



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





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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 injuries 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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High

Medium

Low

IMPACT

ABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

ZNEX

Medium

Low

Low

Low

High

Medium

Low

Medium

LIKELIHOOD

High

High

Medium

High

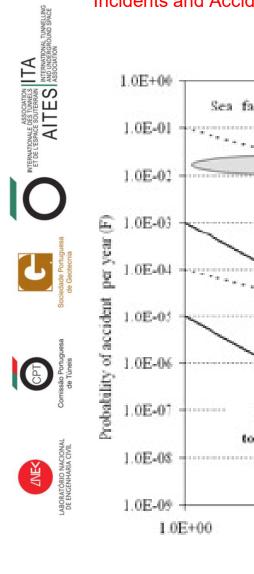
Incidents and Accidents Risk Analysis and the ISO 31000

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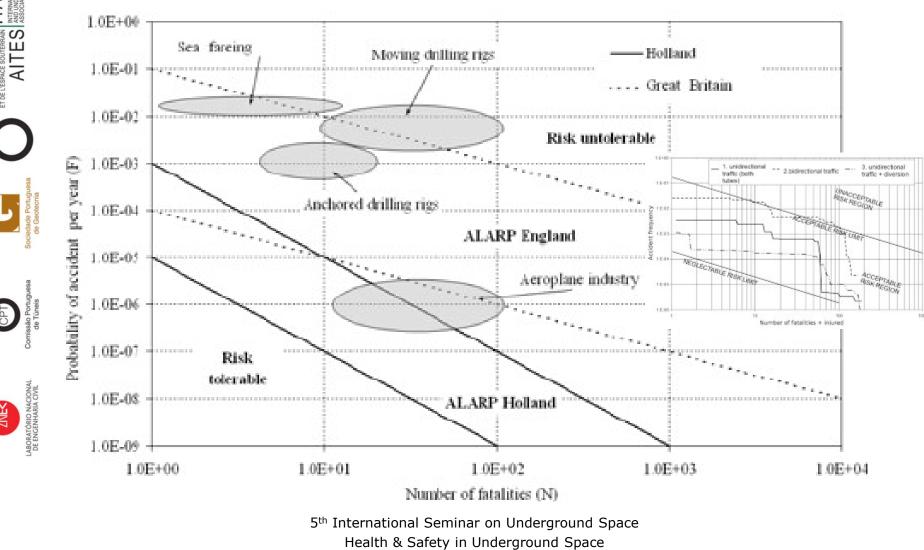
How good can/must be a definition? The Qualitative/Quantitative dilemma

Frequency of Occurrence (or Likelihood) Frequent (5) Occasional (4) Seldom	Consequences (Severity of Accident)											
	Incidental (1)	Minor (2)	Serious (3)	Major (4)	Catastrophic (5)							
	М	н	VН:	VH								
8878.08773.0880.1229.000	м	М	Ĥ	VH	VH							
Seldom (3)	L	М	н	н	VH							
Remote (2)	L	L	М	н	н							
Unlikely (1)	L	L	М	М	н							





Incidents and Accidents Risk Analysis and the ISO 31000

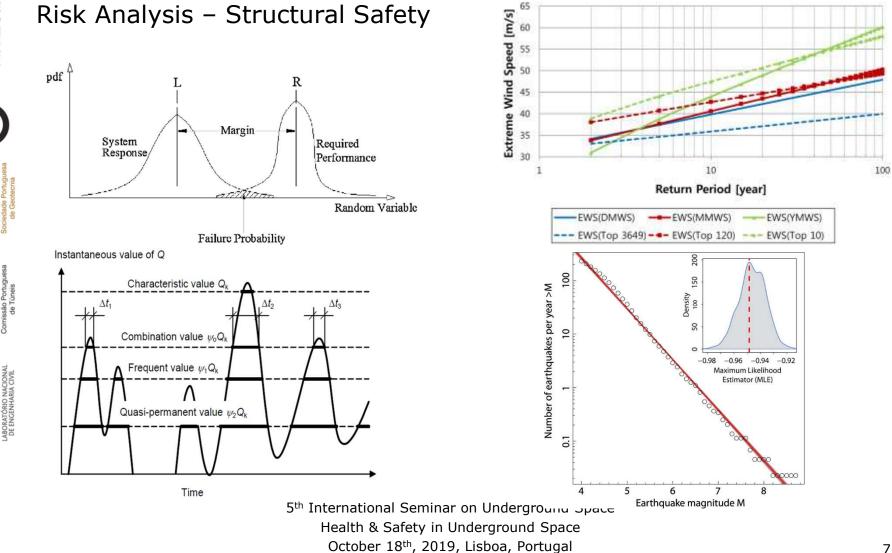


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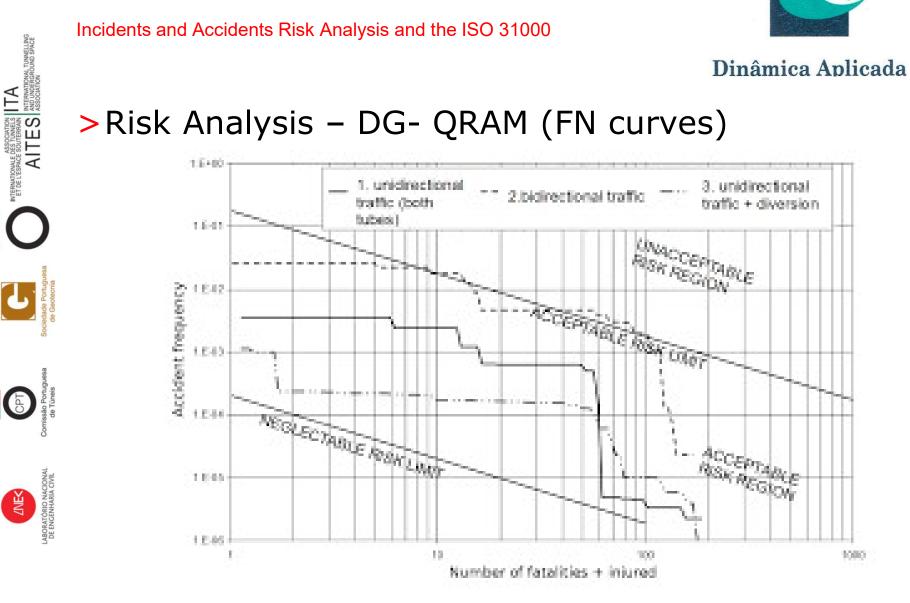
	Pro	ject	Pha	se R	isk I	Matri	ix	Almost	F Not likely to occur	Could occur	Known to occur	Common
Regimes		Health and Safety	Environmental Impacts	Financial & Asset Loss	Reputational Damage	Production / Projects	Information Technology	(1) Occurs less than once in 10 000 years	(2) Occurs once in 1 000 to 10 000 years	(3) Occurs once in 100 to 1 000 years	(4) Occurs once in 10 to 100 years	(5) Occurs once i 1 to 10 years
Catastrophi (5)	Catastrophic (5)	One or more fatalities Irreversible health problems for employees and/or community,	On or of-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
luences	Major (4)	Parsal, or medium- term, disabilities or major health problems for employees and/or	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
U	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
Moderate (3)	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	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	



Incidents and Accidents Risk Analysis and the ISO 31000

> Risk Analysis – Event tree

	traffic modes	vehicles	potential fire sizes	traffic	accident rate	fire/acc. ratio	serious fires	smoke conditions	fatality rate	fatalities
veh.km/yr			MW	veh.km/yr	PIA/veh.km		per year		per fire	per year
	uni-directional	light	15 MW					good		
2.19E+07	0.95	0.85	1.00	1.77E+07	1.20E-07	0.016	3.35E-02	1.000	0.015	5.02E-04
								poor		
								0.000	0.15	0.00E+00
	l 1	heavy	30 MW		.			good		
		0.15	0.75	2.34E+06	1.20E-07	0.016	4.43E-03	1.000	0.15	6.64E-04
								poor		
								0.000	1.5	0.00E+00
			100 MW					good		
			0.25	7 80E+05	1.20E-07	0.016	1.48E-03	0.333	1.5	7.38E-04
			0.25	7.002.00	1.202-07	0.010	1.402-00	poor		
								0.667	15	1.48E-02
					1			1		
	congested	light	15 MW		1			good		
	0.05	0.85	1.00	9.31E+05	1.20E-07	0.016	1.76E-03	1.000	0.03	5.28E-05
								poor		
								0.000	0.3	0.00E+00
			10001000000							
	[heavy	30 MW		4			good		
		0.15	0.75	1.23E+05	1.20E-07	0.016	2.33E-04	1.000	0.3	6.99E-05
								poor	3	0.00E+00
								0.000 3 0	0.002400	
			100 MW					good		
			0.25	4.11E+04	1.20E-07	0.016	7.77E-05	0.333	3	7.77E-05
								poor		
								0.667	30	1.55E-03
	bi-directional	light	15 MW		1			good		
	0.00	0.85	1.00	0.00E+00	1.20E-07	0.016	0.00E+00	1.000	0.015	0.00E+00
								poor		0.00E+00
								0.000	0.15	0.00E+00
		heavy	30 MW					good		
		0.15	0.75	0.005+00	1.20E-07	0.016	0.00E+00	1.000	0.15	0.00E+00
		0.15	0.75	0.002.00	1.202-07	0.010	0.002.00	poor	0.10	0.002.00
								0.000	1.5	0.00E+00
			100 MW		1			good		
			0.25	0.00E+00	1.20E-07	0.016	0.00E+00	0.333	1.5	0.00E+00
								poor		
								0.667	15	0.00E+00





Incidents and Accidents Risk Analysis and the ISO 31000

MTERNATIONAL ASSOCIATION ITA T DE LESPACE SOLTERAMIN AITES ABOURDAUT INVELLING ADDITES ABOURDION SPACE

		2 tubes or more	L> 3000 m re \$2.1 $$ 2.2 $*$ 1 $$ 2.2 $*$ 1 $$ 2.3 $$ $$ $$ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $	~2	ADT (2030) 4500 veh/lane (ref. ADT 10000) ⁽¹⁾	Emergency stations	At least every 150 m					
AITE		Gradients <5%	\$2.2	*	1	Gradients 0.5 and 1% (ref. 3%)	Bala				1	Comply with directive
			-			According with directive	Water supply	At least 250 m	§2.11	•	1	According with directive
A		Emergency		-14		1 elevated walkway and 1 shoulder lane each side					1	Comply with directive
ET DE L'E		walkways	§2.3.	*	>1	(1,2 m) Above directive requirements ⁽²⁾			§2.12	•	>1	Every 300 m Above directive requirements
		Emergency exits at least every 500 m	3 to	*	to	300 m Above directive requirements (ref. 500 m) . Linear Evac					>1	Above Directive requirements
		Cross connections for emergency	9			1200 m Above directive			§2.13	•	2	Two control centers (one as a full reserve in case of failure) ⁽⁵⁾ Above directive requirements
88		services at least every 1500 m		•	1,2	requirements (ref. 1500 m) ⁽³⁾					2	Above directive requirements
Portugue		Crossing of the central reserve outside each portal		•	1	According with directive		Video (CCTV)	§2.14	•	>1	DIA including smoke Above directive requirements
Dociedade de Geo		Lay-bys at least every 1000 m	§2.5	0/•	>1	600 m Above directive requirements (ref. 1000 m)		Automatic incident detection and/or fire detection	§2.14	•	>2	Above directive requirements LHD (3 modes), CCTV(DIA and smoke) CO and oppacity detection ⁽⁶⁾
ŭ		Drainage for flammable and toxic liquids	§2.6	*	1	According with directive	Bala				>2	Above directive requirements
lesa		Fire resistance of structures	§2.7		1	According with directive		Traffic signals before entrances	§2.15.1	•	>1	Above directive requirements (7)
						Above directive		Traffic signals inside the tunnel at least every 1000 m	§2.15.2	0	>1	Every 300 m Above directive requirements ⁽⁷⁾
de Tú					>3	requirements (operational requirements demand compensation)					>1	Above directive requirements
Com		Normal		•	1	According with directive		Radio re-broadcasting for	§2.16.1		1	According with directive
		safety	§2.8.	•	1	According with directive		Italance of emergency stations At least 250 m §2.11 Balance of water supply §2.12 Balance of road signs §2.13 Balance of road signs §2.13 Balance of control centre §2.14 Video (CCTV) §2.14 Automatic incident detection and/or fire detection and/or fire detection and/or fire detection §2.14 Matomatic incident detection and/or fire detection and/or fire detection §2.15 Traffic signals inside the tunnel at least every 1000 m §2.15 Traffic signals inside the tunnel at least every 1000 m §2.16 Radio re-broadcasting for emergency services §2.16 Emergency radio messages for tunnels users §2.16 Loudspeakers in shelters and exits §2.16 Ince of energency prover supply §2.17 ance of communication systems §2.16 Ince of equipments §2.16 Ince of energency prover supply §2.17 Ince of equipments §2.18 Ince of equipments §2.18				
ream		evacuation	§2.8.	•	1	According with directive			§2.16.2	•	1	According with directive
CION					1	requirements(?) Read signs 9.1.2 · · · · · Above 300 m Above directive requirements (ref. 500 m). Control canne 9.1.3 · <t< td=""><td>According with directive</td></t<>	According with directive					
TARIA ON A											1	Comply with directive
		Mechanical Ventilation	§2.9	•	>2	requirements (design fire			§2.17	•	1	According with directive ⁽⁸⁾
BORA							Balance				1	Comply with directive
		Special provisions for (semi-	67 Q						§2.18	•	1	According with directive
)transverse		•	1	According with directive					1	Comply with directive
		ventilation				Above directive						
	Bala					requirements					>24	Strucutral measures, systems and Equipments above directive Requirements
					Eth T.	atawa ati awal Caw	بلمصلل متمايي مستم					

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NTERVITIONALE DES TUNELS REPELESACE SOLTERAM AITES MERVITION DE ADECADONIO SPACE

> ABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

ZNE

L > 3000 m §1.3.2 60% >0.25 ~95% of HGV of 12 to 15 ton⁽⁹⁾ §3.1 1 According with directive 1 According with directive §3.2 §3.3 1 According with directive According with directive §3.4 1 (emergency services at the tunnel portals) §3.5 1 According with directive §3.6 1 According with directive Though above the directive no ADT or vehicle inspection mandatory §3.7 >0.25 (traffic control includes outside overheight, smoke emission and temperature of vehicle)(10) No overtake allowed §3.8 1 (just under operation control) Above the directive requirements (in 2030 \sim 1/2 of tunnel traffic capacity for §3.9 >1 peak hours used)⁽¹¹⁾ §4 1 According with directive Operational conditions heavy demanding >0.06 compensation from minimum requirements

(directive)





The PLAN FOR RISK MANAGEMENT (PRM) must presente 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 secundary subjective criteria

- 2 Risk evaluation (Risks ID; Risk Analysis; and Risk evaluation)
- 3 Risk mitigation (including monitoring and communication)



ZNEK

BORATÓRIO NACION

- At least the following themes must be looked upon: Arquelogy
- Geology and Geotechnics
- Environment
- Local envelopes
- Equipments

MTERNATIONALE ASSOCIATION ITA T DE L'ESPACE SOUTERRAIN MITERNATIONAL TUNNELLING AD UTES AND UND SPACE AD UTES AND UND SPACE O G LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

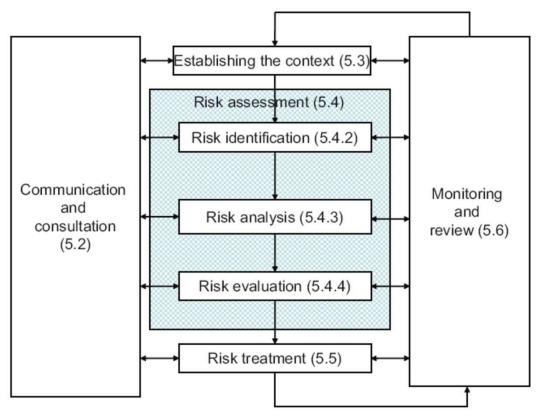
The demands from the bid are those of ISO 31000:2009

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Risk evaluation (5.4.4) Risk treatment (5.5) 5th International Seminar on Underground Space Health & Safety in Underground Space October 18th, 2019, Lisboa, Portugal



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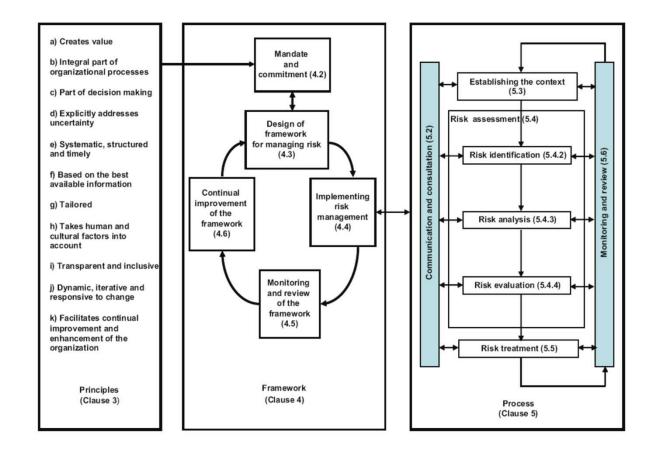


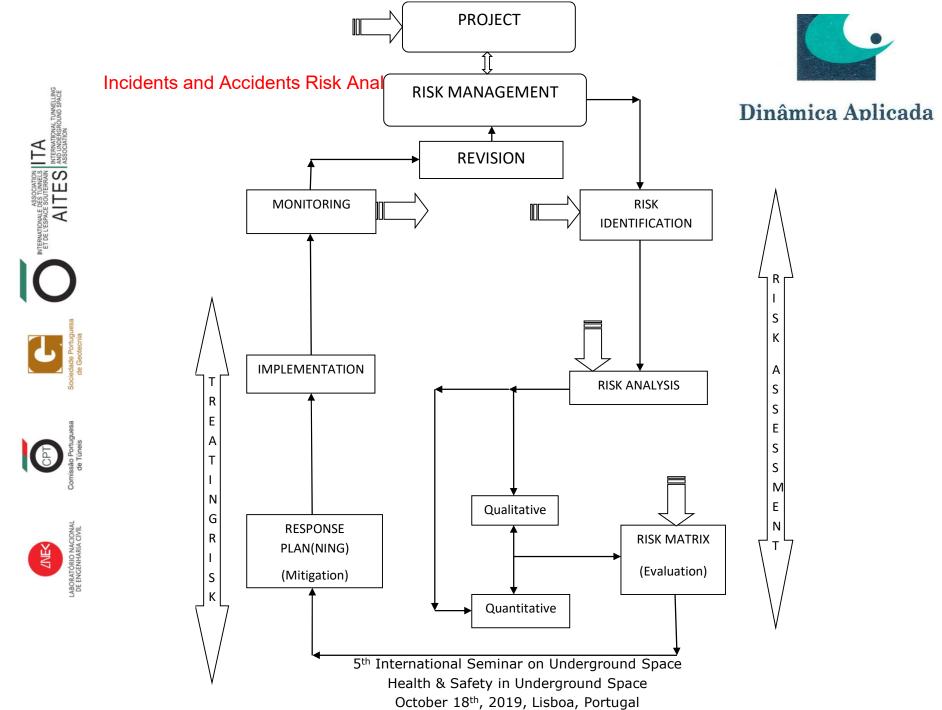






Principles; Framework and Process of risk management









Probability Severity A A Lesser NO NO Greater Lesser Lesser

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

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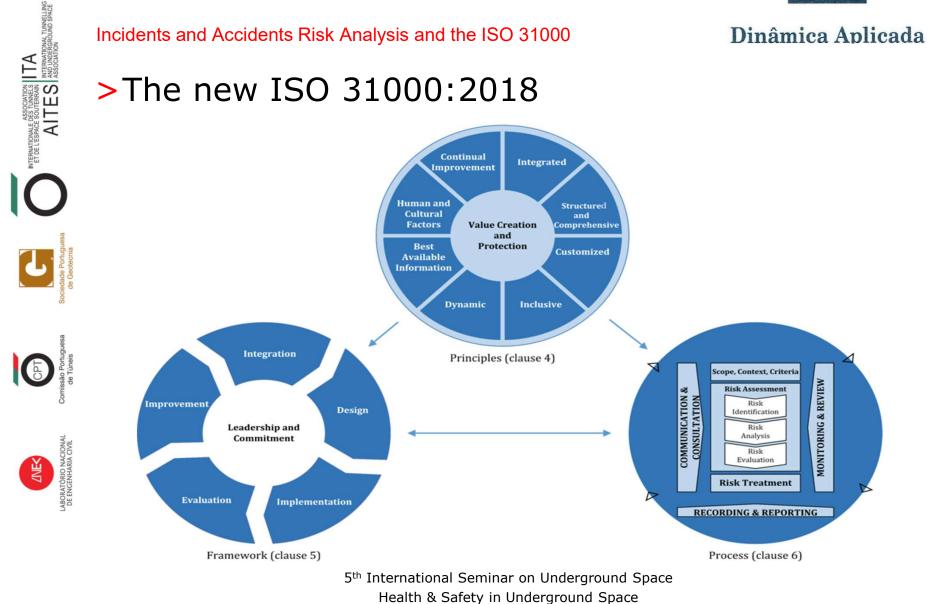
	Likel Event Count per	The cost consec The likelihood is	quence is esti determined fr	usiness-wide impact of failure mated on the DAFT Costing work om the historic frequency occuri ilure Event per Year	ng in you	ur Ope	ration o	or from	other o	ompara	able op	eration	s							
Sigma	Likel Event Count per	The cost consec The likelihood is	quence is esti determined fr	mated on the DAFT Costing work om the historic frequency occuri	ng in you	ur Ope	ration o	or from	other o	ompar	able op	eration	s							
-	Event Count per	The likelihood is	determined fr	rom the historic frequency occuri	ng in you	ur Ope	ration o	or from	other o	ompar	able op	eration	s							
-	Event Count per		ipment Fa	ilure Event per Year	cost per ent															
-	Event Count per		ipment Fa	ilure Event per Year	ost per ent															
-	Count per	Time Scale			DAFT Cost 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
		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
	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
112.001	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	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
2	3	Once per quarter			0.5					4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9
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
	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
4	0.1	Once per 10 years	Possible	Event might occur once in a lifetime career	-1						8		4	4.5	5	5.5	6	6.5	7	7.5
	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
	0.01	Once per 100 years	Rare	Heard of something like it occurring elsewhere	-2										4	4.5	5	5.5	6	6.5
	0.003	Once every 300 years			-2.5											4	4.5	5	5,5	6
5	0.001	Once every 1,000 years	Very Rare	Never heard of this happening	-3												4	4.5	5	5.5
	0.0003	Once every 3,000 years			-3.5													4	4.5	5
1	0.0001	Once every 10,000 years	Almost Incredible		-4								- Brite						4	4.5
	Note:				f \$10,00	0/year							1			11			T)	/
			a service and a second service of the second															IL		ſ
		Amber = High										open' be	ecause	t has	not yet	happe	ned)			
		and a state of the	(4) DAFT Cos	st (Defect and Failure Total Cost)) is the to	otal bus	siness-	wide co	ost from	n the e	vent	C						in the second second		
		Autorital and contributed and	Ris	k = Consequence of	Fail	ure	K IN	o On	por	tunit	ies	x Pro	bab	oility	of	Failu	re a	t Op	por	uni
	3	3 1 0.3 0.1 0.03 0.01 0.003 0.01 0.003 0.001 0.0003 0.0003 0.0001 0.0001	2 3 Once per quarter 3 1 Once per year 0.3 0nce per year 4 0.1 Once per 10 years 0.03 0nce per 10 years 0.01 Once per 10 years 0.03 0nce per 10 years 0.01 Once per 100 years 0.03 Once per 100 years 0.003 Once every 300 years 0.003 Once every 100 years 0.0003 Once every 100 years 0.0001 Once every 100 years 0.0001 Once every 10,000 years 0.0001 Once every 10,000 years 0.0001 Once every 10,000 years Note: Risk Level Red = Edmenter Amber = High Yellow = Medium Green = Low	2 3 Once per quarter 3 1 Once per year Almost Certain 0.3 Once per year Likely 4 0.1 Once per 10 years Possible 0.03 Once per 30 years Unlikely 0.01 Once per 100 years Rare 0.03 Once per 100 years Rare 0.01 Once every 300 years Very Rare 0.003 Once every Very Rare 0.0003 Once every Incredible 0.0001 Once every Almost 0.0003 Once every 2) Based on Amber = High 3) Identify 'Bl Yellow = Mediurr 4) DAFT Core	2 3 Once per quarter Almost Certain Event will occur on an annual basis 3 1 Once per year Almost Certain Event will occur on an annual basis 0.3 Once every 3 years Likely Event has occurred several times or more in a lifetime 4 0.1 Once per 10 years Possible Event might occur once in a lifetime career 0.03 Once per 30 years Unlikely Event does occur somewhere from time to time 0.01 Once per 100 years Rare Heard of something like it occurring elsewhere 0.03 Once every 300 years Note Note every 1,000 years 5 0.001 Once every 1,000 years Note: Namost Incredible 0.001 Once every 0.000 wars 1) Risk Boundary 'LOW' Level is set at total o 2) Based on HB436:2004-Risk Management Amber = High Yellow = Medium 3) Identify 'Black Swan' events as B-S (A 'Bla Yellow = Medium DAFT Cost (Defect and Failure Total Cost)	2 3 Once per quarter Almost Certain Event will occur on an annual basis 0.5 3 1 Once per year Almost Certain Event will occur on an annual basis 0 4 0.1 Once per 10 years Event has occurred several times or more in a lifetime alfetime career -0.5 4 0.1 Once per 10 years Possible Event might occur once in a lifetime career -1 0.03 Once per 100 years Unlikely Event does occur somewhere from time to time -1.5 0.01 Once per 100 years Rare Heard of something like it occurring elsewhere -2 0.003 Once every 1.000 years Very Rare Never heard of this happening -3 0.0003 Once every 1.000 years Almost Incredible Theoretically possible but not expected to occur -4 Note: Risk Level 1) Risk Boundary 'LOW' Level is set at total of \$10,00 2) Based on HB436:2004-Risk Management Amber = High 3) Identify 'Black Swan' events as B-S (A 'Black Swar Yellow = Mediury 'A) DAFT Cost (Defect and Failure Total Cost) is the to Green = Low Blue = Accepted Risk = Consequence of Failure	2 3 Once per quarter Almost Certain Event will occur on an annual basis 0 3 1 Once per year Almost Certain Event will occur on an annual basis 0 0.3 Once every 3 years Likely Event has occurred several times or more in a lifetime -0.5 4 0.1 Once per 10 years Possible Event might occur once in a lifetime -0.5 4 0.03 Once per 30 years Unlikely Event does occur somewhere from time to time -1.5 0.01 Once per 100 years Rare Heard of something like it occuring elsewhere -2 0.003 Once every 300 years Once every 3.00 -2.5 -2.5 5 0.001 Once every 3.00 years Very Rare Never heard of this happening -3 0.003 Once every 3.000 years Incredible expected to occur -4 0.0001 Once every 1.0000 years Very Rare Never heard of this happening -3 0.0001 Once every 1.0000 years 10.000 years -4 -4 0.0001 Once every 1.0000 years 2.000000000000000000000000000000000000	2 3 Once per quarter Almost Certain 0.5 0.5 3 1 Once per year Almost Certain Event will occur on an annual basis 0 0.3 Once every 3 years Likely Event has occurred several times or more in a lifetime -0.5 4 0.1 Once per 10 years Possible Event might occur once in a lifetime career -1 0.03 Once per 30 years Unlikely Event does occur somewhere from time to time -1.5 0.01 Once per 100 years Rare Heard of something like it occurring elsewhere -2.5 5 0.001 Once every 300 years -2.5 -2.5 5 0.001 Once every 3.00 years -3.5 -3.5 0.0003 Once every 3.00 years -3.5 -3.5 -3.5 0.0001 Once every 3.00 years -3.5 -3.5 -3.5 0.0001 Once every 1.00 years Never heard of this happening -3 -3.5 0.0001 Once every 2.00 years -3.5 -3.5 -3.5 0.0001 Once every 3.000 years -3.5 -3.5 -3.5 </td <td>2 3 Once per quarter Almost Certain Event will occur on an annual basis 0 3 1 Once per year Almost Certain basis Event will occur on an annual basis 0 0.3 Once every 3 years Likely Event has occurred several times or more in a lifetime -0.5 4 0.1 Once per 10 years Possible Event might occur once in a lifetime -1 0.03 Once per 30 years Unlikely Event does occur somewhere from time to time -1.5 0.01 Once per 100 years Rare Heard of something like it occurring elsewhere -2 0.003 Once every 300 years -2.5 -2.5 -2.5 5 0.001 Once every 1.000 years -3.5 -3.5 -3.5 0.003 Once every 3.000 years -3.5 -3.5 -3.5 -3.5 -3.5 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5th International Seminar on Underground Space

 ${\it Health \& Safety in Underground Space}$

October 18th, 2019, Lisboa, Portugal





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