Oil and Gas Pipeline Design, Maintenance and Repair

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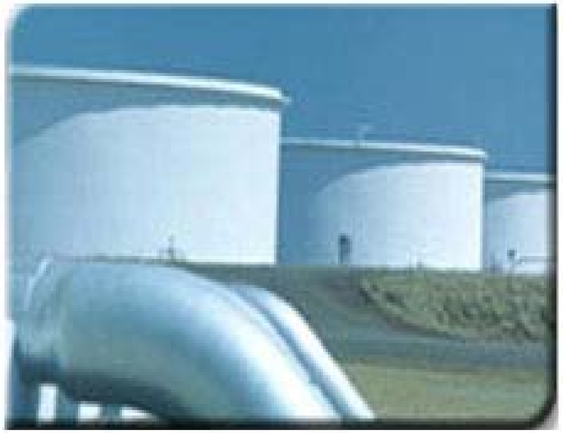
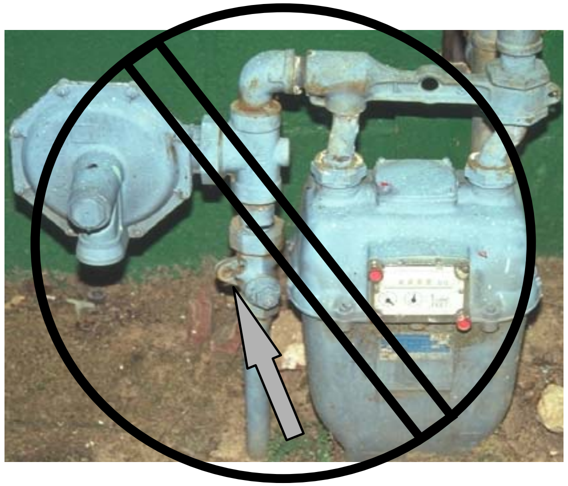
Part 13: Pipeline Risk Assessment

Contents

Hazards Associated





Introduction

- The ability to predict pipeline failures-where and when the next is to occur-would obviously be a great advantage in reducing risk.
- This is not possible except in extreme cases
- Modern risk assessment methodologies provide a surrogate for such predictions.
- Risk efforts are NOT attempts to predict how many failures will occur or where the next failure will occur.
- Efforts are designed to capture and use information to make better decisions.

Formal versus Informal Risk Management

- Risk management has always been practiced by these pipeline operators
- Every time a decision is made to spend resources in a certain way, a risk management decision has been made
- An informal approach to risk management can have the further advantages of being simple, easy to comprehend and to communicate, and the product of expert engineering consensus built upon solid experience

Historical (Informal) Risk Management

Has pluses and minuses

- Simple/intuitive
- Consensus is often sought
- Utilizes experience and engineering judgment
- Somewhat successful, based upon pipeline safety record

Reasons to change:

- More at stake from mistakes
- Inefficiencies/subjectivities inherent in informal systems
- Lack of consistency and continuity in a changing workforce unless decision-support systems are in place
- Need to better consider complicated risk factors and their interactions

Beginning the Risk Modeling Process

Successful risk assessment modeling involves :

- Identifying an exhaustive list of contributing factors versus choosing the critical few to incorporate in a model (complex versus simple)
- "Hard" data and engineering judgment (how to incorporate widely held beliefs that do not have supporting statistical data)
- Uncertainty versus statistics (how much reliance to place on the predictive power of limited data)
- Flexibility versus situation-specific model (ability to use same model for a variety of products, geographical locations, facility types, etc.)

Definition

Risk= Probability x Consequence)

= Likelihood x Severity

Questions to Pipeline Operator

- What data do you have?
- What is your confidence in the predictive value of those data?
- What are the resource demands (and availability) in terms of costs, man-hours, and time to set up and maintain a risk model?
- What benefits do you expect to accrue, in terms of cost savings, reduced regulatory burdens, improved public support, and operational efficiency?

Choices in Risk Assessment Techniques

- The goal is to quantify the risks in either a relative or an absolute sense
- Risk assessment phase is the critical first step in practicing risk management
- No one can definitively state where or when an accidental pipeline failure will occur.
- More likely failure mechanisms, locations, and frequencies can be estimated in order to focus risk efforts.
- There is no universally accepted way to assess risks from a pipeline
- Three general categories of more formal pipeline risk assessment models can be found in use today

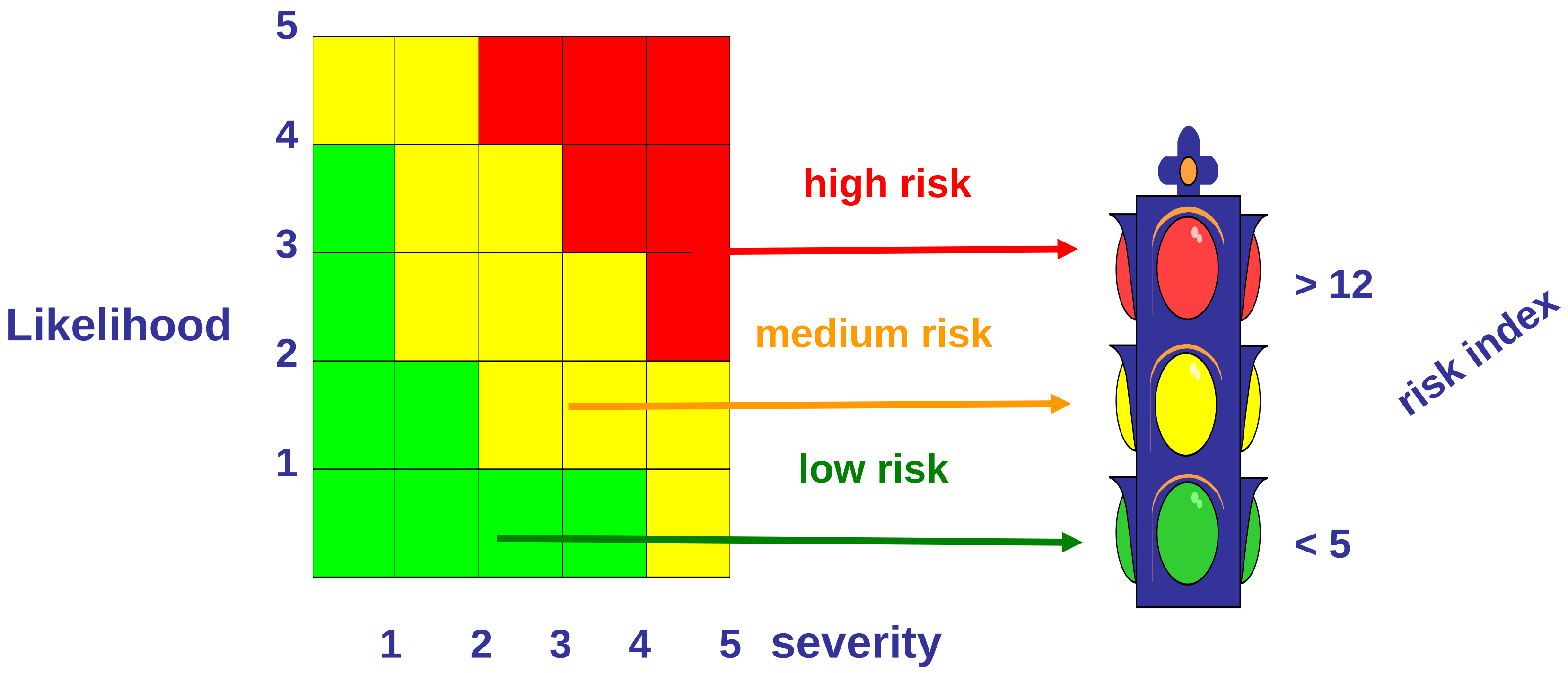
Three General Categories

1. **Simple decision support: Matrix models**
2. **The rigorous approach: Probabilistic/mechanistic models**
3. **The hybrid approach: Indexing models**

Simple Decision Support: Matrix Models

- Ranks risks according to the likelihood and potential consequences of an event by a simple scale, such as high, medium, and low
- Events with both a high likelihood and a high consequence appear higher on the resulting prioritized list
- This approach may be as simple as using an expert's opinion or as complicated as using quantitative data to rank risks

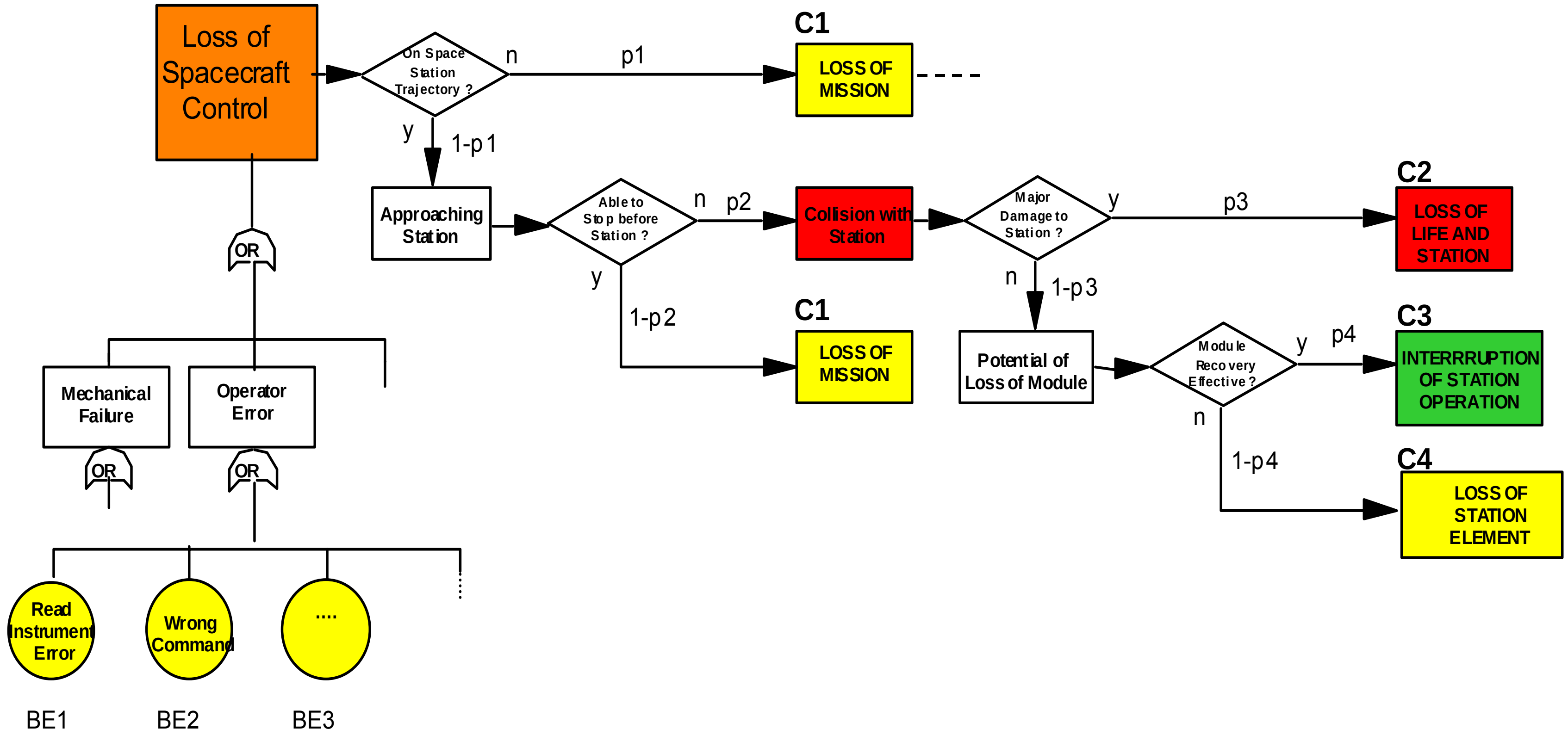
Risk Matrix


5
4
3
2
1
Likelihood
high risk
medium risk
low risk
> 12
< 5
risk index
1 2 3 4 5 severity

Probabilistic/Mechanistic Models

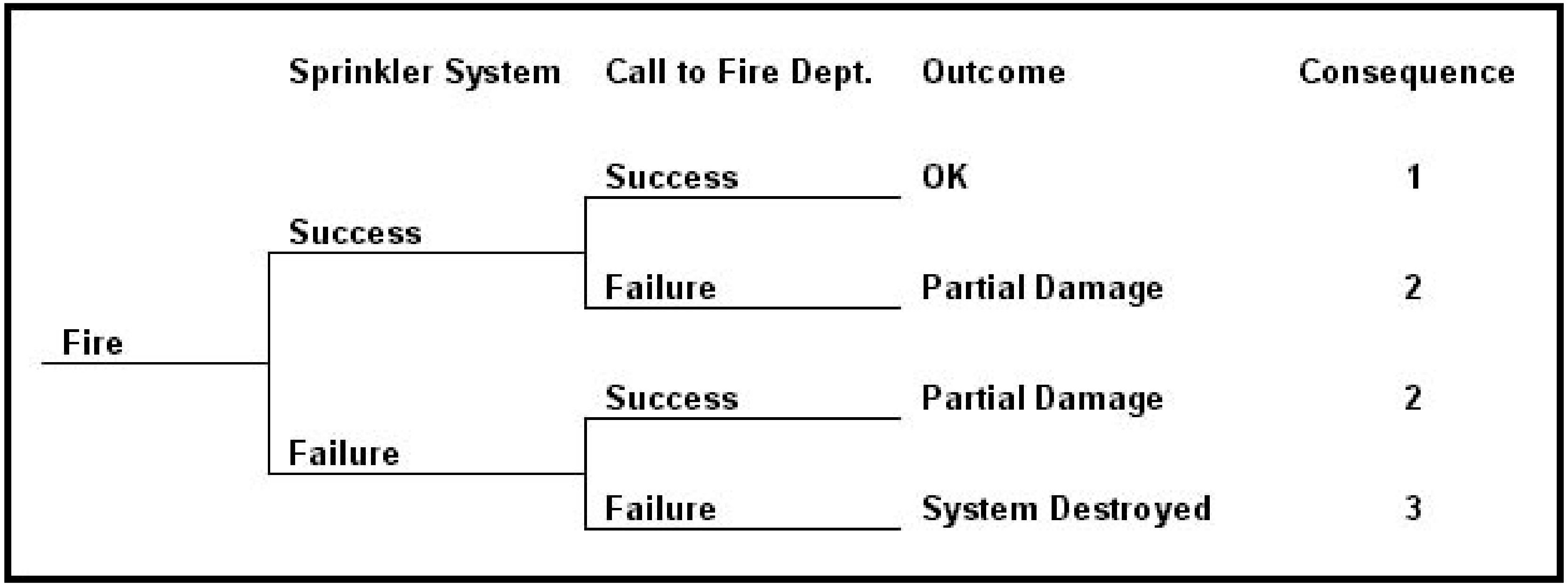
- The more rigorous and complex risk assessment is often called a Probabilistic Risk Assessment (PRA)
- Refers to a technique employed in the nuclear and aerospace industries
- Uses event trees and fault trees to model every aspect of a system
- Initiating events are flowcharted forward to all possible concluding events, with probabilities being assigned to each branch along the way
- Failures are backward flowcharted to all possible initiating events, again with probabilities assigned to all branches
- Relies on historical failure rate data. It yields absolute risk assessments for all possible failure events

Fault Tree

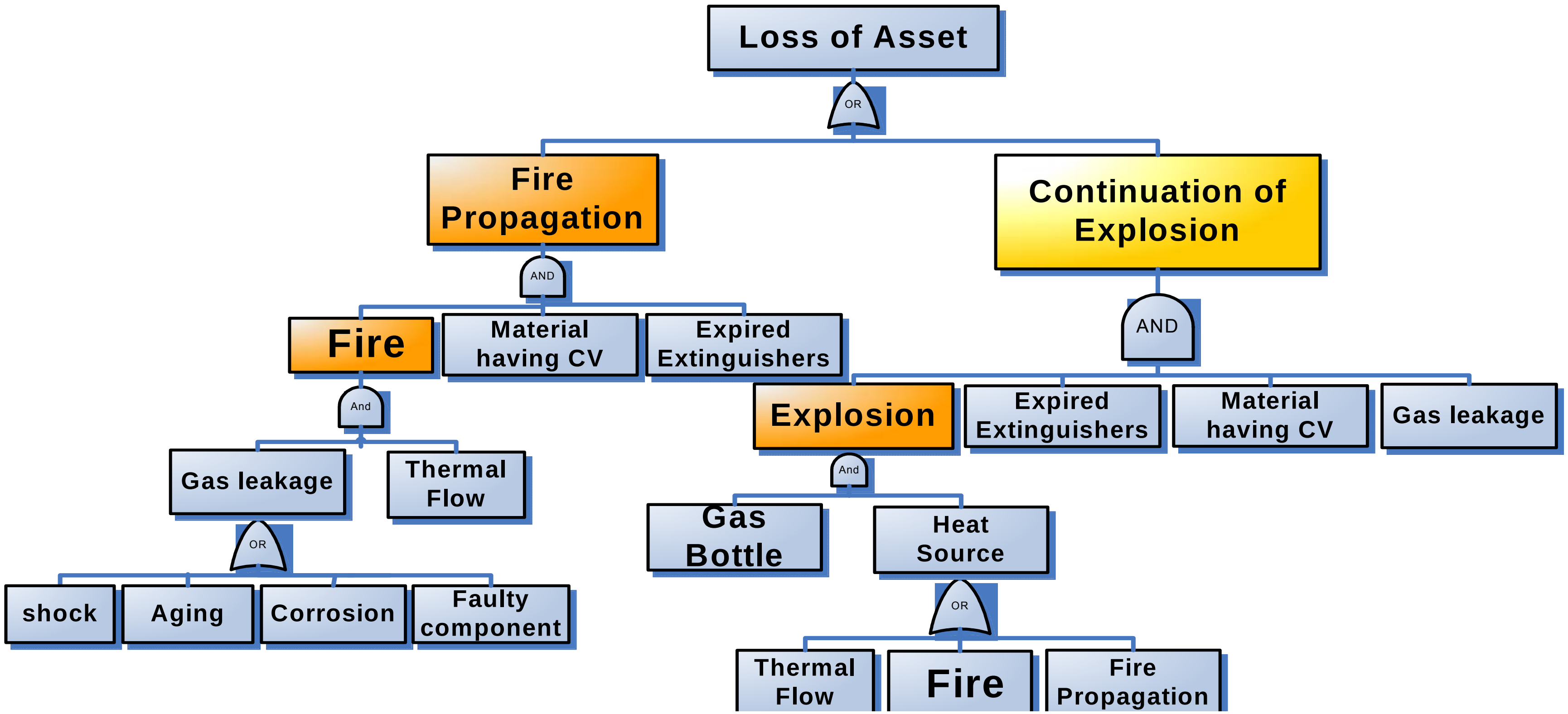


Loss of Spacecraft Control
On Space Station Trajectory ?
n
p1
C1
LOSS OF MISSION
y
1-p1
Approaching Station
Able to Stop before Station ?
n
p2
Collision with Station
Major Damage to Station ?
y
p3
C2
LOSS OF LIFE AND STATION
y
1-p2
C1
LOSS OF MISSION
n
1-p3
Potential of Loss of Module
Module Recovery Effective ?
y
p4
C3
INTERRRUPTION OF STATION OPERATION
n
1-p4
C4
LOSS OF STATION ELEMENT
OR
Mechanical Failure
Operator Error
OR
OR
Read Instrument Error
Wrong Command
....
BE1
BE2
BE3

Event Tree


Sprinkler System
Call to Fire Dept.
Outcome
Consequence
Fire
Success
Failure
Success
OK
1
Failure
Partial Damage
2
Success
Partial Damage
2
Failure
System Destroyed
3

Fault Tree



Loss of Asset
OR
Fire Propagation
Continuation of Explosion
AND
Fire
Material having CV
Expired Extinguishers
AND
And
Explosion
Expired Extinguishers
Material having CV
Gas leakage
Gas leakage
Thermal Flow
And
OR
Gas Bottle
Heat Source
shock
Aging
Corrosion
Faulty component
OR
Thermal Flow
Fire
Fire Propagation

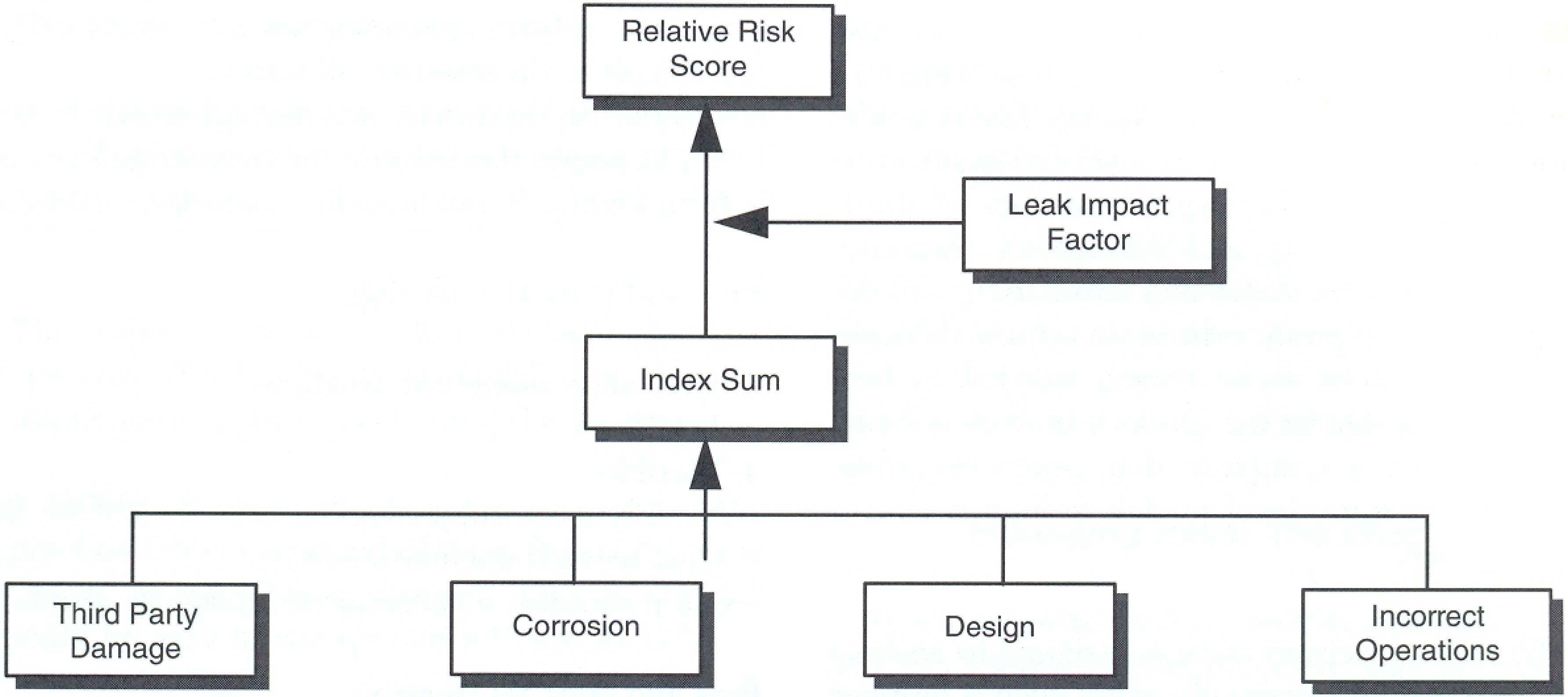
Indexing Models

- Most popular pipeline risk assessment technique
- A relative weight is assigned to every important condition and activity on the pipeline
- This includes both risk-reducing and risk-increas-ing items
- This relative weight reflects the importance of the item in the risk assessment
- The risk component scores are subsequently summed for each pipeline section to obtain a relative risk ranking of all pipe sections
- The various pipe segments may then be ranked according to their relative risk scores in order to prioritize repairs and inspections

Indexing Models

- Among pipeline operators today, this technique is widely used and ranges from a very simple 5-20 factor model
- Models with hundreds of factors considering virtually every item that impacts risk
- When an indexing model is created from probabilistic approach-using scenarios, event/fault trees, and all available historical data-this approach is often a solution with the best cost-benefit ratio

Typical Pipeline Risk Model Structure



Other Issues in Risk Modeling

- **Absolute versus relative risk**
- **Quantitative versus qualitative models**
- **Subjectivity versus objectivity**
- **The use of unquantifiable evidence**
- **Uncertainty**

Choosing a Risk-Assessment Technique

- Any or all of the previously described techniques might have a place in risk assessment/management.
- The choice may well be dependent on the situation.
- Understanding the strengths and weaknesses of the different risk assessment methodologies gives the user the basis for choosing one
- A case can be made for using each in certain situations
- For example, a simple matrix approach crystallizes thinking and is a step above informal risk assessment

Pros and Cons (Matrix)

+ Improvement over informal techniques
+ Forces more logical examination of situation
+ Inexpensive approach
- Limited number of risk factors (not comprehensive)
- Subjective

Pros and Cons (PRA)

+ Rigorous, scientific approach
+ Accepted in other industries
+ Uses all available information
- Costly
- Difficult to do resource allocation
- Difficult to do overall risk management
- Might create the "illusion of knowledge"
- Intimidating to non-technical audience

Pros and Cons (Indexing)

+ Uses all available information + Intuitive
+ Flexible
- Possibly more subjective
- Must be well documented
- Often requires a subsequent linkage to absolute values

Application Choices (Matrix)

- Better quantify a belief
- Create a simple decision support tool
- Combine several beliefs into a single solution
- Document choices in resource allocation

Application Choices (PRA)

- Better quantify a belief
- Create a simple decision support tool
- Combine several beliefs into a single solution
- Document choices in resource allocation

Application Choices (Indexing)

- Obtain an inexpensive overall risk model
- Create a resource allocation model
- Model the interaction of many potential failure mechanisms
- Study or create an operating discipline

The Ideal Risk Assessment Model

Includes the following:

- Costs
- Learning ability
- Signal-to-noise ratio
- Managing Risks: The Cost Connection

Sample Risk Variable List

- Relative Risk = [Index Sum]/[Leak Impact Factor]
- Index Sum = [Third Party] + [Corrosion] + [Design] + [Incorrect Operation]

Third Party Damage Potential

A	Minimum depth cover	20%	0-20 pts
8	Activity level	20%	0-20 pts
C	Above-ground facilities	10%	0-10 pts
D	One-call system	15%	0-15 pts
E	Public education	15%	0-15 pts
F	Right-of-way condition	5%	0-5 pts
G	Patrol	15%	0-15 pts
		100%	100 pts

Corrosion Potential

A. Atmospheric corrosion 0-10 pts

A1	**Atmospheric corrosion**	**0-5 pts**
A2	**Atmospheric type**	**0-2 pts**
A3	**Atmospheric coating**	**0-3 pts**

Corrosion Potential

B. Internal corrosion 0-20 pts

B1	**Product corrosively**	**0-10 pts**
B2	**Internal protection**	**0-10 pts**

Corrosion Potential

C. Subsurface corrosion 0-70 pts

C1	Subsurface environment		0-20 pts
	Soil corrosivity	0-15 pts	
	Mechanical	0-5 pts	
	corrosion		
C2	Cathodic protection		0-25 pts
	Effectiveness	0-15 pts	
	Interference potential	0-10 pts	
C3	Coating		0-25 pts
	Fitness	0-10 pts	
	Condition	0-15 pts	
			70 pts

Design Risk

A	Safety factor	35%	0-35 pts
B	Fatigue	15%	0-15 pts
C	Surge potential	10%	0-10 pts
D	Integrity verification	25%	0-25 pts
E	Land movements	15%	0-15 pts
		100%	0-100 pts

Design Risk

A	Design	30%	0-30 pts
	Hazard identification		0-4 pts
	MAOP potential		0-12 pts
	Safety systems		0-10 pts
	Material selection		0-2 pts
	Checks		0-2 pts
B	Construction	20%	0-20 pts
	Inspection		0-10 pts
	Materials		0-2 pts
	Joining		0-2 pts
	Backfill		0-2 pts
	Handling		0-2 pts
	Coating		0-2 pts

Design Risk

C	Operation	35%	0-35 pts
	Procedures		0-7 pts
	SCADA/ communications		0-3 pts
	Drug testing		0-2 pts
	Safety programs		0-2 pts
	Surveys/maps/ records		0-5 pts
	Training		0-10 pts
	Mechanical error preventers		0-6 pts
D	Maintenance	15%	0-15 pts
	Documentation		0-2 pts
	Schedule		0-3 pts
	Procedures		0-10 pts
		100%	0-100 pts

Leak Impact Factor

- Leak Impact Factor = (Product Hazard) x (Receptors) x (Spill Size) x (Dispersion)

Leak Impact Factor

A: Product hazard

I. (Acute + chronic hazards)

Acute hazards

a.	Nf	0-4
b.	Nr	0-4
c.	Nh	0-4
Total (Nh+Nr+Nf)		0-12
2.	Chronic hazard, RQ	0-1
B	Receptors	0-1
	Population	
	Environment	
	High value areas	
C	Spill size	0-1
D	Dispersion	0-1

Summary

- The move to more formal risk techniques is intended to increase operational consistency and credibility, especially when such techniques are offered for public viewing.
- Risk management has long been recognized as a valuable effort in pipeline operations
- Risk assessment approaches are available to serve many needs

References

1. Muhlbauer, W. Kent: Pipeline Risk Management Manual, 3rd ed., Gulf Publishing Co., Houston (2004).
2. McAllister, E.W. :Pipeline Rules of Thumb Handbook, Elsevier Inc., Printed in USA, 2005