



Dinâmica Aplicada

5th International Seminar on Underground Space
Health & Safety in Underground Space
October 18th, 2019, Lisboa, Portugal

Incidents and Accidents Risk Analysis and the ISO 31000

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Società Italiana Gallerie
Italian Tunnelling Society



FGU Fachgruppe für Untertagbau
GTS Groupe spécialisé pour les travaux souterrains
GLS Gruppo specializzato per lavori in sotterraneo
STS Swiss Tunnelling Society



Incidents and Accidents Risk Analysis and the ISO 31000



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Risk Analysis and the Meaning of Words

Incident(s)/Accident(s) (Definition: Cambridge English Dictionary)

- Incident: an event that is either unpleasant or unusual
- Accident: something bad that happens that is not expected or intended and that often damages something or injures someone

A question arises from the point of view: an accident involving myself can be an incident from an outside observer?

A second question arises from translation:

Segurança (PT): Safety (UK)
Security (UK)



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How good can/must be a definition?
The Qualitative/Quantitative dilemma



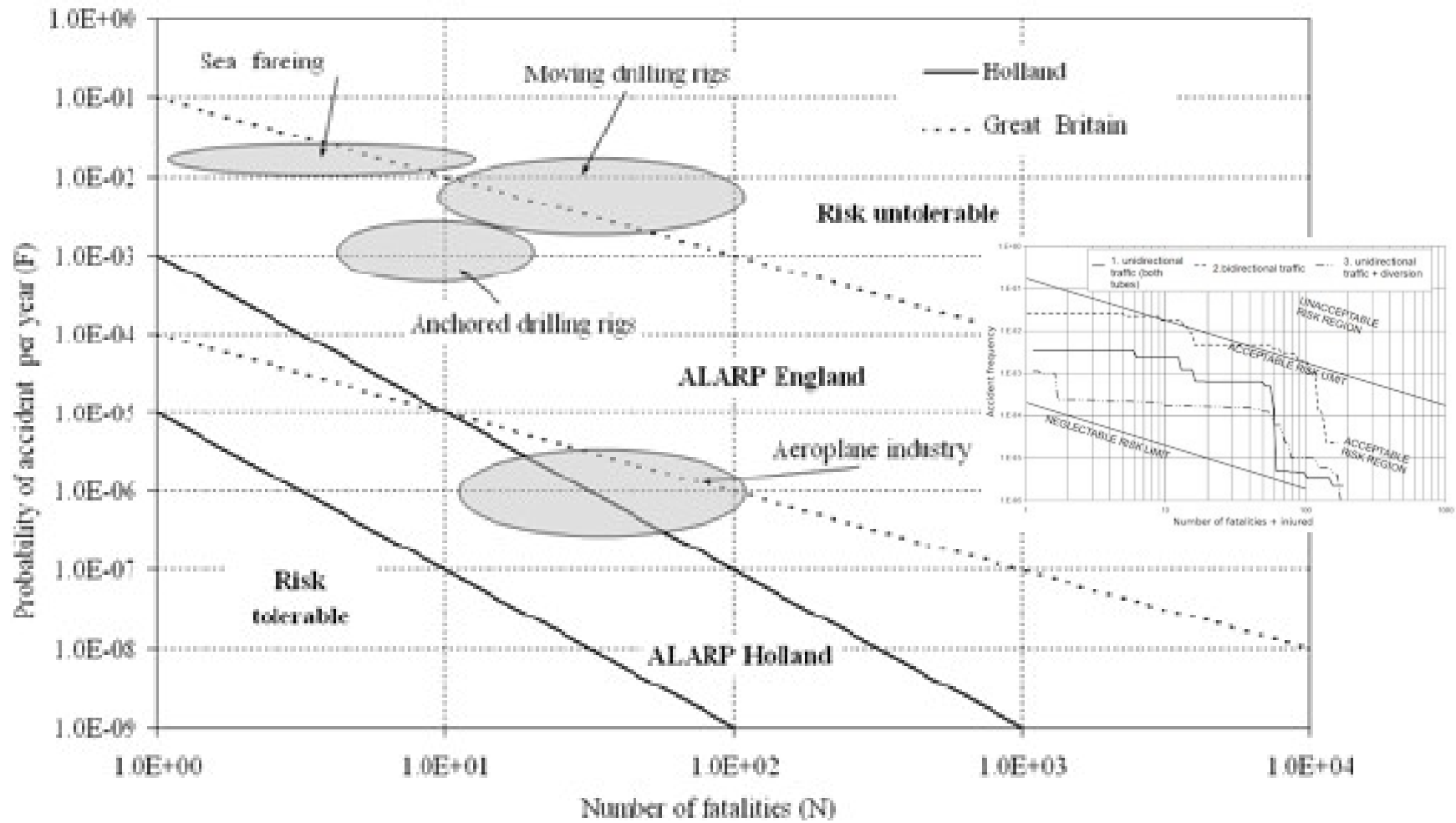
IMPACT	High	Medium	High	High
	Medium	Low	Medium	High
	Low	Low	Low	Medium
		Low	Medium	High

LIKELIHOOD

Frequency of Occurrence (or Likelihood)	Consequences (Severity of Accident)				
	Incidental (1)	Minor (2)	Serious (3)	Major (4)	Catastrophic (5)
Frequent (5)	M	H	VH	VH	VH
Occasional (4)	M	M	H	VH	VH
Seldom (3)	L	M	H	H	VH
Remote (2)	L	L	M	H	H
Unlikely (1)	L	L	M	M	H



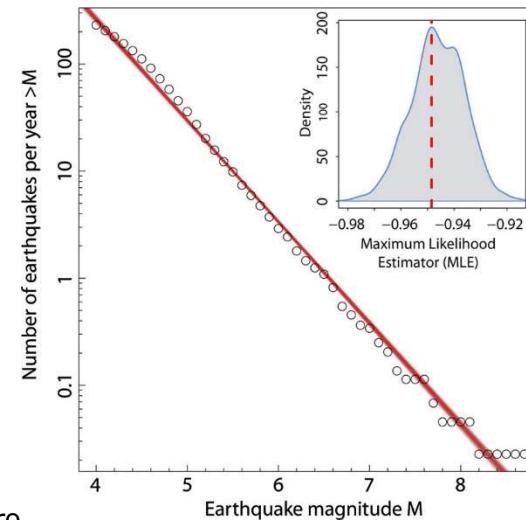
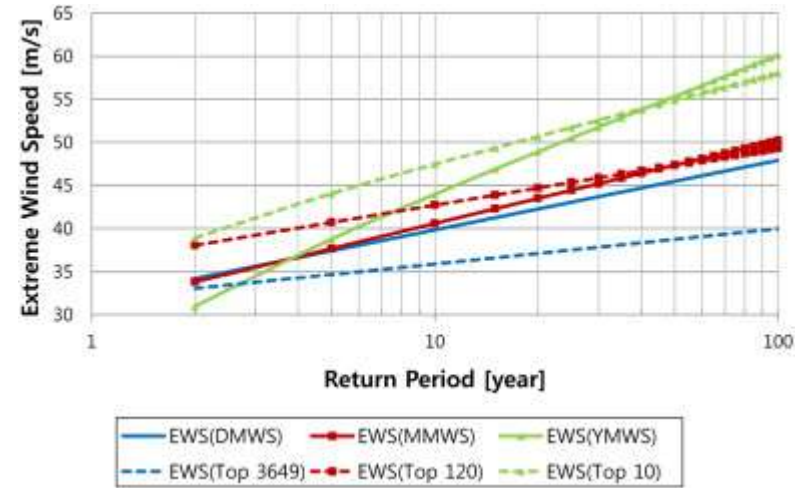
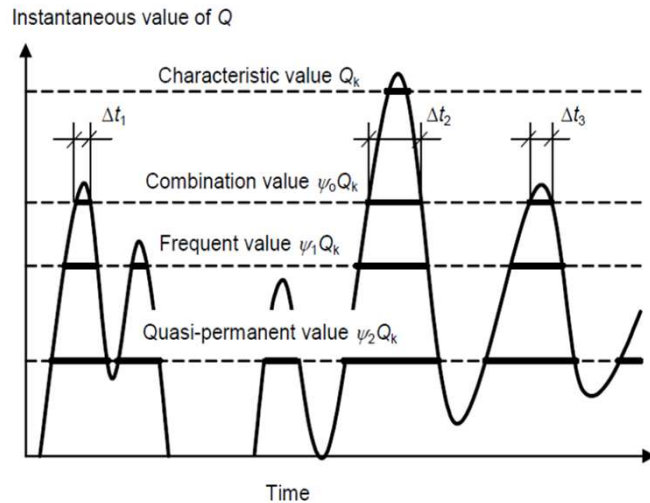
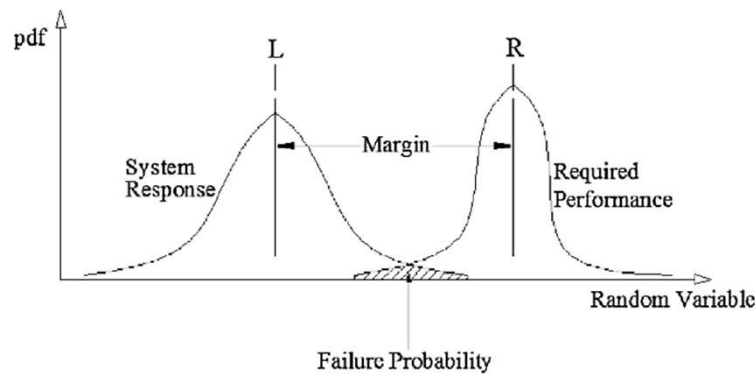
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Risk Analysis – Structural Safety





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Project Phase Risk Matrix							Probability							
							Almost Impossible (1)	Not likely to occur (2)	Could occur (3)	Known to occur (4)	Common occurrence (5)			
Regimes	Health and Safety	Environmental Impacts	Financial & Asset Loss	Reputational Damage	Production / Projects	Information Technology	Occurs less than once in 10 000 years	Occurs once in 1 000 to 10 000 years	Occurs once in 100 to 1 000 years	Occurs once in 10 to 100 years	Occurs once in 1 to 10 years			
Potential Consequences	Catastrophic (5)	One or more fatalities. Irreversible health problems for employees and/or community.	On or off-site spill causing groundwater pollution, with detrimental long-term effects.	Severe financial loss or asset replacement cost impact. (> US\$ 2 million)	International loss of reputation / Damaging International TV exposure with impact	Indefinite cessation of production activity / Extended project schedule slip of > 75% of plan.	Significant failure and operational downtime with permanent loss of critical data integrity.	5	10	15	20	25		
	Major (4)	Partial, or medium-term, disabilities or major health problems for employees and/or community.	Off-site release, contained & medium-term effects on community health and/or groundwater.	Major financial loss or asset cost impact. (> US\$ 1 million < US\$ 2 million)	National loss of reputation / Damaging National TV exposure with impact on customers.	Long-term production cutback / Major project schedule slip of 40 to 75% of plan.	System failure and operational downtime, with loss of critical data integrity and/or confidentiality.	4	8	12	16	20		
	Moderate (3)	Lost-time injuries or potential medium-term health problems for employees and/or community.	On site release, contained & restored, with medium-term effects on employees/groundwater.	Moderate financial loss or asset cost impact. (> US\$ 100 000 < US\$ 1 million)	Regional loss of reputation / Local radio & newspaper reports impacting suppliers/customers.	Medium-term production cutback / Project schedule slip of 20 to 40% of plan.	System downtime with operational impact / restricted loss of data integrity / confidentiality.	3	6	9	12	15		
	Minor (2)	Minor, very short-term health concerns or Recordable Injury cases.	On site release, immediately contained & restored, with short-term effects.	Tolerable financial loss or asset cost impact. (> US\$ 10 000 < US\$ 100 000)	Loss of regional reputation by word of mouth re. safety performance & treatment of workers.	Short-term production cutback / Minor project schedule slip of 10 to 20% of plan.	Limited downtime, recoverable data loss with limited operational impact, no security breach.	2	4	6	8	10		
	Insignificant (1)	Inherently safe, Unlikely to cause health problems. First aid injuries.	Minor localised spill with insignificant effects on employees and/or community.	Relatively low financial loss or asset cost impact. (< US\$ 10 000)	Unsubstantiated rumours with light to moderate impact on reputation.	Very short-term production cutback / schedule slip of up to 10% of plan.	Limited downtime, recoverable data loss, workaround possible, no security breach.	1	2	3	4	5		
							Low risk		Medium risk		Significant risk		High risk	

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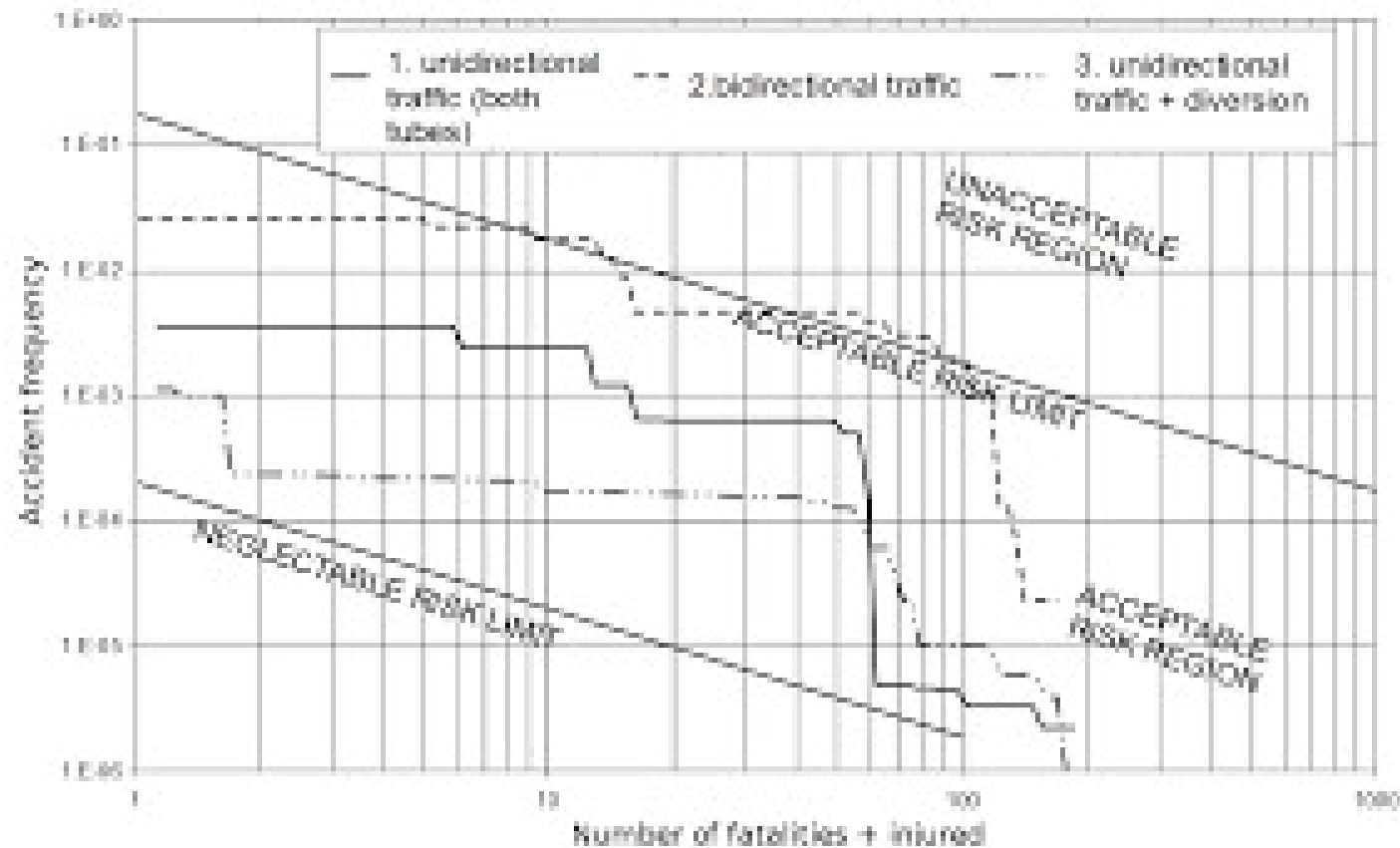
> Risk Analysis – Event tree

total traffic veh. km/yr	traffic modes	vehicles	potential fire sizes MW	traffic veh. km/yr	accident rate PIA/veh. km	fire/acc. ratio	serious fires per year	smoke conditions	fatality rate per fire	fatalities per year
2.19E+07	uni-directional 0.95	light 0.85	15 MW	1.77E+07	1.20E-07	0.016	3.35E-02	good 1.000	0.015	5.02E-04
			1.00				poor 0.000	0.15	0.00E+00	
			0.85							
		heavy 0.15	30 MW	2.34E+06	1.20E-07	0.016	4.43E-03	good 1.000	0.15	6.64E-04
			0.75					poor 0.000	1.5	0.00E+00
			0.15							
	100 MW	0.25	7.80E+05	1.20E-07	0.016	1.48E-03	good 0.333	1.5	7.38E-04	
							poor 0.667	15	1.48E-02	
	congested 0.05	light 0.85	15 MW	9.31E+05	1.20E-07	0.016	1.76E-03	good 1.000	0.03	5.28E-05
			1.00				poor 0.000	0.3	0.00E+00	
			0.85							
heavy 0.15		30 MW	1.23E+05	1.20E-07	0.016	2.33E-04	good 1.000	0.3	6.99E-05	
		0.75					poor 0.000	3	0.00E+00	
		0.15								
100 MW	0.25	4.11E+04	1.20E-07	0.016	7.77E-05	good 0.333	3	7.77E-05		
						poor 0.667	30	1.55E-03		
bi-directional 0.00	light 0.85	15 MW	0.00E+00	1.20E-07	0.016	0.00E+00	good 1.000	0.015	0.00E+00	
		1.00				poor 0.000	0.15	0.00E+00		
		0.85								
	heavy 0.15	30 MW	0.00E+00	1.20E-07	0.016	0.00E+00	good 1.000	0.15	0.00E+00	
		0.75					poor 0.000	1.5	0.00E+00	
		0.15								
100 MW	0.25	0.00E+00	1.20E-07	0.016	0.00E+00	good 0.333	1.5	0.00E+00		
						poor 0.667	15	0.00E+00		





> Risk Analysis – DG- QRAM (FN curves)





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Summary of minimum requirements		Traffic > 2000 per lane L > 3000 m	Weight	Additional conditions for implementation to be mandatory, or comments
Structural measures	2 tubes or more	§2.1	~2	ADT (2030) 4500 veh/lane (ref. ADT 10000) ⁽¹⁾
	Gradients <5%	§2.2	1	Gradients 0.5 and 1% (ref. 3%) According with directive
	Emergency walkways	§2.3.1 §2.3.2	>1	1 elevated walkway and 1 shoulder lane each side (1,2 m) Above directive requirements ⁽²⁾
	Emergency exits at least every 500 m	§2.3.3 §2.3.9	1,2 to 1,5	300 m Above directive requirements (ref. 500 m) . Linear Evac model ⁽³⁾
	Cross connections for emergency services at least every 1500 m	§2.4.1	1,2	1200 m Above directive requirements (ref. 1500 m) ⁽³⁾
	Crossing of the central reserve outside each portal	§2.4.2	1	According with directive
	Lay-bys at least every 1000 m	§2.5	>1	600 m Above directive requirements (ref. 1000 m)
	Drainage for flammable and toxic liquids	§2.6	1	According with directive
	Fire resistance of structures	§2.7	1	According with directive
Balance for structural measures			>3	Above directive requirements (operational requirements demand compensation)
Lighting	Normal	§2.8.1	1	According with directive
	safety	§2.8.2	1	According with directive
	evacuation	§2.8.3	1	According with directive
Balance for lighting			1	Comply with directive
Ventilation	Mechanical Ventilation	§2.9	>2	100 % redundant system. Above directive requirements (design fire 30 MW – capability of the system above 50 MW) ⁽⁴⁾
	Special provisions for (semi-)transverse ventilation	§2.9.5	1	According with directive
Balance of Ventilation			>2	Above directive requirements

Emergency stations	At least every 150 m	§2.10	*	1	According with directive, (2 portable extinguishers, voice communication)
Balance of emergency stations				1	Comply with directive
Water supply	At least 250 m	§2.11	•	1	According with directive
Balance of water supply				1	Comply with directive
Road signs		§2.12	•	>1	Every 300 m Above directive requirements
Balance of road signs				>1	Above Directive requirements
Control centre		§2.13	•	2	Two control centers (one as a full reserve in case of failure) ⁽⁵⁾ Above directive requirements
Balance of control centre				2	Above directive requirements
Monitoring systems	Video (CCTV)	§2.14	•	>1	DIA including smoke Above directive requirements
	Automatic incident detection and/or fire detection	§2.14	•	>2	Above directive requirements LHD (3 modes), CCTV(DIA and smoke) CO and opacity detection ⁽⁶⁾
Balance of monitoring systems				>2	Above directive requirements
Equipment to close the tunnel	Traffic signals before entrances	§2.15.1	•	>1	Above directive requirements ⁽⁷⁾
	Traffic signals inside the tunnel at least every 1000 m	§2.15.2	@	>1	Every 300 m Above directive requirements ⁽⁷⁾
Balance of equipments to close the tunnel				>1	Above directive requirements
Communication systems	Radio re-broadcasting for emergency services	§2.16.1	•	1	According with directive
	Emergency radio messages for tunnels users	§2.16.2	•	1	According with directive
	Loudspeakers in shelters and exits	§2.16.3	•	1	According with directive
Balance of communication systems				1	Comply with directive
Emergency power supply		§2.17	•	1	According with directive ⁽⁸⁾
Balance of emergency power supply				1	Comply with directive
Fire resistance of equipments		§2.18	•	1	According with directive
Balance of fire resistance of equipment				1	Comply with directive
* Mandatory; *Mandatory with exceptions; o not mandatory; @ recommended					
RESULT (infrastructure)				>24	Structural measures, systems and Equipments above directive Requirements

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Summary of minimum requirements	Traffic > 2000 per lane		Weight	Additional conditions for implementation to be mandatory, or comments
	L > 3000 m			
OPERATIONAL REQUIREMENTS				
Presence and percentage of HGV	§1.3.2	60%	>0.25	~95% of HGV of 12 to 15 ton ⁽⁹⁾
Operating Means	§3.1		1	According with directive
Emergency planning	§3.2		1	According with directive
Works in tunnel	§3.3		1	According with directive
Management of I/A	§3.4		1	According with directive (emergency services at the tunnel portals)
Activity of the control centre	§3.5		1	According with directive
Tunnel closure	§3.6		1	According with directive
Transport of dangerous goods	§3.7		>0.25	Though above the directive no ADT or vehicle inspection mandatory (traffic control includes outside overheight, smoke emission and temperature of vehicle) ⁽¹⁰⁾
Overtaking	§3.8		1	No overtake allowed (just under operation control)
Distance between vehicles and speed	§3.9		>1	Above the directive requirements (in 2030 ~1/2 of tunnel traffic capacity for peak hours used) ⁽¹¹⁾
Information campaigns	§4		1	According with directive
RESULT (OPERATION)			>0.06	Operational conditions heavy demanding compensation from minimum requirements

GLOBAL SAFETY COEFFICIENT	~1.5	The probability of an accident involving fatalities is about 2/3 that to be expected for the reference tunnel (directive)
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Incidents and Accidents Risk Analysis and the ISO 31000

The PLAN FOR RISK MANAGEMENT (PRM) must present a detailed procedure for RM following ISO 31000; the following minimum requirements must be considered:

- 1 - Definition of the context using minimum cost and scheduling as the main criteria and reputation and image as secondary subjective criteria
- 2 - Risk evaluation (Risks ID; Risk Analysis; and Risk evaluation)
- 3 - Risk mitigation (including monitoring and communication)

At least the following themes must be looked upon:

Arqueology

Geology and Geotechnics

Environment

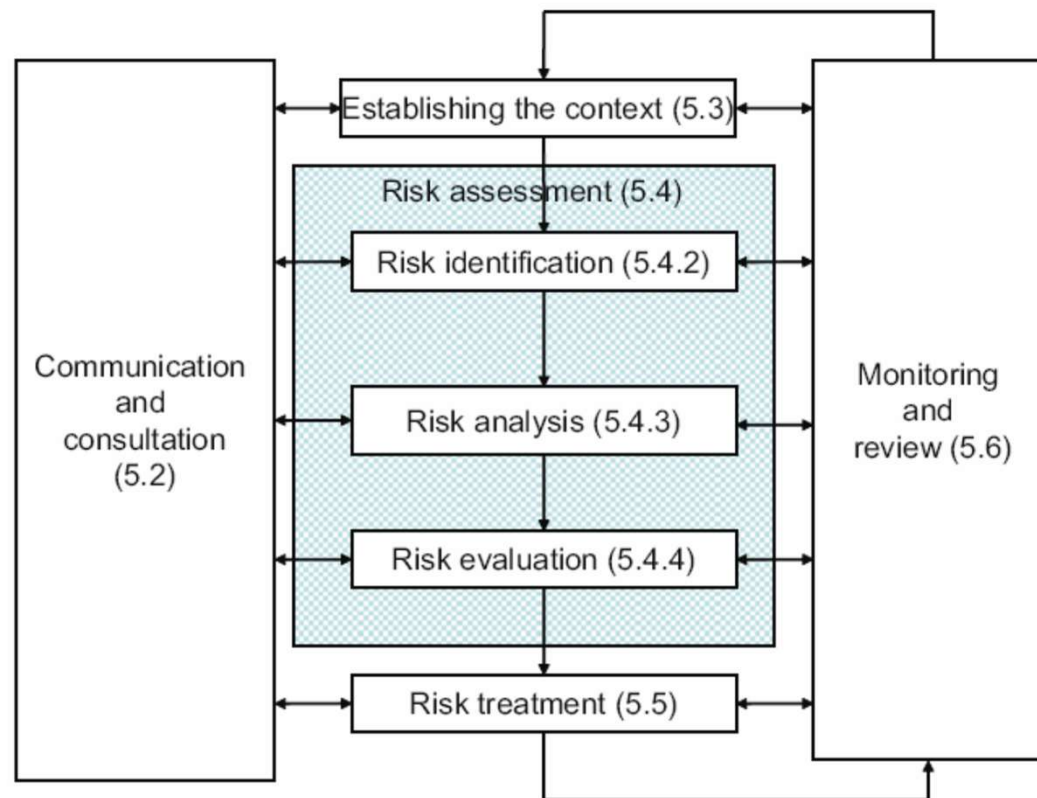
Local envelopes

Equipments



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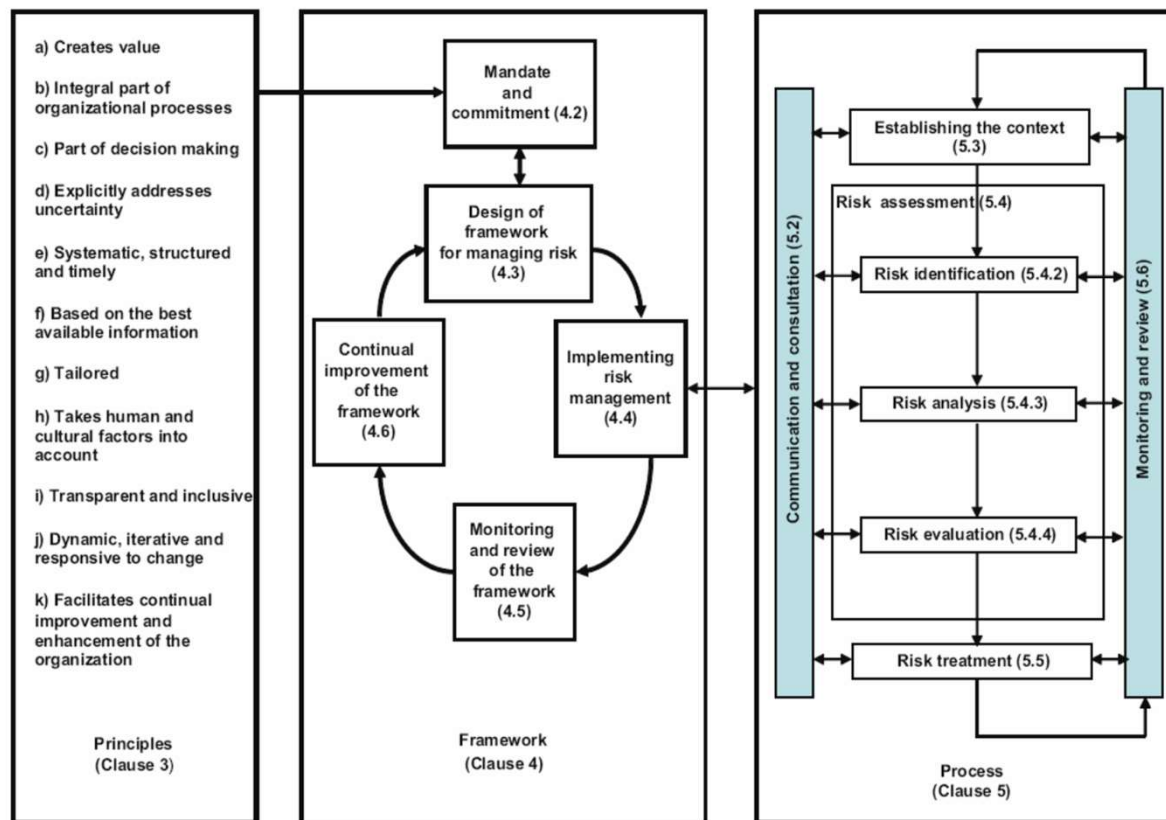
The demands from the bid are those of ISO 31000:2009



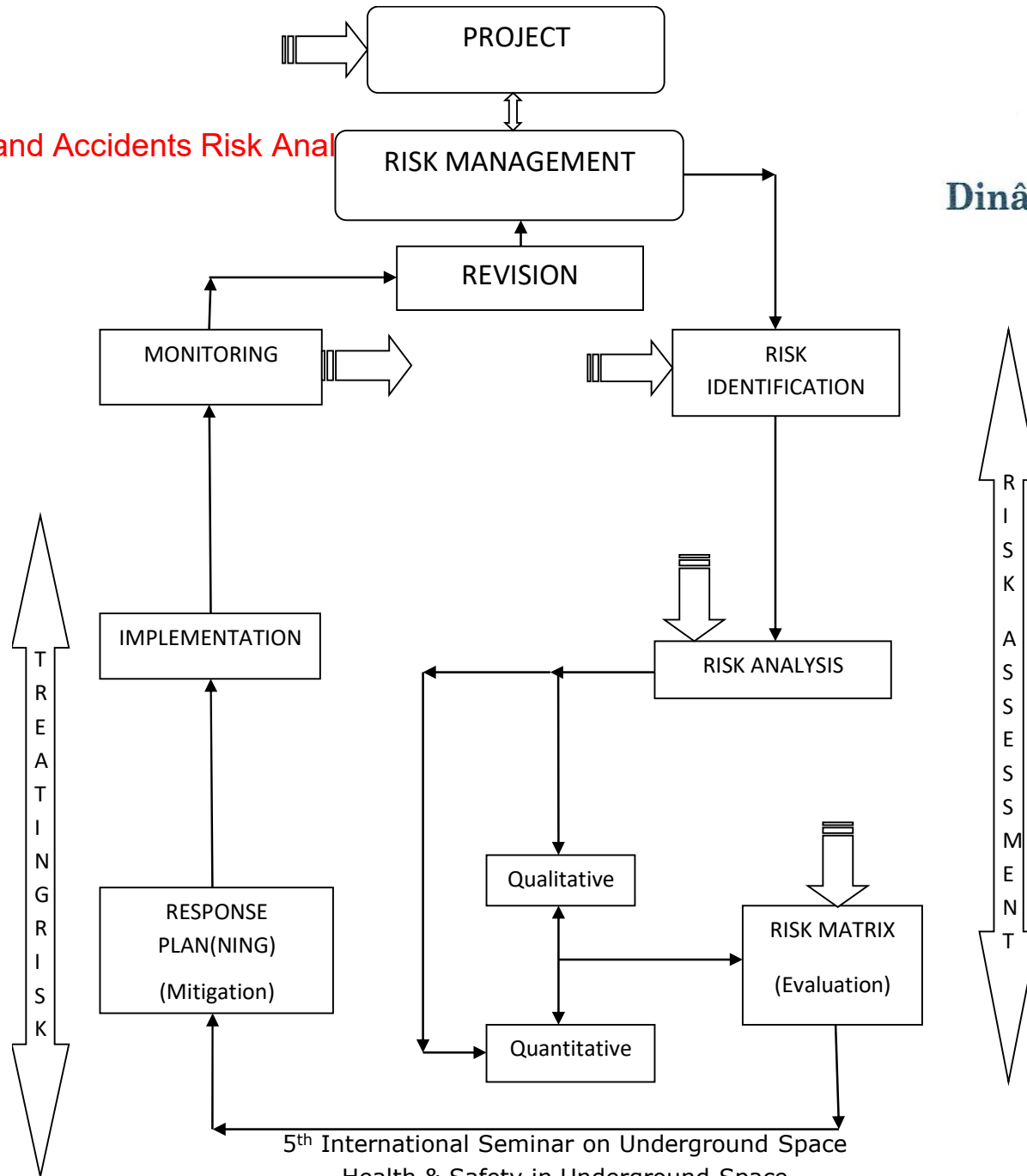


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Principles; Framework and Process of risk management



Incidents and Accidents Risk Anal





Incidents and Accidents Risk Analysis and the ISO 31000



Probability			Greater		
Severity			Lesser		
	A			NO	
		L			
Greater			A		
Lesser		OK		R	
					P

ALARP (As Low As Rationally Possible)

Probability	Excepcional	Remote	Medium	Ocasional	Frequent
Severity	(1)	(2)	(3)	(4)	(5)
Catastrofic (5)	5	10	15	20	25
High (4)	4	8	12	16	20
Medium (3)	3	6	9	12	15
Small (2)	2	4	6	8	10
Incident (1)	1	2	3	4	5

Risk Classification = ProbabilityxSeverity



Calibrated Risk Matrix																							
Calibrate the matrix to reflect your Operations business-wide impact of failure																							
The cost consequence is estimated on the DAFT Costing worksheet																							
The likelihood is determined from the historic frequency occurring in your Operation or from other comparable operations																							
Likelihood of Equipment Failure Event per Year							DAFT Cost per Event	\$30	\$100	\$300	\$1,000	\$3,000	\$10,000	\$30,000	\$100,000	\$300,000	\$1,000,000	\$3,000,000	\$10,000,000	\$30,000,000	\$100,000,000	\$300,000,000	\$1,000,000,000
Probability (per Opportunity)	Sigma Level	Event Count per	Time Scale	Descriptor Scale	Historic Description		1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	
		100	Twice per week			2	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	
		30	Once per fortnight			1.5		3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	
1		10	Once per month	Certain		1			3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	
0.3	2	3	Once per quarter			0.5					4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	
0.1	3	1	Once per year	Almost Certain	Event will occur on an annual basis	0						4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	
0.03		0.3	Once every 3 years	Likely	Event has occurred several times or more in a lifetime	-0.5							4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	
0.01	4	0.1	Once per 10 years	Possible	Event might occur once in a lifetime career	-1								4	4.5	5	5.5	6	6.5	7	7.5	8	
0.003		0.03	Once per 30 years	Unlikely	Event does occur somewhere from time to time	-1.5									4	4.5	5	5.5	6	6.5	7	7.5	
0.001		0.01	Once per 100 years	Rare	Heard of something like it occurring elsewhere	-2										4	4.5	5	5.5	6	6.5	7	
0.0003		0.003	Once every 300 years			-2.5											4	4.5	5	5.5	6	6.5	
0.0001	5	0.001	Once every 1,000 years	Very Rare	Never heard of this happening	-3												4	4.5	5	5.5	6	
0.00003		0.0003	Once every 3,000 years			-3.5													4	4.5	5	5.5	
0.00001		0.0001	Once every 10,000 years	Almost Incredible	Theoretically possible but not expected to occur	-4														4	4.5	5	

Note:

- Risk Level**
- Red = Extreme
- Amber = High
- Yellow = Medium
- Green = Low
- Blue = Accepted

1) Risk Boundary 'LOW' Level is set at total of \$10,000/year
 2) Based on HB436 2004-Risk Management
 3) Identify 'Black Swan' events as B-S (A 'Black Swan' event is one that people say 'will not happen' because it has not yet happened)
 4) DAFT Cost (Defect and Failure Total Cost) is the total business-wide cost from the event

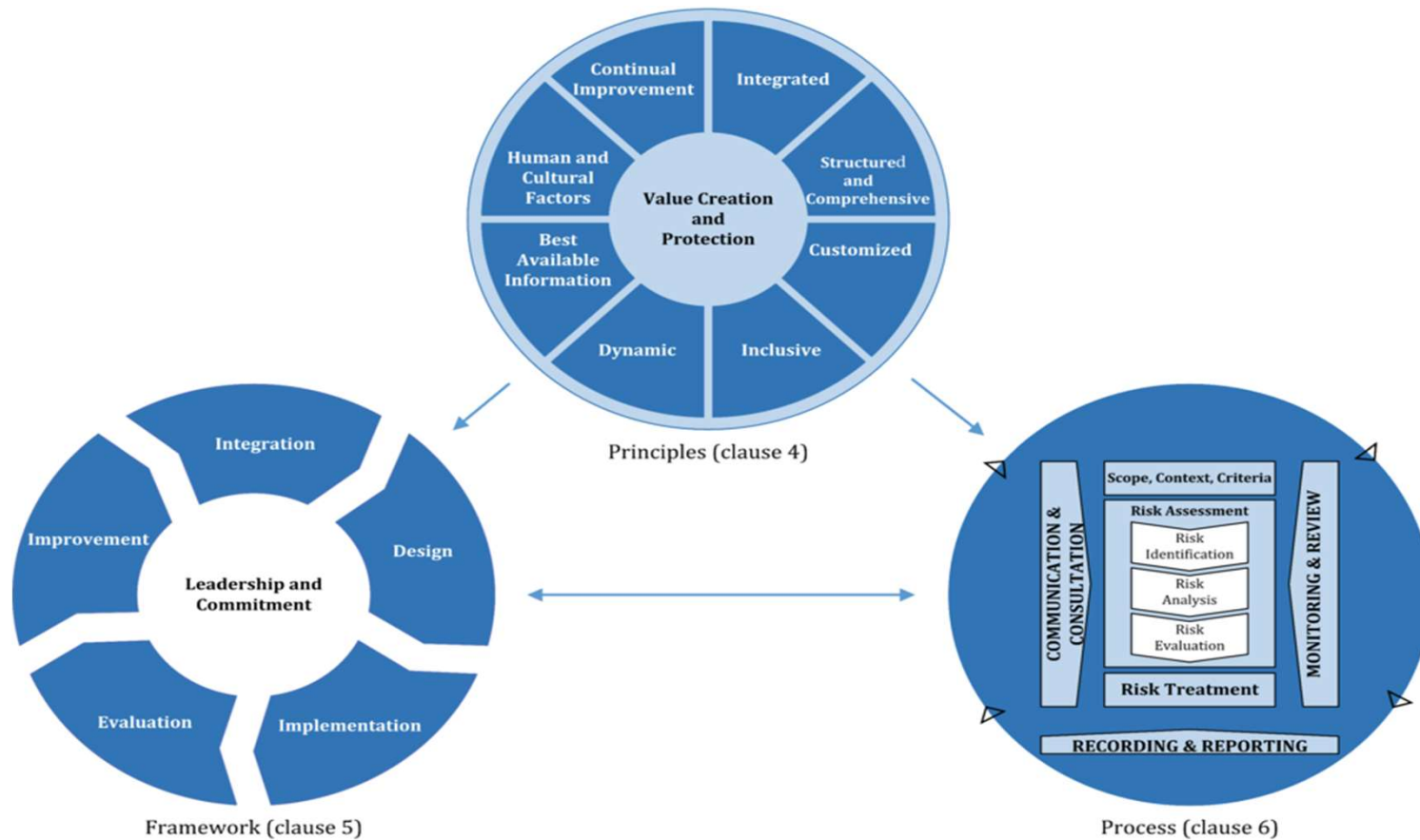
Risk = Consequence of Failure x [No Opportunities x Probability of Failure at Opportunity]

1-RELIABILITY



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> The new ISO 31000:2018





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THANK YOU

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