Risk management and safety

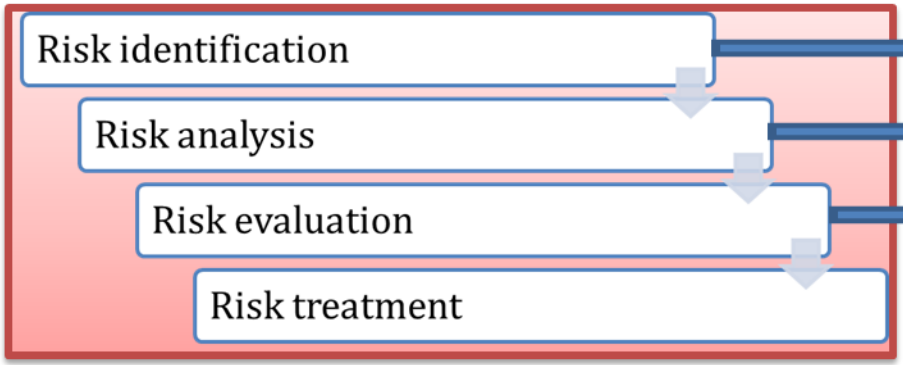
Torbjörn Ylipää
torbjorn.ylipaa@chalmers.se
0721-87 91 26

LEARNING OBJECTIVE

After this lecture, the students should be able to:

LO1: Describe and apply risk and safety concepts and use engineering tools to analyze, evaluate, and reduce risks

Risk Management Methodology and Tools



- What-if
- Hazop
- FMEA

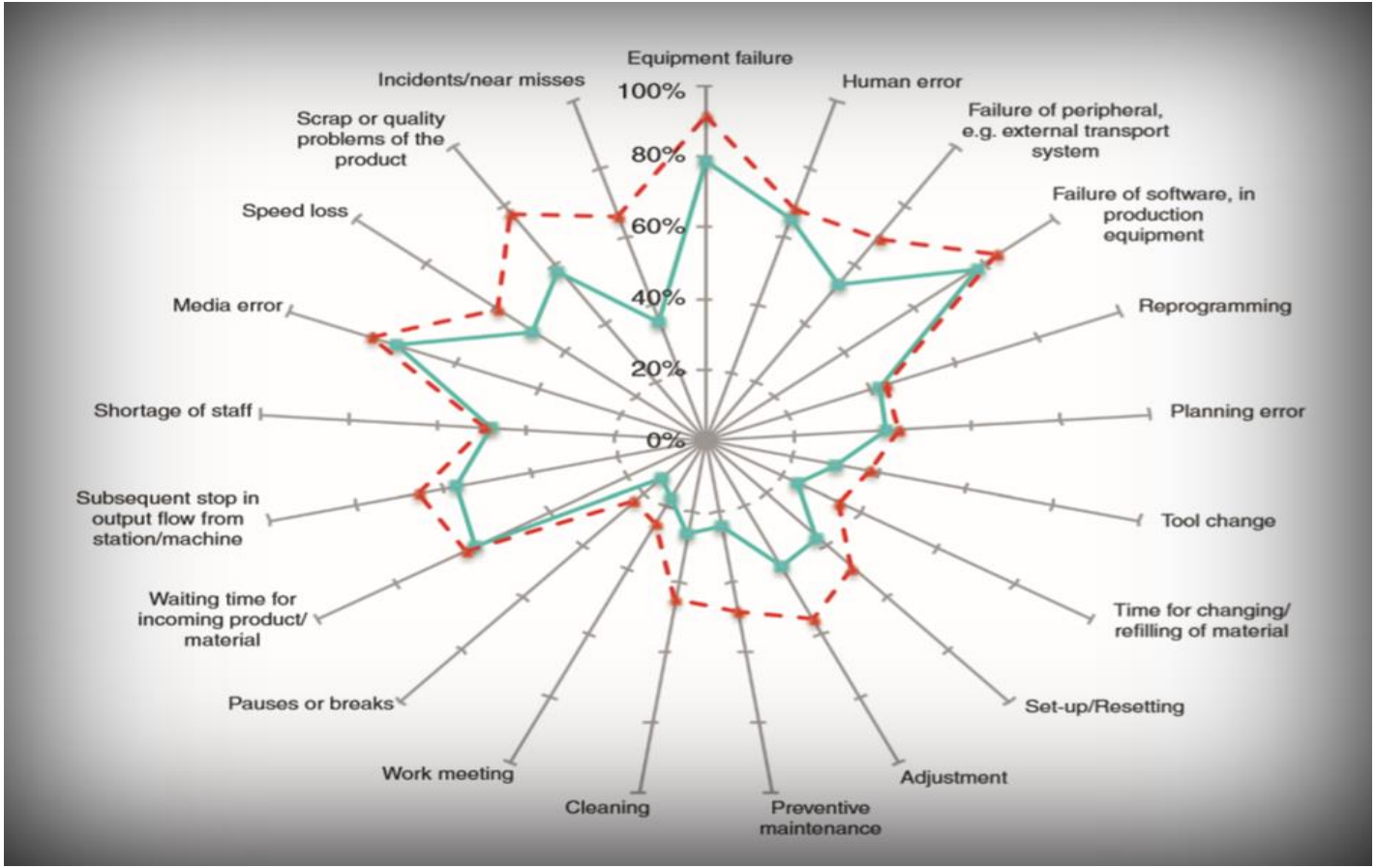
- ✓ Risk Marix
- ✓ FMECA

- ➢ Fault Tree Analysis (FTA)
- ➢ Event Tree Analysis (ETA)

D3H
Data-Driven Disturbance Handling

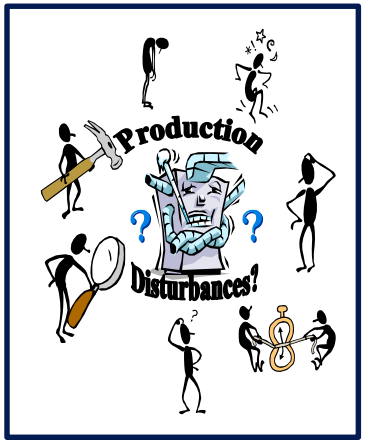
Production distrubances in SME’s

What is a production disturbance?



Jon Bokrantz, Anders Skoogh, Torbjörn Ylipää, Johan Stahre (2016)

Produktion Disturbances

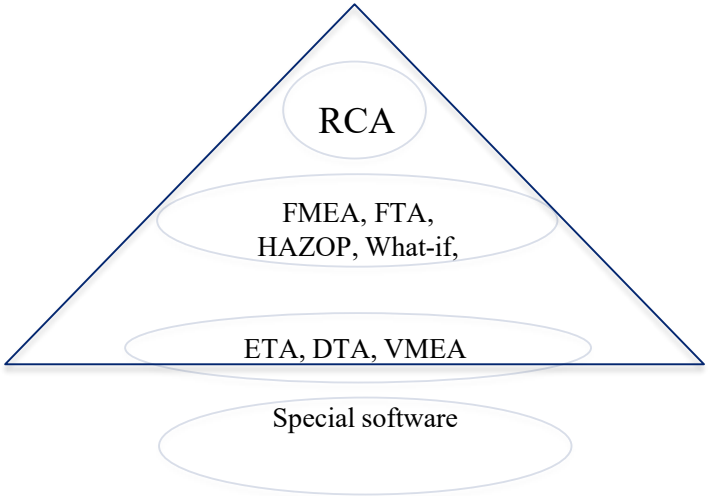


Affects

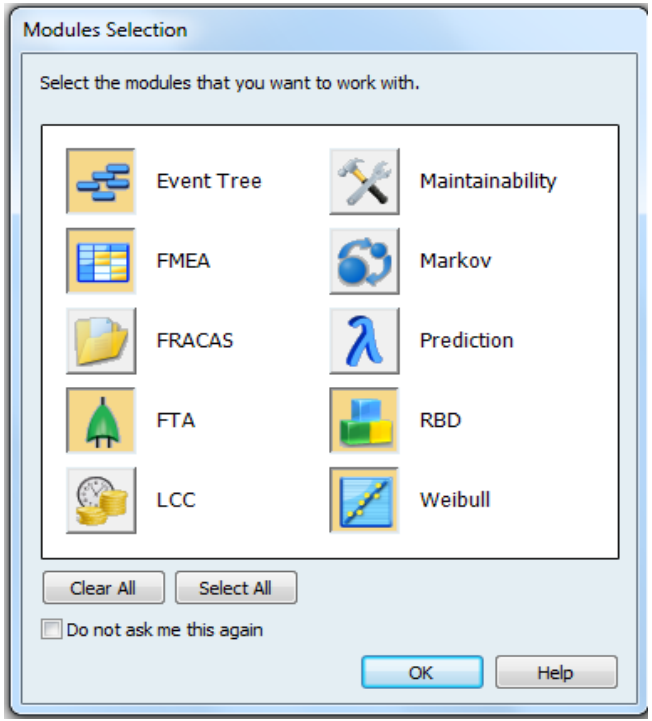
Several different factors

- Revenues
- Costs
- Productivity
- Product Quality
- Safety
- Environment
- Ergonomics
  - Psychosocial
  - Physical

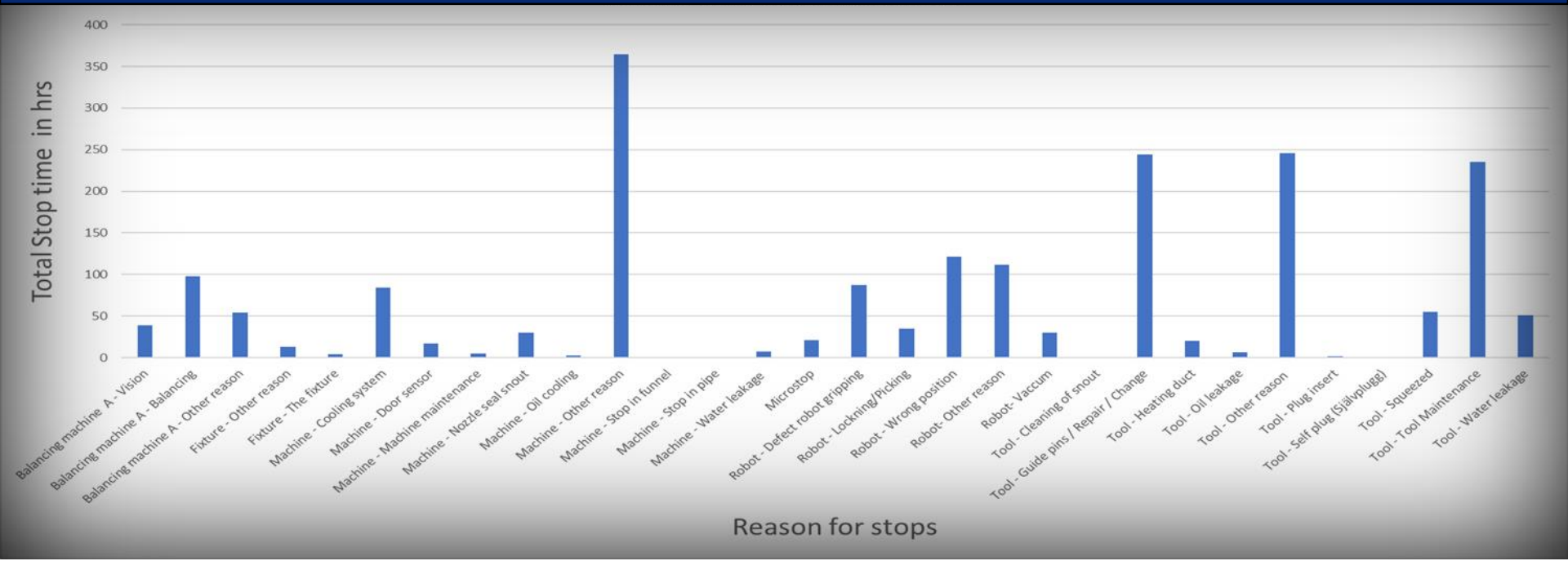
Engineering tools and software



Windchill Risk and Reliability - WRR



Why D3H tools?

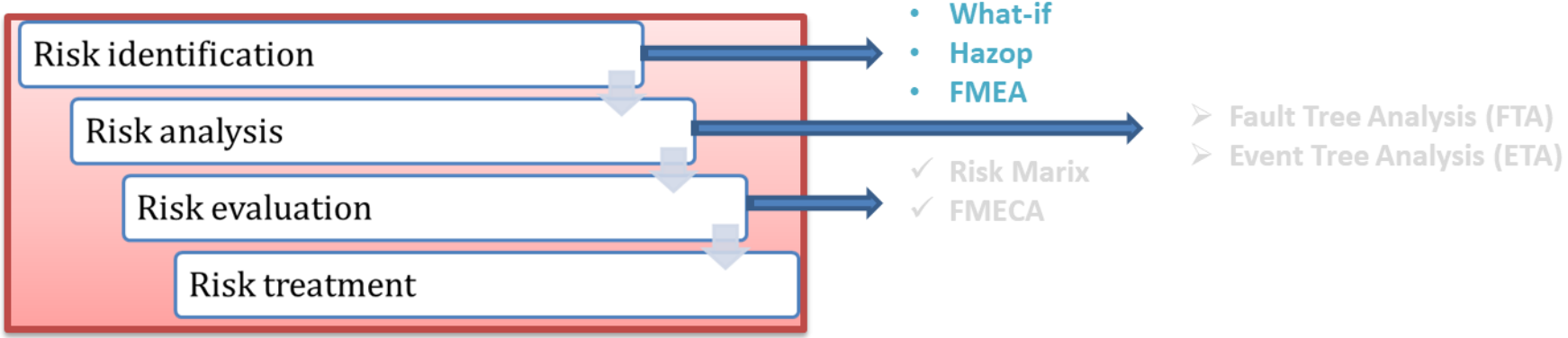

Total Stop time in hrs
400
350
300
250
200
150
100
50
0
Balancing machine A - Vision
Balancing machine A - Balancing
Balancing machine A - Other reason
Fixture - Other reason
Fixture - The fixture
Machine - Cooling system
Machine - Door sensor
Machine - Machine maintenance
Machine - Nozzle seal snout
Machine - Oil cooling
Machine - Other reason
Machine - Stop in funnel
Machine - Stop in pipe
Machine - Water leakage
Microstop
Robot - Defect robot gripping
Robot - Lockning/Picking
Robot - Wrong position
Robot- Other reason
Robot- Vaccum
Tool - Cleaning of snout
Tool - Guide pins / Repair / Change
Tool - Heating duct
Tool - Oil leakage
Tool - Other reason
Tool - Plug insert
Tool - Self plug (Självplugg)
Tool - Squeezed
Tool - Tool Maintenance
Tool - Water leakage
Reason for stops

Sum of Total Stop time in Hours	Column Labels				
Downtime Reasons	Afternoon	Morning	Night	Weekend Overtime	Grand Total
Machine Failure	794.48	1077.02	772.64	448.95	3093.09
Material Shortage	887.98	1328.62	853.43	148.34	3218.37
Set Up	1037.02	1380.63	897.31	547.35	3862.31
Uncategorized	351.9	475.99	335.39	1567.18	2730.46
Work Around	885.21	1041.68	948.22	580.65	3455.76
Grand Total	**3956.59**	**5303.94**	**3807**	**3292.47**	**16359.99**

Top 5 disturbances shift wise

- Machine failure is more in morning shift by 300 hours. Reason could be attributed to cold start or start-up losses.
- Material shortage downtime is higher in 1st shift by 400 hours possibly due to higher buffer consumption in night shift and improper planning due to lack of supervision.

Risk Management Methodology and Tools



Hazard/Risk Identification

- What-if
- HAZOP Study
- FMEA

What-If Analysis

- What-If Analysis is based on creative, brainstorming for examination of a process or operation
- It should be performed by a team, if the process is complex
- It is a powerful hazard identification technique if the analysis staff is Experienced
- The result of a what-if analysis usually address potential accident situations implied by the questions and issues posed by the team.
- These questions and issues often suggest specific causes for the identified accident situations.

An example:

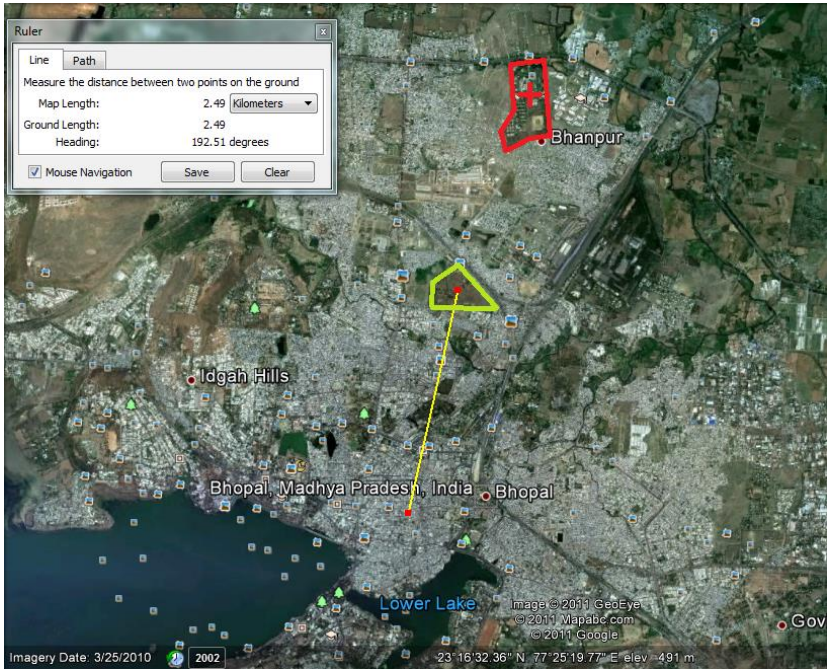
”*What if the container is contaminated by another material*”
Consequences*: Quality problem, reaction which may cause corrosion, or a chemical runaway,…*
recommendation*: Check up the container before loading*

BHOPAL, INDIA

- Union Carbide India Ltd.
- Pesticide plant, 1970

Accident:

- 3.12.1984, 02:30
- MIC gas leak
- 4 000 dead
- 500 000 injured



What-If analysis worksheet

Study area:	Meeting date:
Team members:	Page number:

What-If	Consequence/Hazard	recommendation

Hazard & Operability Study (HAZOP)

What is HAZOP?

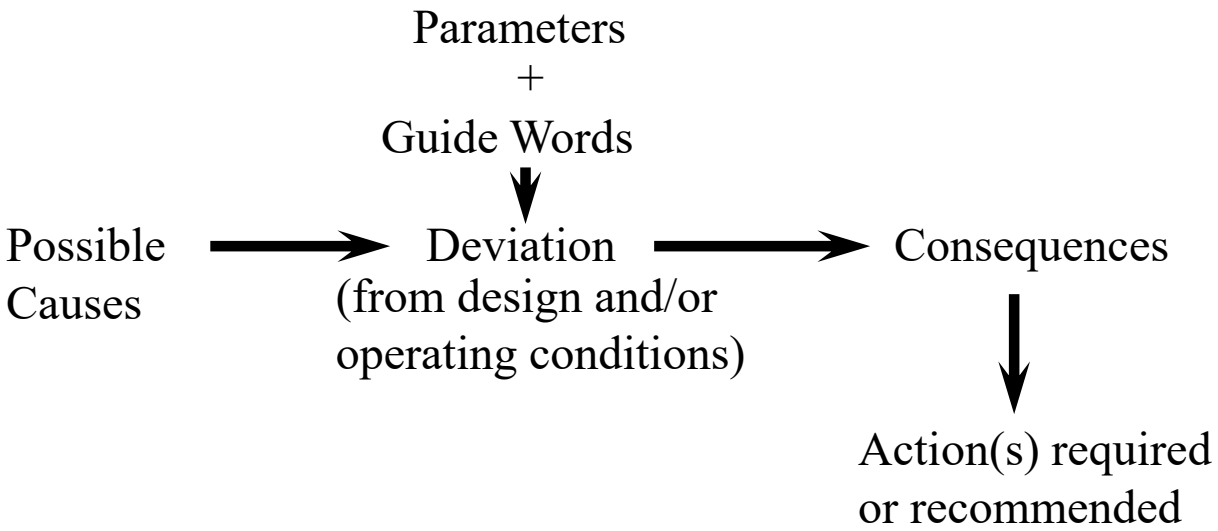
It is a ***systematic method*** for identifying :

- potential hazards
- operability deviations within the system

and

specifying the means by which either the probability of their occurrence can be reduced or the consequences of undesirable incidents can be minimised.

Hazard & Operability Study (HAZOP)- Application of the method



Guide Words covering every parameters relevant to the system under review i.e., flow rate, pressure, temperature, etc

HAZOP Study Report Form

Study Area:		Meeting Date:		
Team Members:		Page NO.:		
Guide Words	Deviation	Causes	Consequences	Recommendations

IEC 60812

Edition 3.0 2018-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Failure modes and effects analysis (FMEA and FMECA)

Analyse des modes de défaillance et de leurs effets (AMDE et AMDEC)

AIAG Automotive Industry Action Group & VDA Verband der Automobilindustrie

Failure Mode and Effects Analysis

FMEA Handbook

Design FMEA
Process FMEA
Supplemental FMEA for Monitoring & System Response

1st Edition 2019

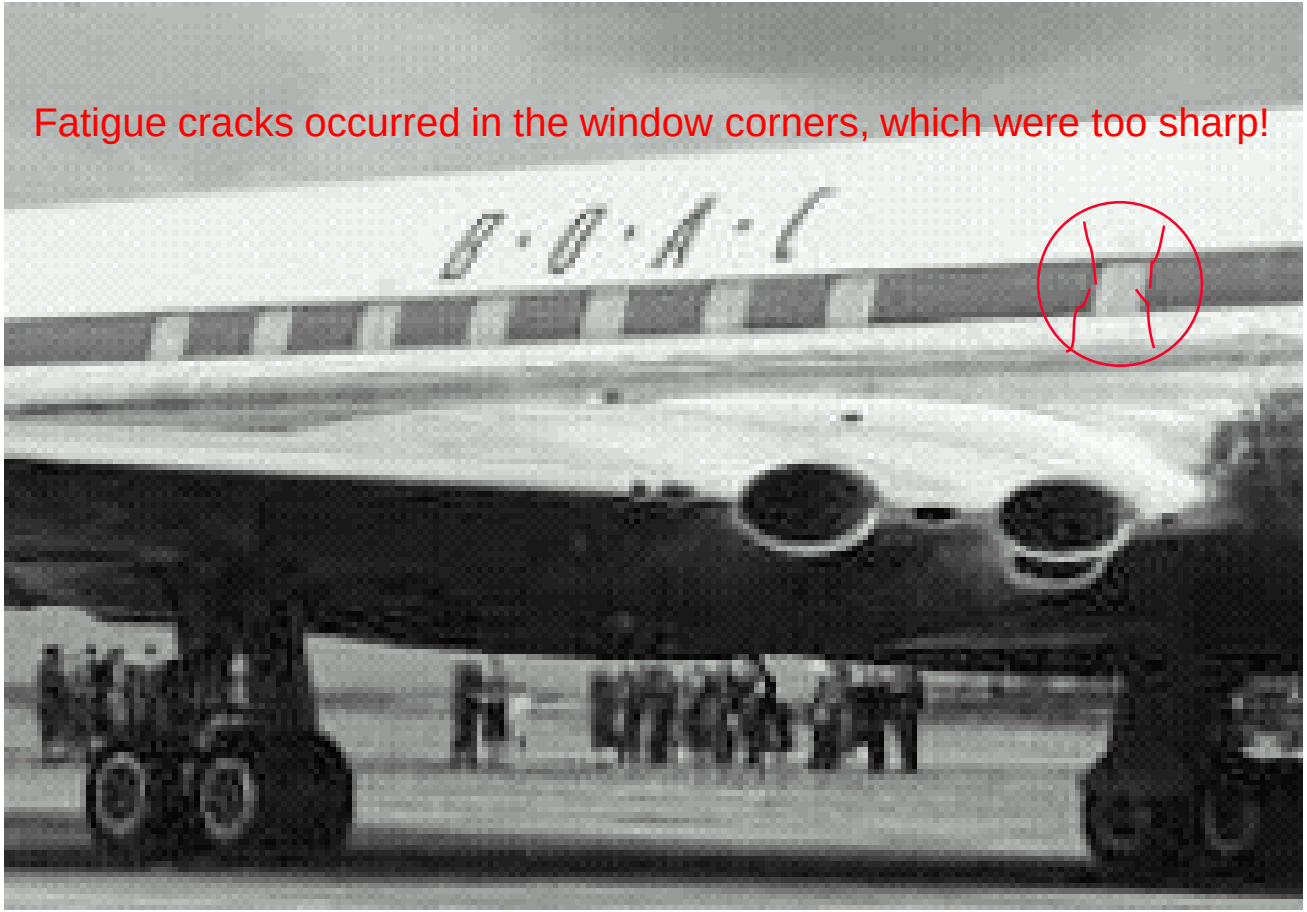
FMEA: Failure Mode and Effect analysis

Failure Mode and Effects Analyses (FMEAs) evaluate the ways a failure can occurre or be improperly operated and the effects these failures can have.
In an FMEA, each individual failure is considered as an independent occurrence with no relation to other failures in the system

In short, FMEAs identify single failure modes that either directly result in or contribute significantly to a production disturbance, an accident, etc.

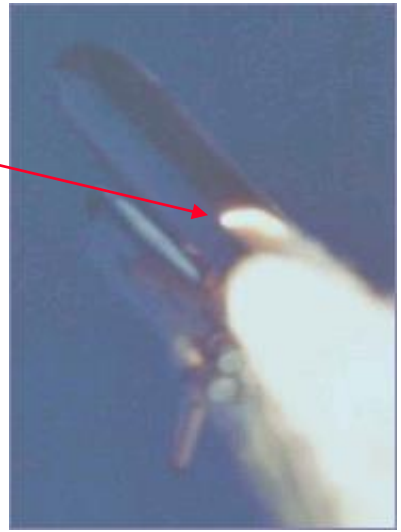
The purpose of FMEA

- Identify and evaluate during the design process, what can go wrong, how, and what the effects of it can be
- Identify the component that directly leads to system failure
- Avoid errors in previous designs repeated
- Search and compare alternative solutions
- Provide a basis for improvement of a product and initiate preventive measures
- Identifying areas where special measures of quality management and maintenance required
- Ensure that product specifications are met
- Detect any deviations from established safety requirments
- Replace the old way of working to find and fix errors ("fire") with the new learning and prevent errors

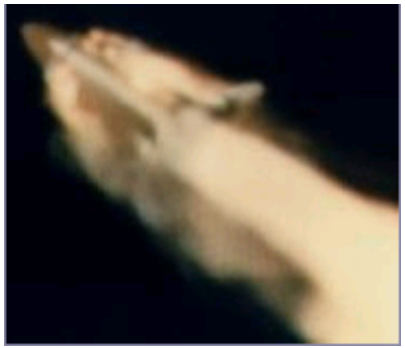

Fatigue cracks occurred in the window corners, which were too sharp!

Space Shuttle Challenger, January 28, 1986

The night before the start was cold, and an O-ring in a of solid fuel rockets were not tightly, i.e. leakage



The ferry starts to fall apart 73 seconds after the start

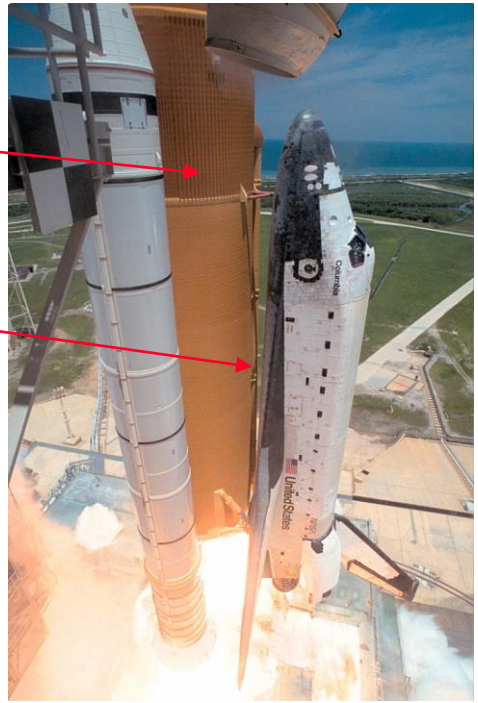


Space Shuttle Columbia, February 1, 2003

Insulated tank for liquid oxygen and hydrogen to the main engines

A piece of insulation fell off the tank during take-off and struck the left wing on the ferry

The ferry broke apart on re-entering the atmosphere before landing



Windchill Risk and Reliability - WRR

Name: Garage Door Opener
Design Responsibility:
Key Date:
Core Team:

FMEA Identifier: FMEA1
Page 1 **of** 1
Prepared By:
FMEA Date (Orig.) **(Rev.)** 2011-11-18

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanisms of Failure	Occur	Current Controls	Detec	R.P.N.	Recommended Actions	Responsibility & Target Completion Date	Action Results					
												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
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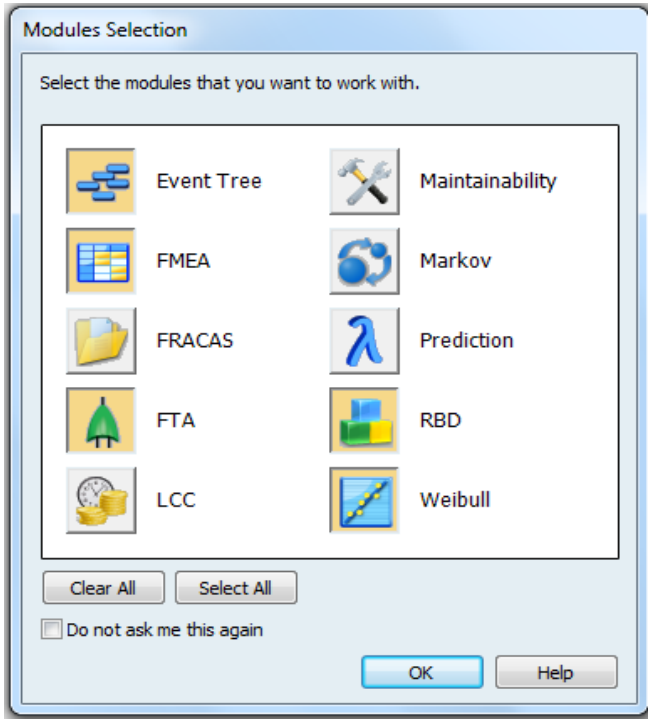

WQS

POTENTIAL FAILURE MODE AND EFFECTS ANALYSIS (DESIGN FMEA)

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																	0,00

(1)

(1) Item / Function, e.g. ”cylinder”, ”shaft” or a ”bearing”. Try to write simply and in plain language so that outsiders understand what is meant

Don´t forgett the prestanda and secondary functions!

Secondary functions - ESCAPES

- Environmental integrity
- Safety / Structural integrity
- Control / Containment / Comfort
- Apperance
- Protection
- Economy/efficiency
- Superflous function

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
	(2)																0,00
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(2) Failure Mode: What can happen that make it a function disturbed or absent? Write down all possible Failure Modes before the next point deals!

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
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(3) Failure Effect: How is the customer affected (or any other) if the failure occur?
Note that the effect may occur long after the failure occurred!

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
																	0,00
																	0,00

(4)

(4) Severity: Enter a factor of 1-10 as a measure of how serious it is (for the customer or someone else) if the failure occurs

Serverity if a failure occurre

Serverity	Consequence	Factor
Effects hardly noticeable	The failure has no impact on product function (The customer is unlikely to notice the error)	1
Failures not important	The failure has little effect on the operation of the product	2-3
Reasonably serious failure	This failure can result in impaired function of the product	4-6
Serious failure	The failure can cause loss of function of the product	7-8
Failure with large negative effects	The failure may cause injury or result in the regulatory requirements not met	9-10

WQS

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
					(5)												0,00
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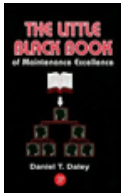
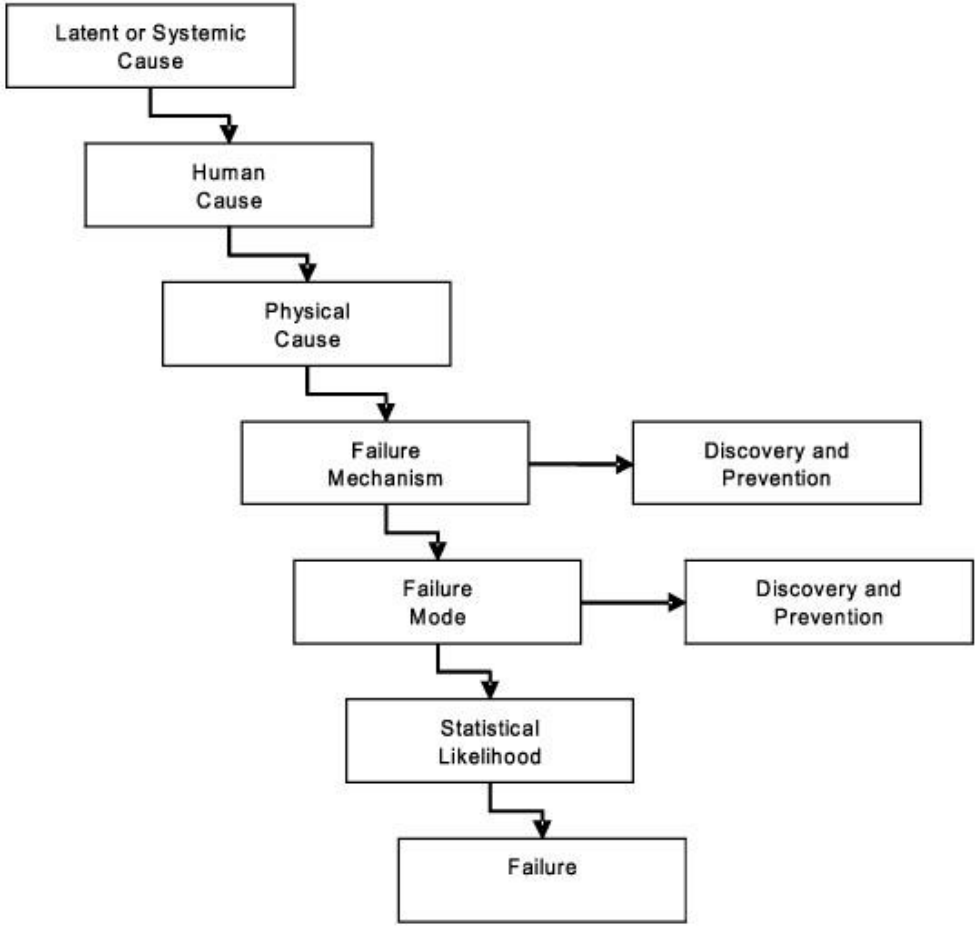
(5) Cause: What reasons are there for the failure occurs?
Discuss and try to understand what should be done!



The Little Black Book of Maintenance Excellence



The value of understanding the Path to Failure is knowing that both the failure mechanism and the defect can be discovered before failure, and that the failure can be prevented. **Wise people also learn from failures, and they identify the three levels of cause in time to take corrective action.**

In order to create Predictive Maintenance tasks, you need to understand the failure mechanisms that "are" at work and those that "can be" at work. That is an important point to emphasize. Many people simply copy the PM tasks recommended by the manufacturer, and then perform them by rote without really understanding why they are doing them.

Predictive Maintenance tasks are intended to:

1. Evaluate failure mechanisms that are known to be at work.
2. Identify failure mechanisms that can be at work.

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
																	0,00
																	0,00

(6)

(6) Occurrence: Enter a factor of 1-10 as a measure of the probability for the Failure to occur

Probability of occurrence

Probability	Frequence	Factor
Very low	1 på 10 000	1
	1 på 5 000	2
Medium low	1 på 2 000	3
	1 på 1 000	4
Medium	1 på 500	5
	1 på 200	6
Medium high	1 på 100	7
	1 på 50	8
High	1 på 20	9
	>1 på 10	10

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
							(7)										0,00

(7) Control: The control / management. Describe existing controls or control to prevent the failure from occurring or to detect it **if** it occurs (e.g. testing). Also describe any improvements to these measures, and indicate when they are inserted

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
								(8)									0,00
																	0,00

(8) Detection: Enter a factor of 1-10 as a measure of the probability for the detection of a fault before the effect reach the customer (or anyone else)

Likelihood of a failure is detected

Probability	Factor
Almost certain that the fault is detected	1
Very likely that the fault is detected	2
It is likely that the fault is detected	3
Moderately high probability that the fault is detected	4
Moderate probability that the fault is detected	5
Low probability that the fault is detected	6
Moderate low probability that the fault is detected	7
Unlikely that the fault is detected	8
Very unlikely that the fault is detected	9
Fault will be passed to customer undetected	10

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
									(9)								0,00
																	0,00

(9) Risk Priority Number = RPN: Calculate the RPN, i.e.

RPN = Sev*Occur*Detec

Risk Priority Number = RPN

RPN is calculated as the product of severity (factor 4), occurrence (factor 6) and detection (factor 8). Since each of the factors in the range of 1-10, we have:

$$1 \leq RPN \leq 1000$$

The RPN is a basis for prioritization. High values indicate where action should be initiated. Low values should also examine whether any of these three factors has a value of nine or ten. This is especially true if the failure probability or severity is high

S	x	O	x	D	=	RPN
10		2		2		40
3		10		2		60
2		5		10		100

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
										(10)							0,00
																	0,00

(10) Recommended actions: What should be done to eliminate the cause of the Failure to occur?

One should therefore ***prevent*** Failures, and not primarily focus on to detect and correct failures that have already occurred!

WQS

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												Actions Taken	Sev	Occ	Det	R.P.N.	RPN Improve. %
												(12)					0,00
																	0,00

(12) Action taken: At the next meeting notice the real measures that have been taken

WQS

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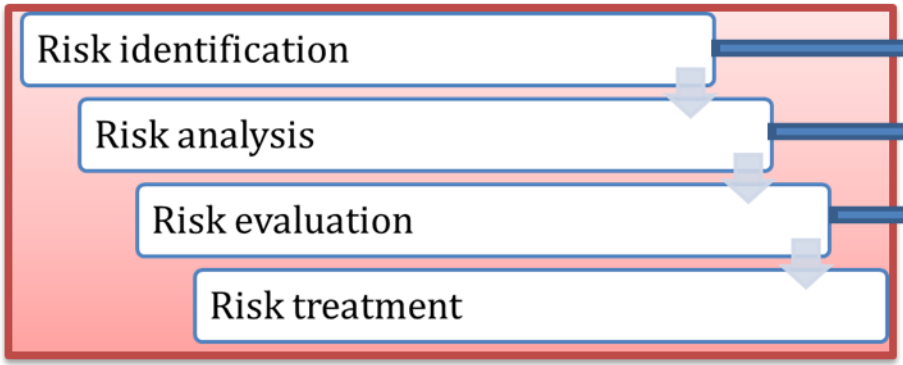
																	0,00
																	0,00

(13)

(13) Results after action: New assessments under paragraphs 4-9 of the result after improvement actions.
If the new RPN is not acceptable you may think about it again and recommend new measures.

What is an acceptable risk?

Risk Management Methodology and Tools



- What-if
- Hazop
- FMEA

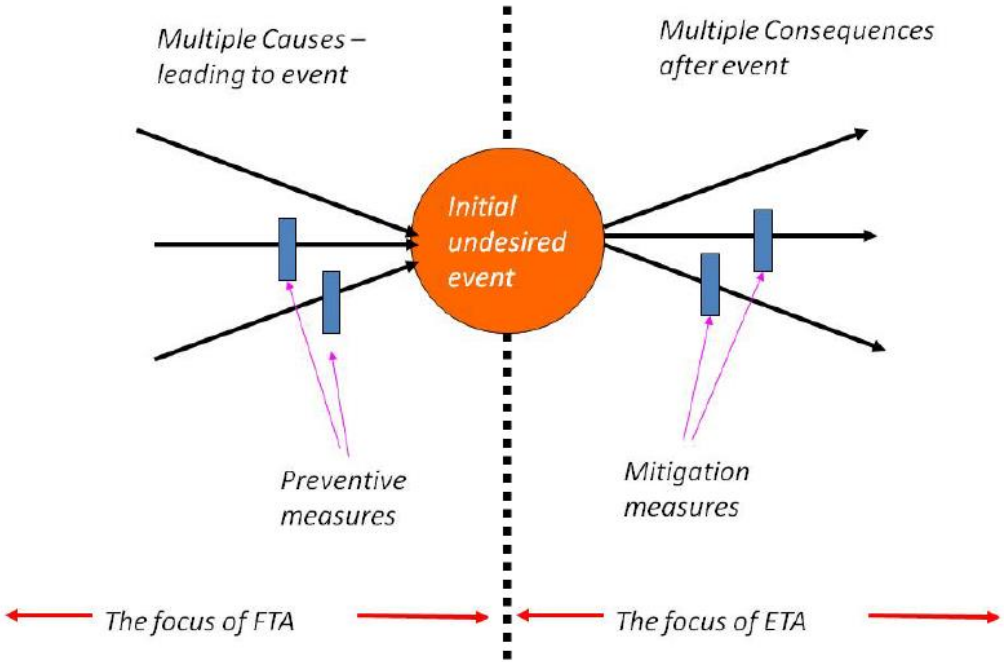
✓ Risk Marix

- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)
- Swiss Cheese Model

Risk Analysis

- Fault Tree Analysis - FTA
- Event Tree Analysis - ETA

Bow-Tie Diagram



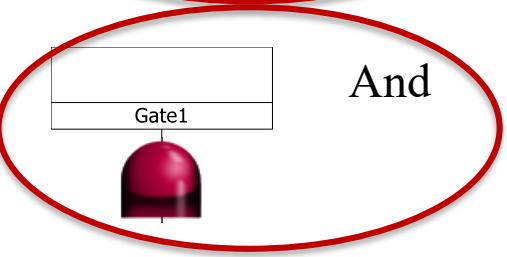
Fault Tree Analysis (FTA)

- Is a graphical and logic technique
- It is a backward method
- Is used for cause analysis of a top event as an output of ”Hazard Identification”
- It can be used for calculation of frequency of an incident

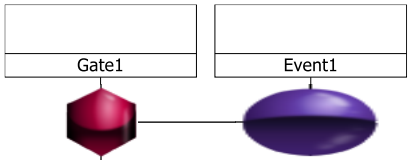
Main FTA Symbols

Gate Symbols

OR

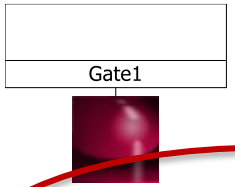


And

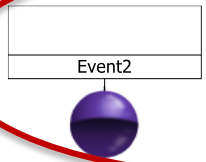


INHIBIT
Output fault
Occurs if single
Input fault occurs

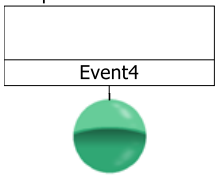
Event Symbols



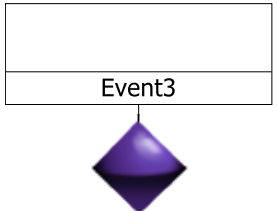
Intermediate Event



Basic Event

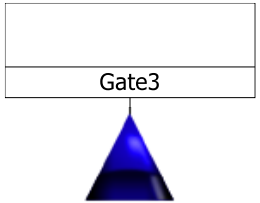


Repeted Event

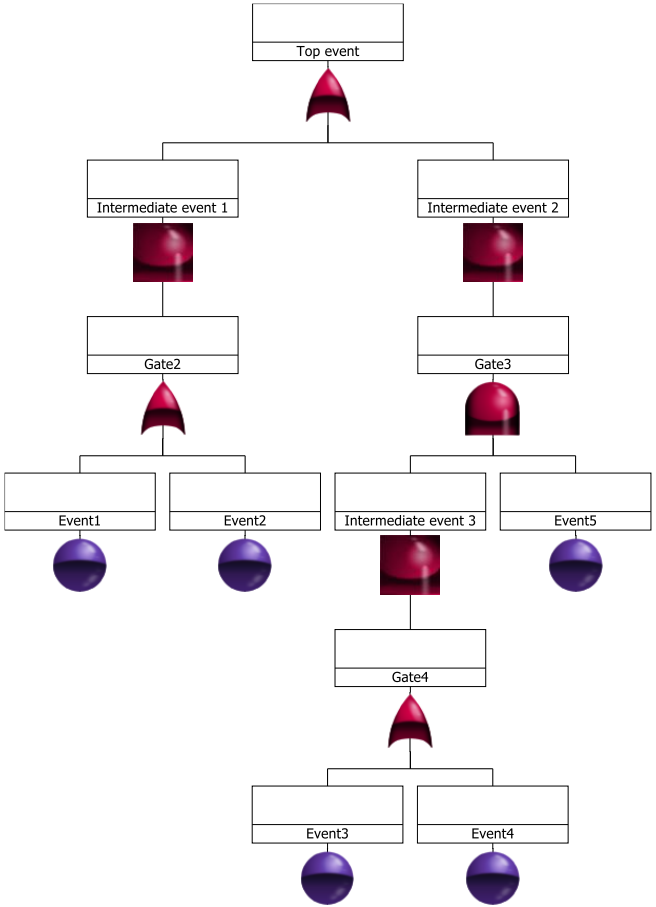


Undeveloped Event

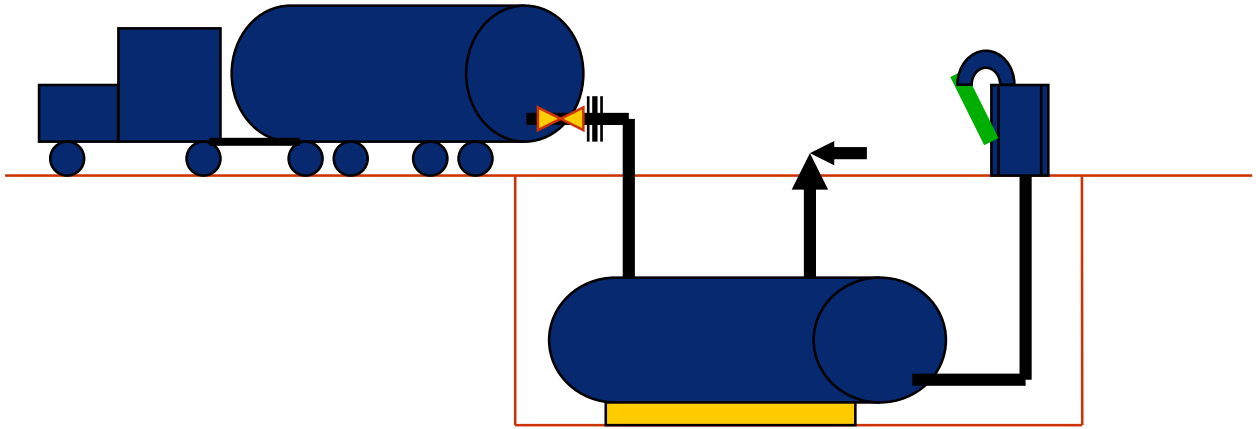
Transfer Symbols



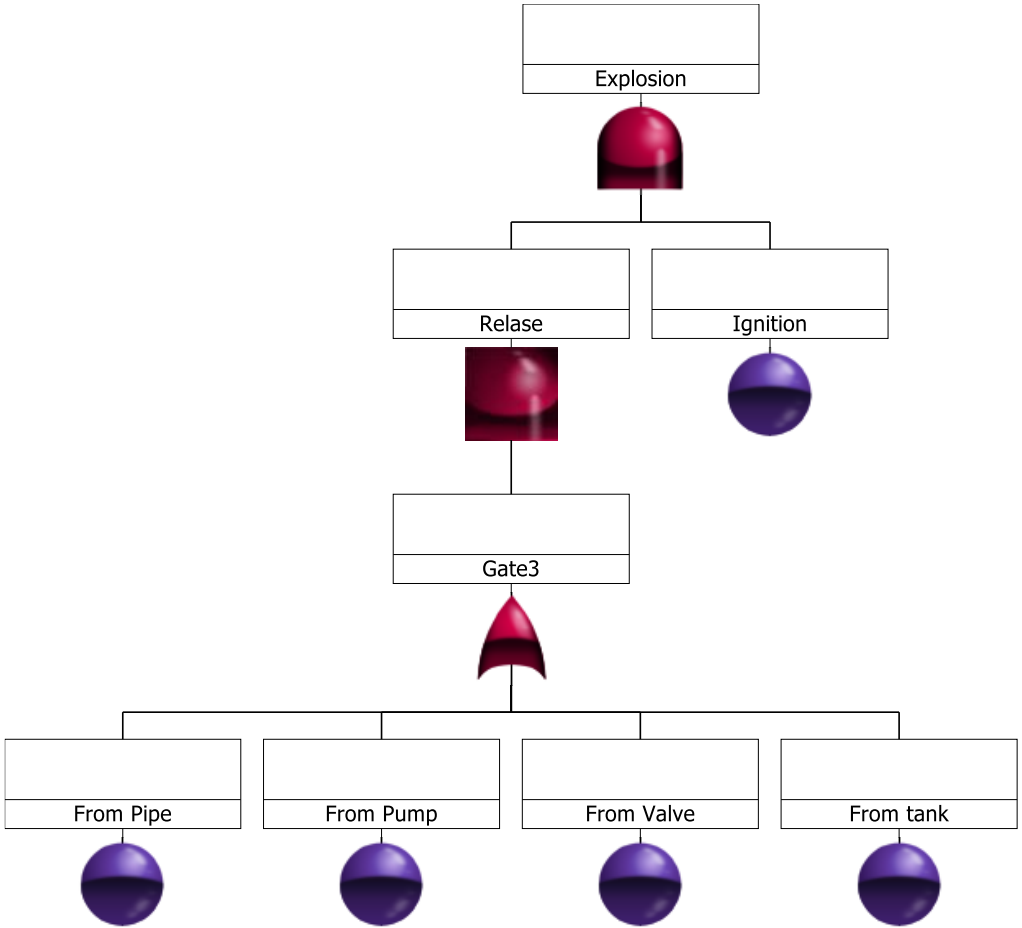
A Typical Fault Tree



FTA: A Gas Station

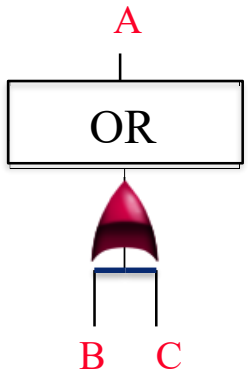


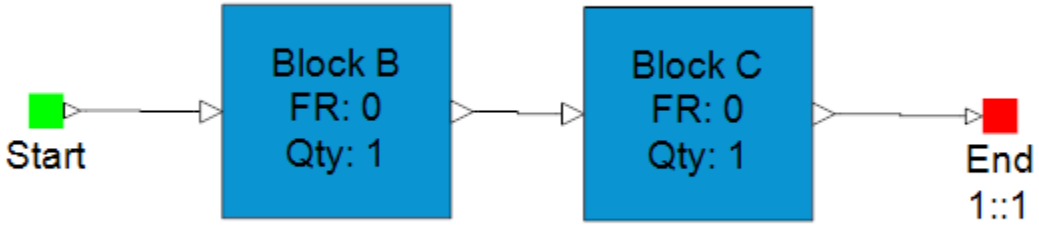
Explosion in a gas station



Application of Boolean Algebra to Fault Trees

Probability relations associated with Fault Tree logic gates



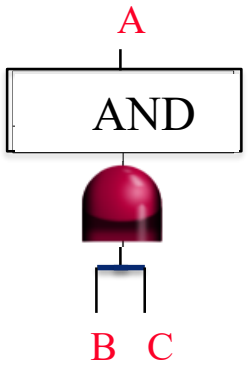


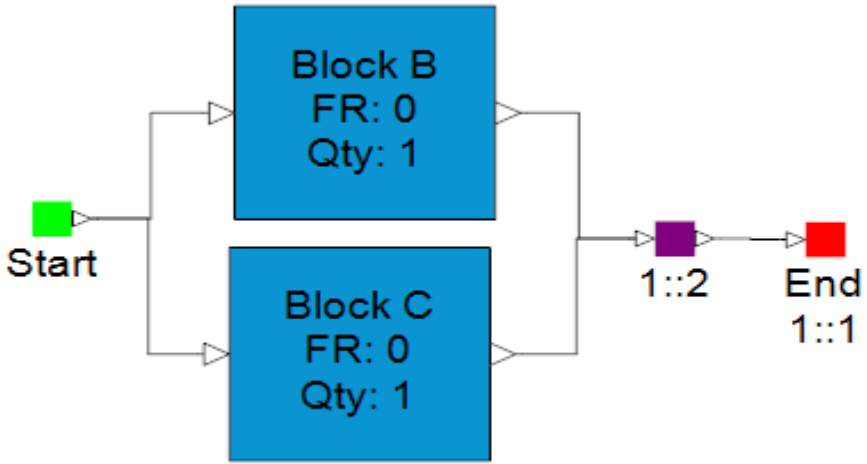
Boolean algebra relation	Probability relation

$$P(A) = P(B \text{ or } C) = P_B + P_C - P_B P_C = 1 - (1-P_B)(1 - P_C)$$

Application of Boolean Algebra to Fault Trees

Probability relations associated with Fault Tree logic gates





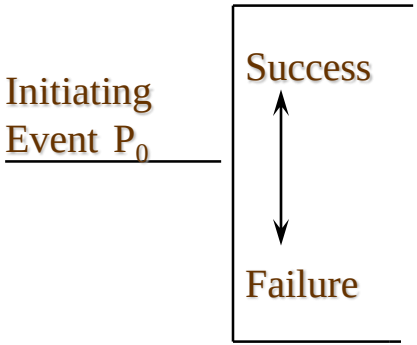
Boolean algebra relation	Probability relation
$P(A) = P(B \text{ and } C) = P_B * P_C$	

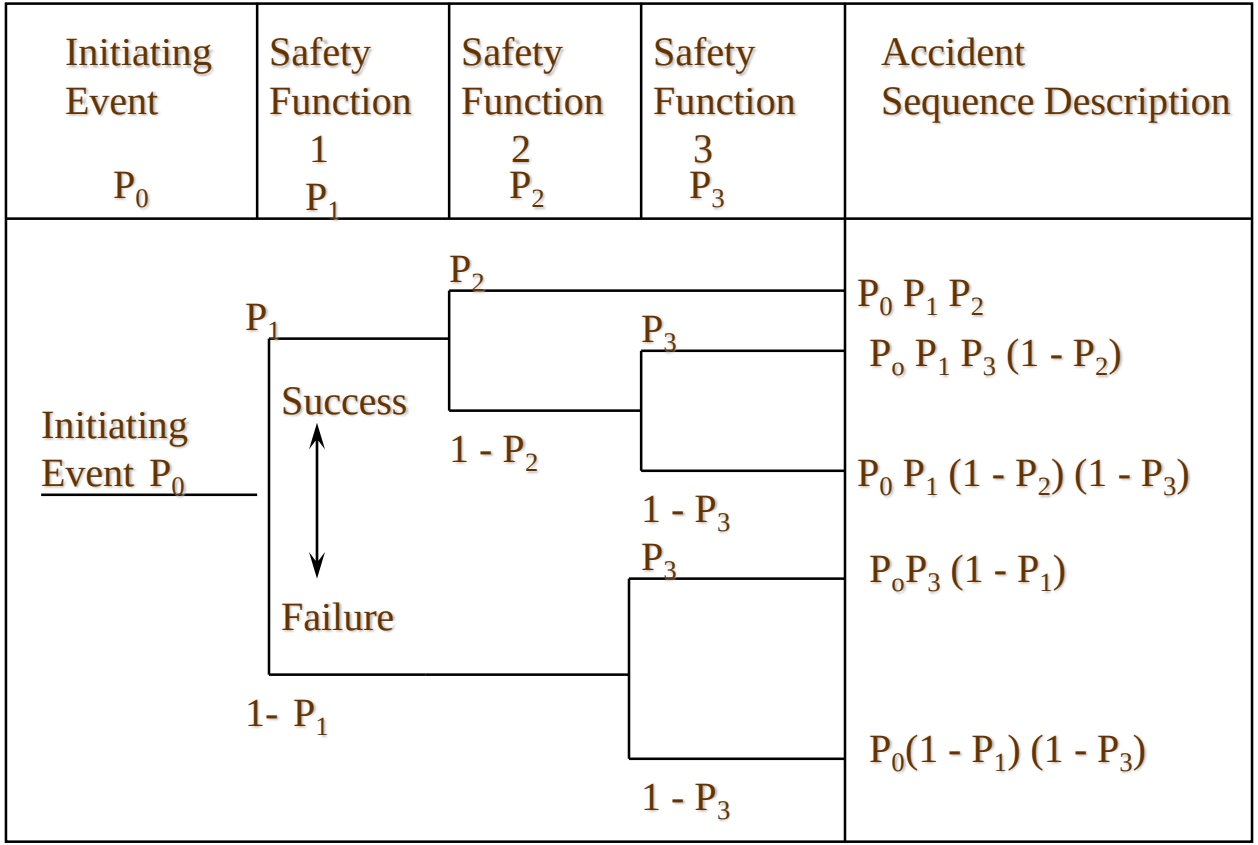
Fault Tree Analysis

What is cut set? A cut set is a set of events which must all occur in order for the top event to occur

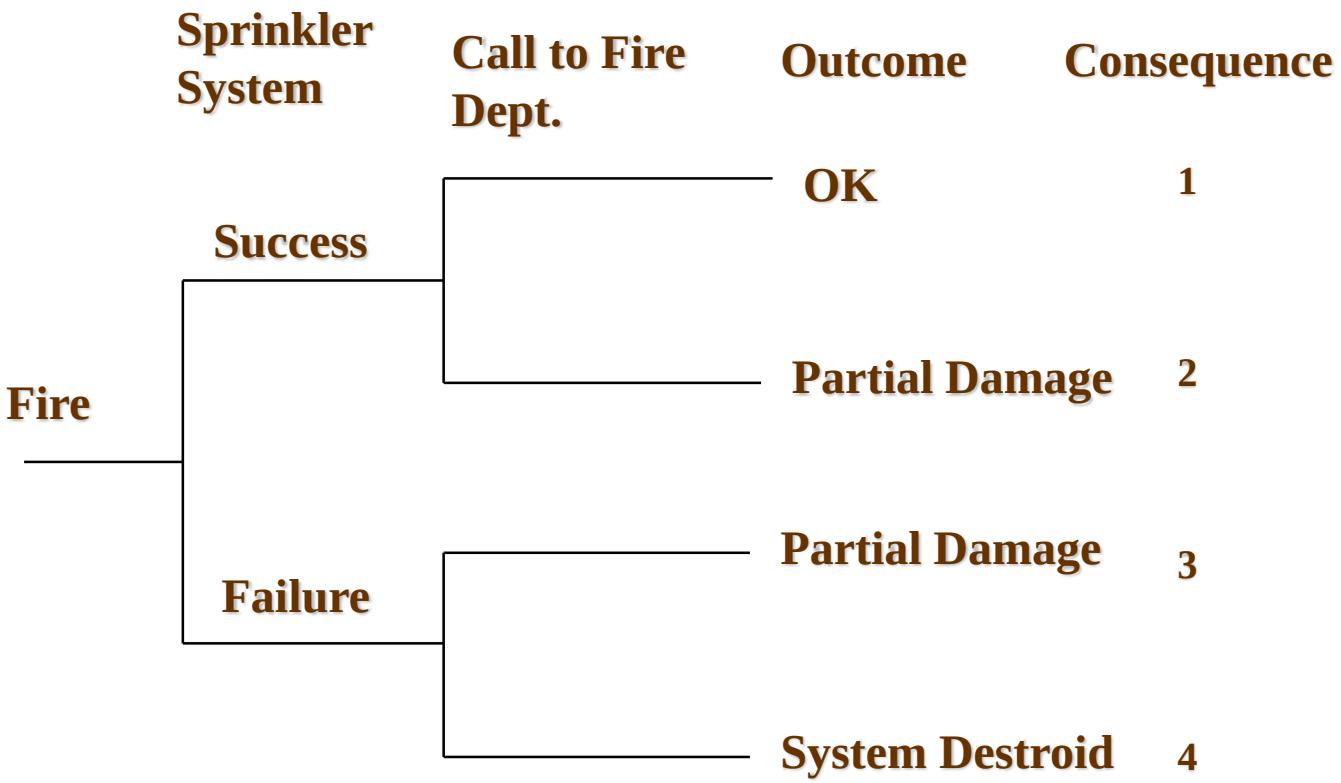
Event Tree Analysis

Initiating Event P_0	Safety Function 1 P_1	Safety Function 2 P_2	Safety Function 3 P_3	Accident Sequence Description

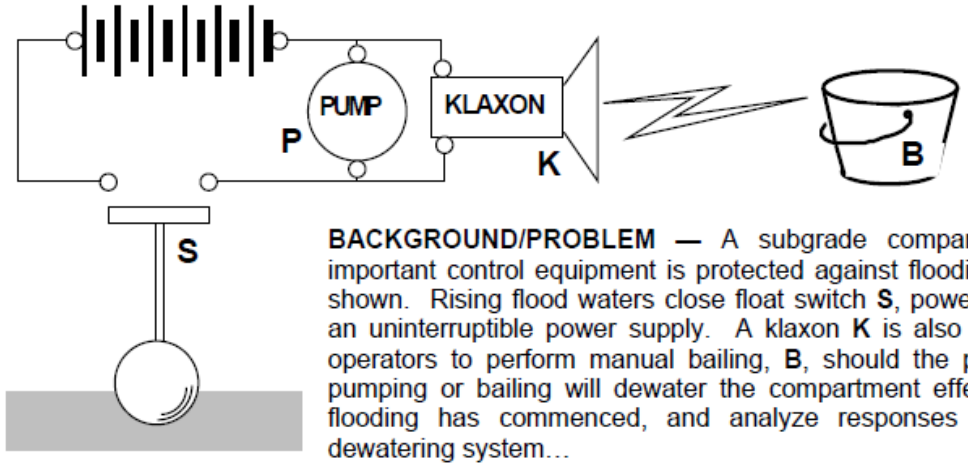



Initiating Event
Safety Function 1
Safety Function 2
Safety Function 3
Accident Sequence Description
P0
P1
P2
P3
Initiating Event P0
Success
Failure
P1
1- P1
P2
1 - P2
P3
1 - P3
P3
1 - P3
P0 P1 P2
Po P1 P3 (1 - P2)
P0 P1 (1 - P2) (1 - P3)
PoP3 (1 - P1)
P0(1 - P1) (1 - P3)

A Simple Example of an Event Tree



AN EXAMPLE PROBLEM...



BACKGROUND/PROBLEM — A subgrade compartment containing important control equipment is protected against flooding by the system shown. Rising flood waters close float switch **S**, powering pump **P** from an uninterruptible power supply. A klaxon **K** is also sounded, alerting operators to perform manual bailing, **B**, should the pump fail. Either pumping or bailing will dewater the compartment effectively. Assume flooding has commenced, and analyze responses available to the dewatering system…

- ~~Develop an event tree representing system responses~~.
- Develop a reliability block diagram for the system.
- Develop a fault tree for the TOP event *Failure to Dewater*.

SIMPLIFYING ASSUMPTIONS:

- Power is available full time.
- Treat only the 4 system components **S**, **P**, **K**, and **B**.
- Consider operator error as included within the bailing function, **B**.

Calculation data for calculation of RBD and FTA:

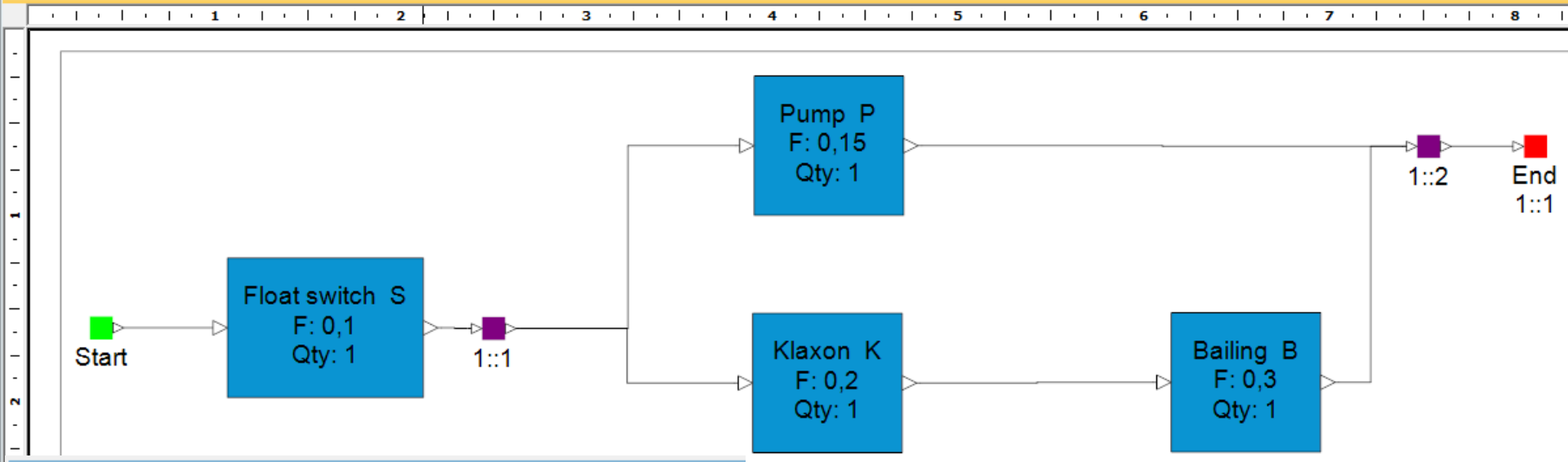
S (Float switch) 0,10

P (Pump) 0,15

K (Klaxon) 0,2

B (Bailing) 0,3

RBD Diagram - Block Diagram1



RBD General Results

Results for Block Diagram1:

Steady state results:

Calculation method: Analytical

Results at Time 1000,00:

Reliability: 0,8406

Unreliability: 0,1594

Time	Reliability	Unreliability
0	0,840600	0,159400
100,00	0,840600	0,159400
200,00	0,840600	0,159400
300,00	0,840600	0,159400
400,00	0,840600	0,159400
500,00	0,840600	0,159400
600,00	0,840600	0,159400
700,00	0,840600	0,159400
800,00	0,840600	0,159400
900,00	0,840600	0,159400
1000,00	0,840600	0,159400

FTA Diagram - Översvämning

View Calculation Results

FTA Results

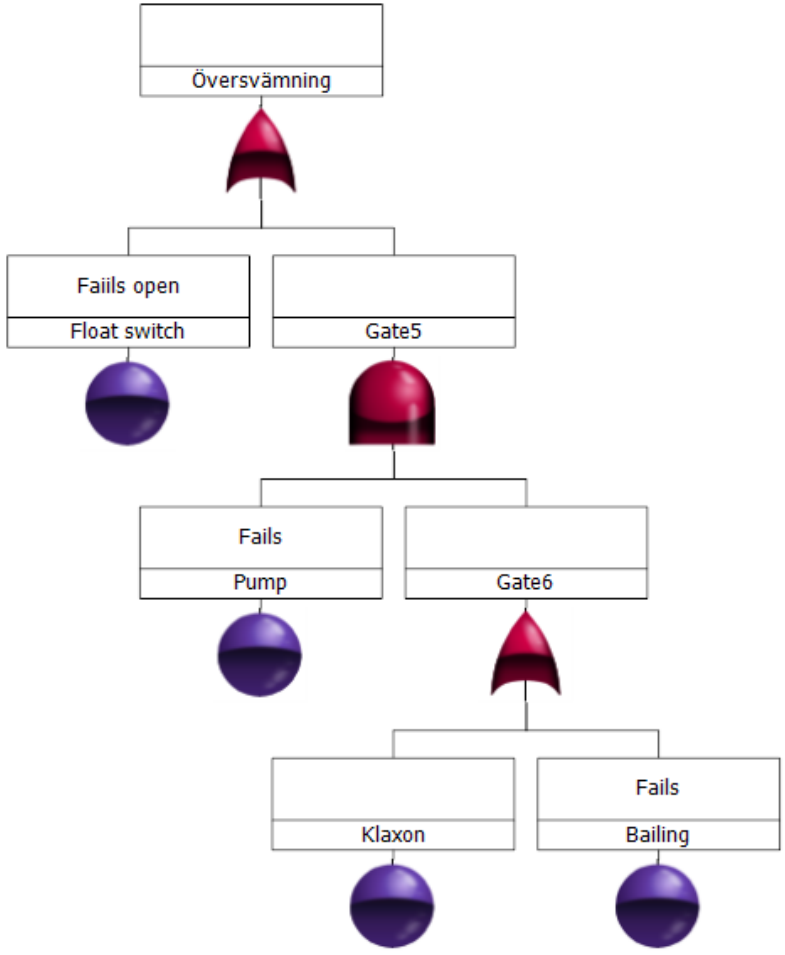
Results for Gate: Översvämning

Results at Time 1000,00:
Unreliability (F): 0,159400

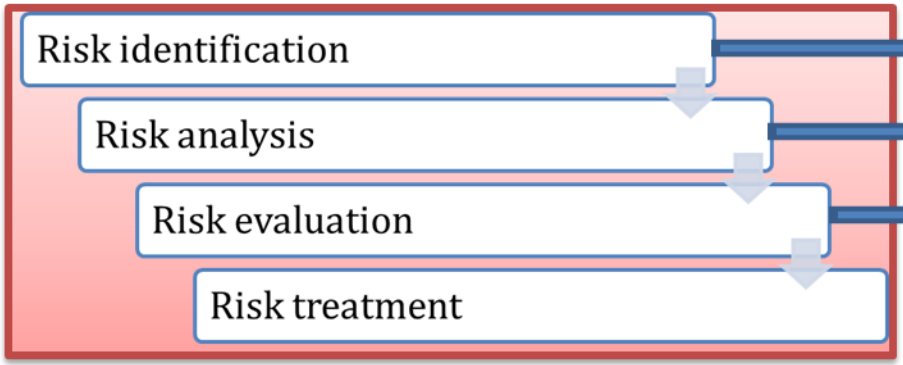
Time	Unreliability
0	0,159400
100,00	0,159400
200,00	0,159400
300,00	0,159400
400,00	0,159400
500,00	0,159400
600,00	0,159400
700,00	0,159400
800,00	0,159400
900,00	0,159400
1000,00	0,159400

Cut Sets

	Probability		
1	0,100000	Float switch: 0,1000...	
2	0,045000	Bailing: 0,3000000	Pump: 0,1500000
3	0,030000	Klaxon: 0,2000000	Pump: 0,1500000



Risk Management Methodology and Tools



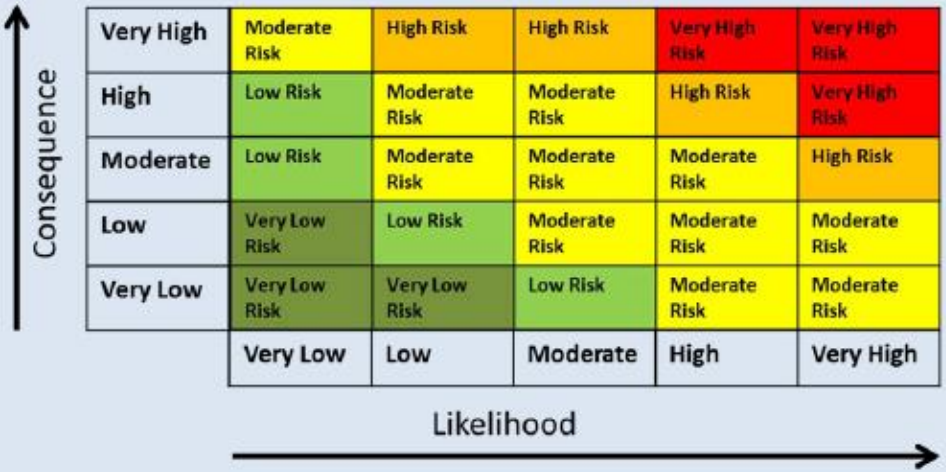
- What-if
- Hazop
- FMEA

- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)

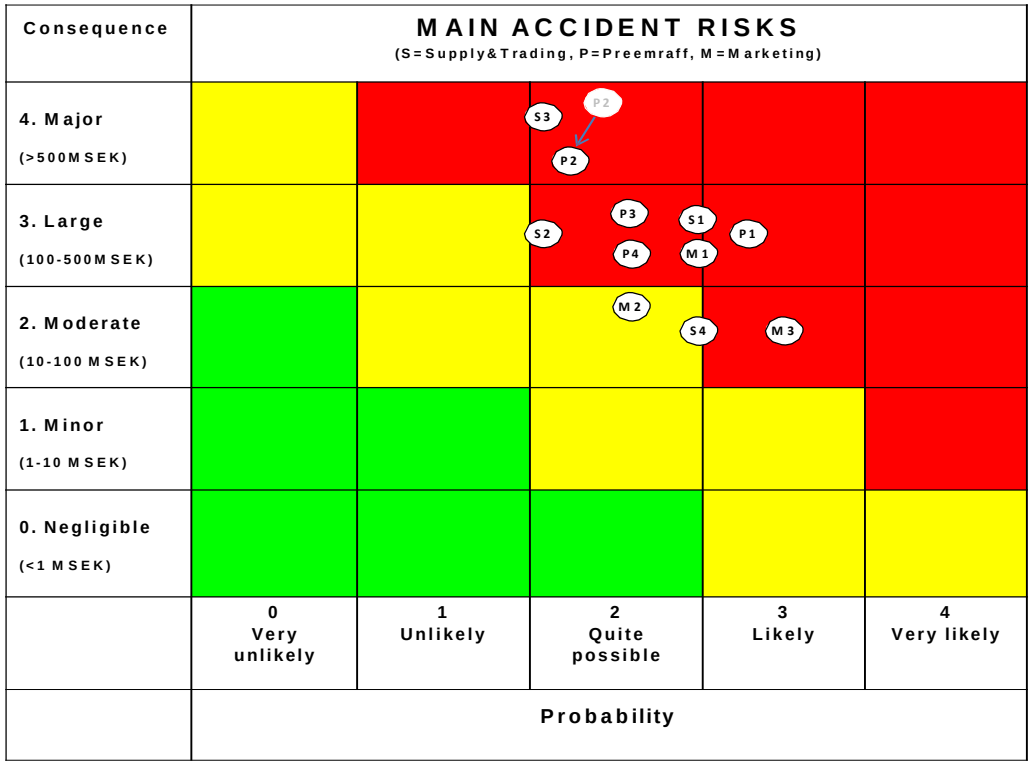
✓ Risk Marix

Risk Evaluation - Risk Matrix

- Systematic hazard identification and risk assessment



Risk Matrix



Identified aggregated accident type

S1 Serious injury
S2 Fire/explosion at depot
S3 Shipping disaster
S4 Truck accident

P1 Serious injury
P2 Fire/explosion at refinery
P3 Vital equipment failure
P4 Large oil spill in port

M1 Serious injury
M2 Fire/explosion
M3 Soil pollution

CHALMERS