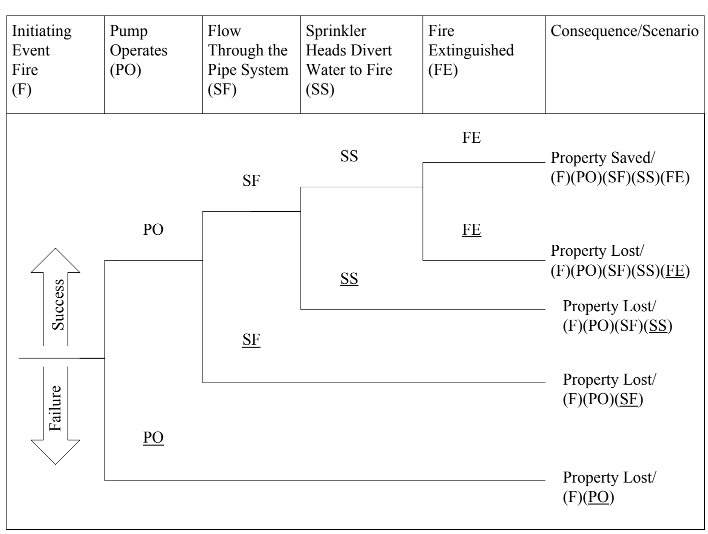
	A	L	M	M	H	H	H
	B	L	L	M	M	H	H
	C	L	L	L	M	M	H
Probability	**D**	L	L	L	L	M	M
Category	**E**	L	L	L	L	L	M
	F	L	L	L	L	L	L
		VI	**V**	**IV**	**III**	**II**	**I**
	Consequence Category						

Risk Assessment (cont'd)

- Event Modeling, Event Trees, Success Trees, and Fault Tress
  - Event modeling is a systematic and often most complete way to identify accident scenarios and quantify risk for risk assessment.
  - This risk-based technology tool provides a framework for identifying scenarios to evaluate the performance of a system or component through system modeling.
  - The combination of event-tree analysis (ETA), success-tree analysis (STA), and fault-tree analysis (FTA) can provide a structured analysis to system safety.

Risk Assessment (cont'd)

– **Event-Tree Example for Sprinkler System**



Risk Assessment (cont'd)

– Fault-Tree and Success-Tree Analyses

- *Basic events*. These events cannot be decomposed further into lower level events. They are the lowest events that can be obtained. For these events, failure probabilities need be obtained.
- *Events that can be decomposed further.* These events can be decomposed further to lower levels. Therefore, they should be decomposed until the basic events are obtained.
- *Undeveloped events*. These events are not basic and can be decomposed further. However, because they are not important, they are not developed further. Usually, the probabilities

Risk Assessment (cont'd)

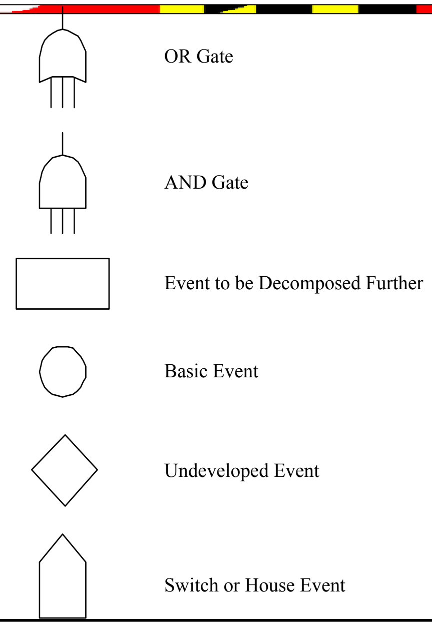
of these events are very small or the effect of their occurrence on the system is negligible, or can be controlled or mediated.

- *Switch (or house) events.* These events are not random, and can be turned on or off with full control.

The symbols shown in the following figure (Figure 2) are used for these events.

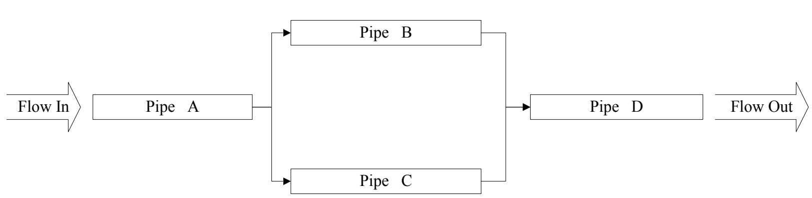
Risk Assessment (cont'd)

- Figure 2. Symbols Used in Fault-Tree Analysis



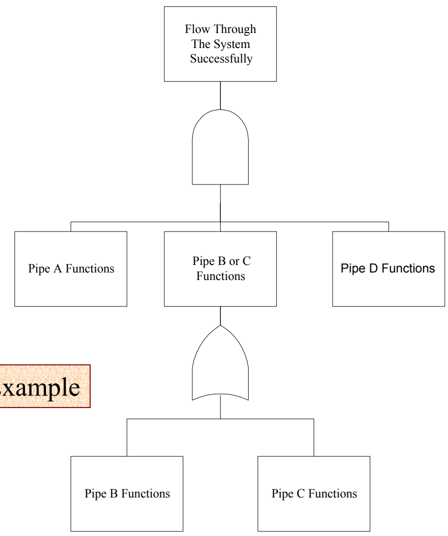
Risk Assessment (cont'd)

- FTA requires the development of a tree-looking diagram for the system that shows failure paths and scenarios that can result in the occurrence of a top event. The construction of the tree should be based on the building blocks and the Boolean logic gates.
- **Example: Piping System**



Risk Assessment (cont'd)

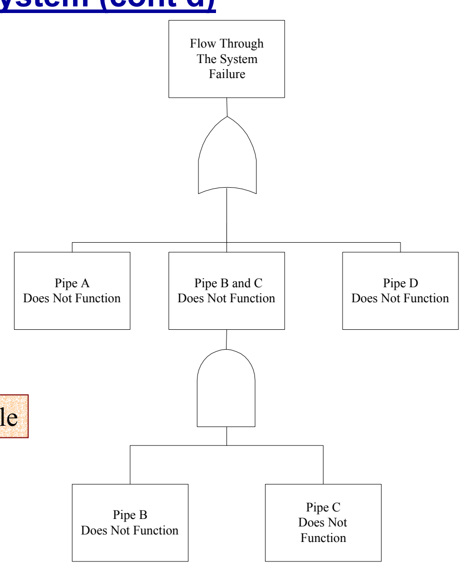
- **Example: Piping System (cont'd)**



Success Tree for the Pipe System Example

Risk Assessment (cont'd)

- **Example: Piping System (cont'd)**



Fault Tree for the Pipe System Example

Risk Assessment (cont'd)

- **Example: Piping System (cont'd)**
  - Using the fault tree model, the top event (T) can be given as

$$T = A \text{ or } (B \text{ and } C) \text{ or } D \qquad (5)$$

  - Based on the theory of probability, the probability (P) of the top event can be computed as a function of pipe failure probabilities as follows:

$$P(T) = 1 - [1 - P(A)][1 - P(B)P(C)][1 - P(D)] \qquad (6)$$

Risk Assessment (cont'd)

- **Example: Piping System (cont'd)**
  - The number of possible failure scenarios (assuming only two possible outcomes for each basic event) is bounded by:

$$\text{Failure paths} = 2^n \qquad (7)$$

Risk Assessment (cont'd)

- Several methods for generating minimal cut sets are available. One of the methods is based on a top-down search of the Boolean logic.
- Another algorithm for generating cut sets is based on a bottom up approach that substitutes the minimal cut sets from lower level gates into upper level gates.
- According to Eq. 5, the minimal cut sets are

A (8a)

D (8b)

B and C (8c)

Risk Assessment (cont'd)

- A minimal cut set includes events that are all necessary for the occurrence of the top event. For example, the following cut set is not a minimal cut set:

B and C (9)

- The minimal cut sets can be systematically generated using the following algorithm:
  1. Provide a unique label for each gate.
  2. Label each basic event.
  3. Set up a two cell array

Risk Assessment (cont'd)

4. Place the top event gate label in the first row, first column:

Top	

5. Scan each row from left to right replacing:
   - each OR gate by a vertical arrangement defining the input events to the gate, and
   - each AND gate by a horizontal arrangement defining the input events to the gate.

   For example, the following table sequence can be generated for an AND top gate with two gates below (Gate 1 of OR type, and Gate 2 of AND type):

Top (AND)	

Risk Assessment (cont'd)

Leading to the following:

Gate1(OR)	Gate2(AND)

Gate 1 has two events (1 and 2), leading to

Event 1	Gate2
Event 2	Gate2

Gate 2 has two events (3 and 4), leading to

Event 1	Event 3	Event 4
Event 2	Event 3	Event 4

Risk Assessment (cont'd)

6. When no gate events remain, each row is a cut set.
7. Remove all non-minimal combinations of events such that only minimal cut sets remain.
8. Compute the occurrence probability for each minimal cut set as the products of the probabilities of its underlying events.
9. Compute the system (top event) occurrence probabilities as the sum of the occurrence probabilities of all the minimal cut sets.

Risk Assessment (cont'd)

– Common Cause Scenarios
- Common-cause scenarios are events or conditions that result in the failure of seemingly separate systems or components.
- Common-cause failures complicate the process of conducting risk analysis because a seemingly redundant system can be rendered ineffectively by common-cause failure

Risk Assessment (cont'd)

– Sensitivity Factors

- ***Fussell-Vesely Factor***. For any event (basic or undeveloped) in a fault tree, the Fussell-Vesely factor (FVF) for the event is given by

$$FVF = \frac{\sum_{\text{all sets containing the event}} \text{occurrence probability of minimal cut set}}{\sum_{\text{all sets}} \text{occurrence probability of minimal cut set}} \quad (10)$$

Risk Assessment (cont'd)

The FVF measures the contribution significance of the event to the failure probability of the system. Events of large FVF should be used to reduce failure probability of the system by reducing their occurrence probabilities.

- ***Birnbaum Factor.*** For any event (basic or undeveloped) in a fault tree, the Birnbaum factor (BF) for the event is given by

$$BF = \frac{\sum_{\text{all sets containing the event}} \text{occurrence probability of minimal cut set}}{\text{occurrence probability of the event}} \quad (11)$$

Risk Assessment (cont'd)

- The BF measures the sensitivity of the failure probability of the system to changes to the occurrence probability of the event. Events of large BF should be used to reduce failure probability of the system by reducing their occurrence probabilities.

Risk Assessment (cont'd)

- Human-Related Risks
  - Human Error Identification
    - Human errors are unwanted circumstances caused by humans that result in deviations from expected norms that place systems at risk.
    - It is important to identify the relevant errors to make a complete and accurate risk assessment.
    - Human error identification techniques should provide a comprehensive structure for determining significant human errors within a system.
    - Quality HRA allows for accuracy in both the HRA assessment and overall system risk assessment.

Risk Assessment (cont'd)

- Human-Related Risks (cont'd)
  - Human Error Modeling
    - Currently, there is no consensus on how to model human reliably. The human-error rate estimates are often based on simulation tests, models, and expert estimation.
  - Human Error Quantification
    - still a developing science requiring understanding of human performance, cognitive processing, and human perceptions.

Risk Assessment (cont'd)

- Human-Related Risks (cont'd)
  - Reducing Human Errors
    - Error reduction is concerned with lowering the likelihood for error in an attempt to reduce risk.
    - The reduction of human errors may be achieved by human factors interventions or by engineering means.
    - Engineering means of error reduction may include automated safety systems or interlocks.
  - Game Theory for Intelligent Threats
    - Game theory can be used to model human behavior, herein as a threat to a system.

Risk Assessment (cont'd)

- Economic and Financial Risks
  - Market Risks
    - Fluctuating of Interest rates
  - Credit Risks
    - Credit risks are associated with potential defaults on notes or bonds, as examples, by corporations including subcontractors.
    - Also, credit risks can be associated with market sentiments that determine a company likelihood of default that could affect its bond rating and ability to purchase money, and maintain projects and operations.

Risk Assessment (cont'd)

- Economic and Financial Risks (cont'd)
  - Operational Risks
    - Operational risks are associated with several sources that include out-of-control operations risk that could occur when a corporate branch undertake significant risk exposure that is not accounted for by a corporate headquarters leading potentially to its collapse.
    - an example being the British Barings Bank that collapsed as a result of primarily its failure to control the market exposure being created within a small overseas branch of the bank.

Risk Assessment (cont'd)

- Economic and Financial Risks (cont'd)
  - Reputation Risks
    - The loss of business attributable to decrease in a corporation's reputation can pose another risk source.
    - This risk source can affect its credit rating, ability to maintain clients, workforce, etc.
    - This risk source usually occurs at a slow attrition rate.
    - It can be an outcome of poor management decisions and business practices.

Risk Assessment (cont'd)

- Data Needs for Risk Assessment
  - Methods of Probability Theory
  - Quantitative Risk Assessment
  - Data can be classified as
    - Failure probability data
    - Failure consequence data.

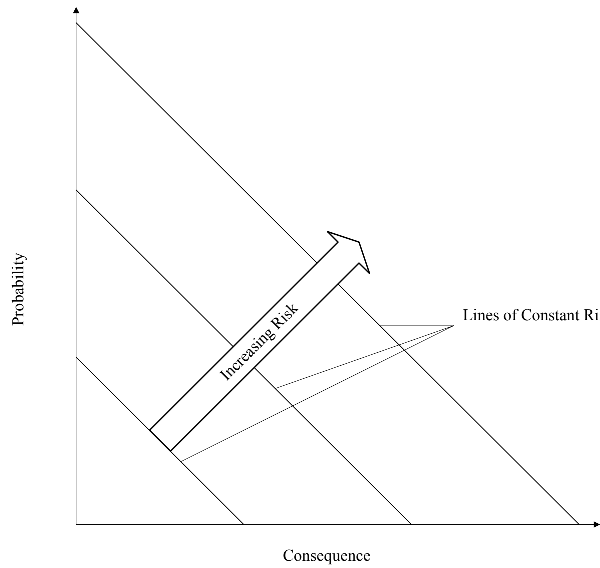
Risk Management and Control

- Adding risk control to risk assessment produces risk management.
- Risk management is the process by which system operators, managers, and owners make safety decisions, regulatory changes, and choose different system configurations based on the data generated in the risk assessment.

Risk Management and Control (cont'd)

- Risk management involves using information from the previously described risk assessment stage to make educated decisions about system safety.
- Risk control includes failure prevention and consequence mitigation.

Risk Management and Control (cont'd)



Risk Management and Control (cont'd)

Assessing and Managing Risk

Since risk can not be eliminated, the problem people face, individually and collectively, is how much risk should they live with and how should they go about managing the risk?

To answer the above questions, analytical tools must be built that will allow the exposure, effects, human perception, and human evaluation processes to be understood and described for specific tasks. In parallel with this, the alternative social and technical implications of risk-management philosophies must be explored and philosophies selected that are compatible with the goals of society. Then a set of incentives and institutions must evolve that will implant them.

Risk Management and Control (cont'd)

Components of Risk Management

Objective	Subjective
Characterized Risk	Risk Perception
Comparative Risk Assessment	Political and Legal Constraints
Cost Assessment	Intangible Values
Cost benefit Assessment	
Management Decisions	

Risk Management is primarily a societal, political, or management process.

Risk Management and Control (cont'd)

- The cornerstone of risk management is risk assessment.
- Under ideal conditions, the risk manager would decide a management option solely on the basis of a cost/benefit assessment whereby the benefit is expressed in reduction of risk. In practice, there are significant obstacles for such a decision.
- Risk management is inherently complex and includes a large number of elements.
- Contrary to the general opinion, risk management includes not only subjective but also objective elements.

Risk Management and Control (cont'd)

Qualitative Risk Assessment Using Severity/Probability Factor Rating

High	2	2	3
Medium	1	1	2
Low	0	1	2
Severity Factor	Low	Medium	High
	Probability Factor		

Severity/Probability Factor Rating
3: Mitigation strategy and detailed contingency plan
2: Mitigation strategy and outlined contingency plan
1: Mitigation strategy
0: Treat as a project base assumption

Risk Management and Control (cont'd)

- Risk Acceptance

Table 11. Methods for Determining Risk Acceptance

Risk Acceptance Method	Summary
Risk Conversion Factors	This method addresses the attitudes of the public about risk through comparisons of risk categories. It also provides an estimate for converting risk acceptance values between different risk categories.
Farmers Curve	It provides an estimated curve for cumulative probability risk profile for certain consequences (e.g., deaths). It demonstrates graphical regions of risk acceptance/non-acceptance.
Revealed Preferences	Through comparisons of risk and benefit for different activities, this method categorizes society preferences for voluntary and involuntary exposure to risk.
Evaluation of Magnitude of Consequences	This technique compares the probability of risks to the consequence magnitude for different industries to determine acceptable risk levels based on consequence.
Risk Effectiveness	It provides a ratio for the comparison of cost to the magnitude of risk reduction. Using cost-benefit decision criteria, a risk reduction effort should not be pursued if the costs outweigh the benefits. This may not coincide with society values about safety.
Risk Comparison	The risk acceptance method provides a comparison between various activities, industries, etc., and is best suited to comparing risks of the same type.

Risk Management and Control (cont'd)

- Risk Conversion Factors
  - The public is willing to accept voluntary risks roughly one thousand times greater than that for involuntary imposed risks;
  - The statistical death rate appears to be a psychological yardstick for establishing the level of acceptability of other risks; and
  - The acceptability of risk appears to be crudely proportional to the third power of the benefits, either real or imaginary.

Risk Management and Control (cont'd)

Table 12. Risk Conversion Values for Different Risk Factors

Risk Factors	Risk Conversion (RF) Factor	Computed RF Value
Origin	Natural/human-made	20
Severity	Ordinary/catastrophic	30
Volition	Voluntary/involuntary	100
Effect	Delayed/immediate	30
Controllability	Controlled/uncontrolled	5 to 10
Familiarity	Old/new	10
Necessity	Necessary/luxury	1
Costs	Monetary/non-monetary	NA
Origin	Industrial/ Regulatory	NA
Media	Low profile/ high profile	NA

NA = not available

Risk Management and Control (cont'd)

Table 13. Classification of Common Risks

		Voluntary		Involuntary	
Source	Size	Immediate	Delayed	Immediate	Delayed
Human	Catastrophic	Aviation		Dam failure Building fire Nuclear accident	Pollution Building fire
Made	Ordinary	Sports Boating Automobiles	Smoking Occupation Carcinogens	Homicide	
Natural	Catastrophic			Earthquakes Hurricanes Tornadoes Epidemics	
	Ordinary			Lighting Animal bites	Disease

Table 14. Individual Fatality Rates

Fatal Event	Total Number	Fatalities/year (10^{-4})	Age-adjusted Rate (10^{-4})
Total Deaths:	2,312,200	88.0	50.3
Disease:			
Cardiovascular	952,500	36.3	17.5
Cancer	538,000	20.5	13.0
Pulmonary	188,300	7.2	3.4
AIDS	31,256	1.2	NA
Accidents:			
Motor vehicle	41,800	1.6	1.6
Falls	13,450	0.52	NA
Poisons	8,994	0.35	NA
Fires/Electrical	4,547	0.17	NA
Drownings	3,404	0.13	NA
Firearms/Handguns	1,356	0.05	NA
Air/Space	1,075	0.04	NA
Water Transport	723	0.03	NA
Railway	635	0.02	NA
Suicide	30,900	1.2	1.1
Homicide	21,600	0.8	0.8

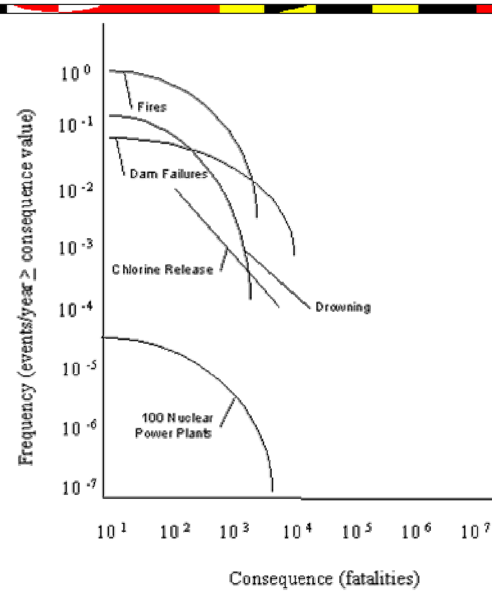
Risk Management and Control (cont'd)

Table 15. Natural Disaster Fatality Rates

Disaster	Years	Deaths	Rate (10^{-7})
Lightning	1959 to 1993	91	4.2
Tornadoes	1995	30	1.1
	1985 to 1994	48	1.9
Hurricanes/Tropical Storms	1995	29	1.1
	1985 to 1994	20	0.8
Floods	1995	103	3.9
	1985 to 1994	105	4.2

Risk Management and Control (cont'd)

- Farmer's Curve



Risk Management and Control (cont'd)

- Method of Revealed Preferences
  - This technique assumes that the risk acceptance by society is found in the equilibrium generated from historical data on risk versus benefit.
  - The estimated lines for acceptance of different activities are separated by the voluntary/involuntary risk categories.

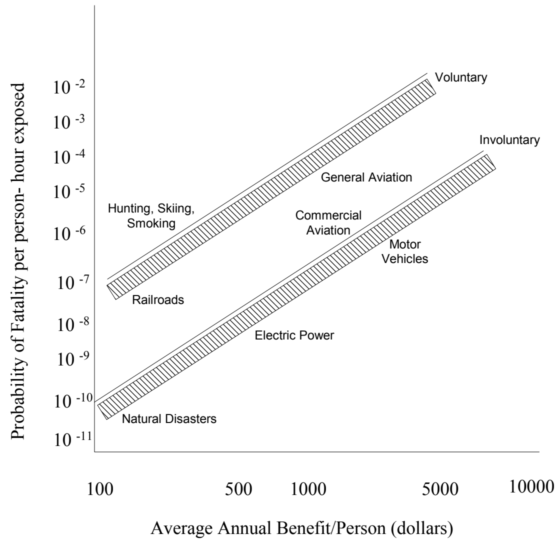
Risk Management and Control (cont'd)

- Method of Revealed Preferences (cont'd)
  - Further analysis of the data led to estimating the relationship between risk and benefit as follows:

$$Risk \sim Benefit^3 \qquad (12)$$

Risk Management and Control (cont'd)

Accepted Risk of Voluntary and Involuntary Activities



Risk Management and Control (cont'd)

- Magnitudes of Risk Consequence
  - Magnitude of Consequences
  - The larger the consequence, the less the likelihood that this event may occur.

$$P_f = 10^{-4}\frac{KT}{n} \qquad (13)$$

T = life of the structure
K = a factor regarding the redundancy of the structure
n = the number of people exposed to risk.

Risk Management and Control (cont'd)

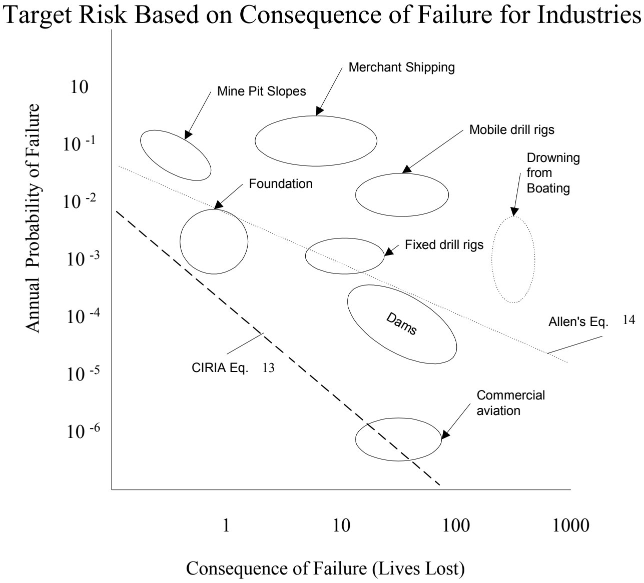
- Magnitudes of Risk Consequence (cont'd)
  - Another estimate is Allen's equation that is given by:

$$P_f = 10^{-5} \frac{TA}{W\sqrt{n}} \qquad (14)$$

T = the life of the structure
n = is the number of persons exposed to risk
A and W = factors regarding the type and redundancy of the structure

Risk Management and Control (cont'd)

Target Risk Based on Consequence of Failure for Industries



Risk Management and Control (cont'd)

- Risk Reduction Cost Effectiveness Ratio

$$Risk\ \text{Re}duction\ Effectiveness = \frac{Cost}{\Delta\ Risk} \quad (15)$$

– where the cost should be attributed to risk reduction, and *ΔRisk* is the level of risk reduction as follows:

$$\Delta\ Risk = \text{(Risk before mitigation action) – (Risk after mitigation action)} \quad (16)$$

Risk Management and Control (cont'd)

Cost Effectiveness of Risk Reduction

Risk Management and Control (cont'd)

- Risk Comparisons

Ways to Identify Risk of Death	Summary
Number of Fatalities	This measure shows the impact in terms of the number of fatalities on society. Comparison of these values is cautioned since the number of persons exposed to the particular risk may vary. Also, the time spent performing the activity may vary. Different risk category types should also be considered to compare fatality rates.
Annual Mortality Rate/Individual	This measure shows the mortality risk normalized by the exposed population. This measure adds additional information about the number of exposed persons; however, the measure does not include the time spent on the activity.
Annual Mortality	This measure provides the most complete risk value since the risk is normalized by the exposed population and the duration of the exposure.
Loss of Life Exposure (LLE)	This measure converts a risk into a reduction in the expected life of an individual. It provides a good means of communicating risks beyond probability values.
Odds	This measure is a layman format for communicating probability, for example, 1 in 4.

Risk Management and Control (cont'd)

- Rankings Based on Risk Results
  - Another tool for risk management is the development of risk ranking.
  - The elements of a system within the objective of analysis can be analyzed for risk and consequently ranked.
  - This relative ranking may be based on the failure probabilities, failure consequences, risks, or other alternatives with concern towards risk.

Risk Management and Control (cont'd)

- Rankings Based on Risk Results (cont'd)
  - Generally risk items ranked highly should be given high levels of priority; however, risk management decisions may consider other factors such as costs, benefits and effectiveness of risk reduction measures.
  - The risk ranking results may be presented graphically as needed.

Risk Management and Control (cont'd)

- Decision Analysis

> "Decision Analysis is an analytic and systematic approach to studying decision making"

  - A good decision is one that is based on logic, considers all available data and possible alternatives, and applies the qualitative and quantitative approaches to solve them.

Risk Management and Control (cont'd)

- Decision Analysis (cont'd)
  - Decision Analysis is a method by which non transparent situations can be made transparent so that every one knows what to do relative to their objectives.
  - In fact, if situation were transparent enough, people probably would not make bad decisions.

Risk Management and Control (cont'd)

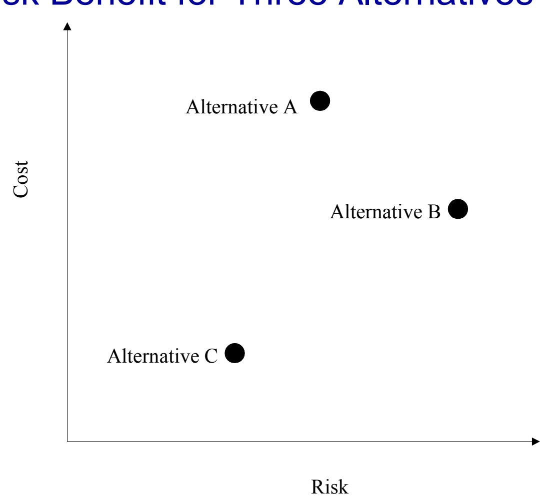
- Decision Analysis (cont'd)
  - Decision making is used to identify decision in three Environment/Cases:
    - Decision-making Under Certainty
    - Decision-making Under Uncertainty
    - Decision-making Under Risk
  - Benefit-cost analysis, decision trees, influence diagrams, and the analytical hierarchy process are some of the tools to assist in decision analysis.

Risk Management and Control (cont'd)

- Cost-Benefit Analysis
  - Risk managers commonly weigh various factors including cost and risk.
  - The analysis of three different alternatives is shown graphically in the following figure (next slide) as an example.
  - The graph shows that alternative (C) is the best choice since the level of risk and cost is less than alternatives (A) and (B).
  - However, if the only alternatives were A and B, the decision would be more difficult.

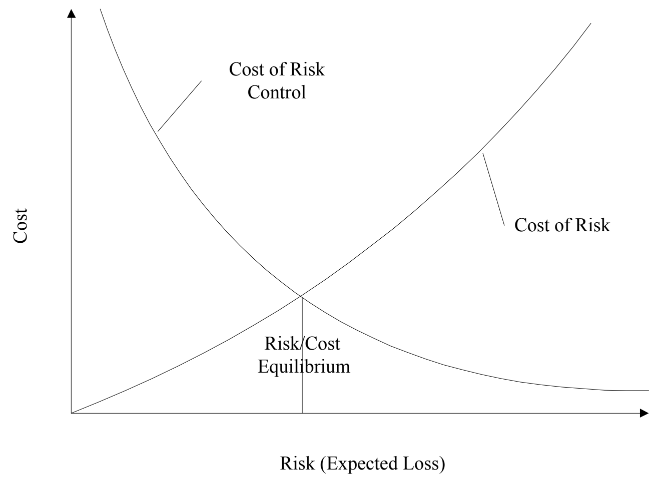
Risk Management and Control (cont'd)

Risk Benefit for Three Alternatives



Risk Management and Control (cont'd)

Comparison of Risk and Control Costs



Risk Management and Control (cont'd)

- Risk Mitigation
  - Four primary ways are available to deal with risk within the context of a risk management strategy as follows:
    - Risk reduction or elimination,
    - Risk transfer, e.g., to a contractor or an insurance company,
    - Risk avoidance, and
    - Risk absorbance or pooling.

Risk Management and Control (cont'd)

- Risk Mitigation (cont'd)
  - *Risk reduction or elimination* is often the most fruitful approach. For example, could the design of a system be amended so as to reduce or eliminate either the probability of occurrence of a particular risk event or the adverse consequences if they occur?
  - *Risk transfer.* A general principle of an effective risk management strategy is that commercial risks in projects and other business ventures should be borne where-ever possible by the party that is best able

Risk Management and Control (cont'd)

- Risk Mitigation (cont'd)

  to manage them and thus mitigate the risks. Most often, contracts and financial agreements are used to *transfer* risks.
  - *Risk Avoidance.* A most intuitive way of avoiding a risk is not to undertake a project in a such a way that involves that risk.
  - *Risk absorbance or pooling*. Cases where risks cannot (economically) be eliminated, transferred, or avoided, they must be absorbed if the project is to proceed.

Risk Communication

"Risk = Hazard + Outrage"

Peter M. Sandman

Risk Communication

Risk Communication (cont'd)

- Components of Risk Communication
- A Formula for Effective Risk Communication, Part I

Until the end of the seventies, it was assumed that once a risk management decision was made it was a matter of public education to inform the public of the final decision. If the decision were made logically, the public would understand and accept it. Numerous unfinished projects, significant problems in siting industrial plants and repeated inability to convince the public have demonstrated that **risk communication is a distinct and important part of risk analysis**. It requires the same level of understanding and research as the other segments of risk analysis.

Risk Communication (cont'd)

- Components of Risk Communication

The Message
The Source (of the message)
The Channel
The Recipient

Risk Communication (cont'd)

- The Message
  - There is overwhelming evidence that the general public has difficulty in comprehending information expressed in probabilities and that a risk is often considered a reality.
  - The public has significant problems in understanding scientific language.
  - Discussions of legitimate uncertainties by the scientific community are often considered as a sign of disagreement.
- The Source
  - The public trust in social institutions has been eroded.
  - Risk information originating from the government and industry is often considered biased and thus is mistrusted.
  - The scientific community has had an extremely limited role in providing relevant information to the public.
  - Most scientific (including engineering professional) societies have chosen not to participate in the debate on the risk of various technologies.
  - Congress and the media have taken insufficient advantage of the availability of professional societies which constitute a reliable and often inexpensive resource.

Risk Communication (cont'd)

- The Channel
  - The news media is the channel for the dissemination of risk information to the public.
  - The news media makes its own independent judgment on what is newsworthy and how it is to be covered.
  - One of the major reasons for the emergence of advocacy organizations as a trustworthy source-of information was that they were considered newsworthy and, after some initial mistakes, they learned how to deal with the news media.
  - The news media can be bypassed by direct contact with the affected community. However, direct contact with a large community is laborious and expensive.

Risk Communication (cont'd)

- The Recipient
  - Even if the message is properly prepared, the public trusts the messenger, and the news media chooses the technically correct message and messengers, the recipient of the risk message may misconstrue it.
  - Contradiction among messages the public has received.

Risk Communication (cont'd)

- The USACE has a 1992 Engineering Pamphlet (EP) on risk communication (EP 1110-2-8). The following are guiding considerations in communicating risk:
  – Risk communication must be free of jargon,
  – Consensus of expert needs to be established,
  – Materials cited, and their sources must be credible,
  – Materials must be tailored to audience,

Risk Communication (cont'd)

  – The information must be personalized to the extent possible,
  – Motivation discussion should stress a positive approach and the likelihood of success, and
  – Risk data must be presented in a meaningful manner.

Homework Assignment #2

Problems:
2.2
2.7
2.9
2.13