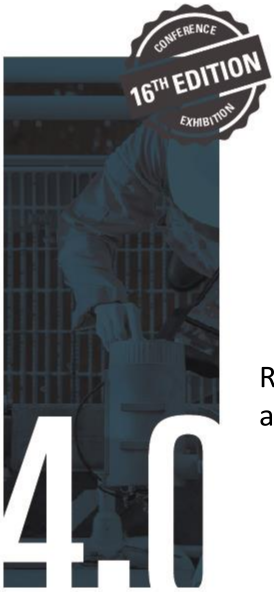


OMAINTEC CONFERENCE 2018 EXHIBITION

INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE
IN THE ARAB COUNTRIES
UNDER THE THEME
"MANAGING MAINTENANCE WITHIN INDUSTRY 4.0"
CONICIDE WITH THE 16TH ARAB MAINTENANCE EXHIBITION

Resilience of Critical Infrastructures: Lessons learned after the accident in in the Gotthard motorway tunnel

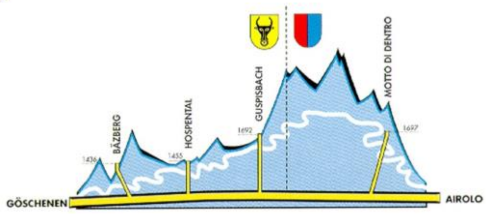
Claudio Rolandi

The accident in the Gotthard tunnel

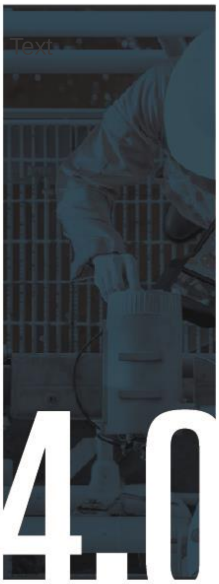
Gotthard Tunnel

The tunnel is part of the motorway A2 and connects North to South of Alps

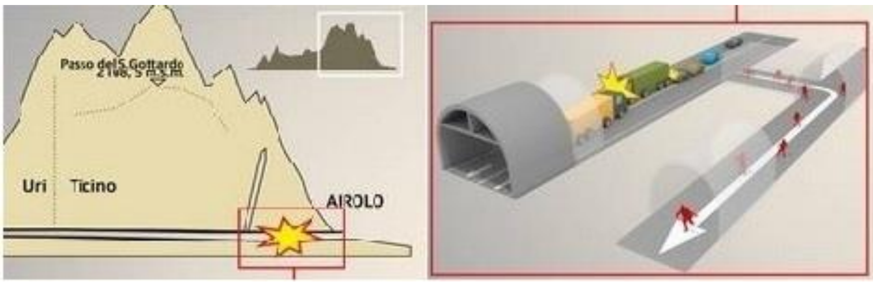
Work beginning: 1970	Opening: 1980	Cost: 686 M CHF	Length: 16.9 Kms
Escape routes: every 250 metres and connected to the safety tunnel	Lighting: 14000 light points	Surveillance: 86 cameras	Height: 4.5 metres
Ventilation: 23 fans	Suction hoods: every 90 metres	Traffic: about 10 million vehicles per year of which almost 1 million trucks	Width: 7.8 metres



The accident in the Gotthard tunnel



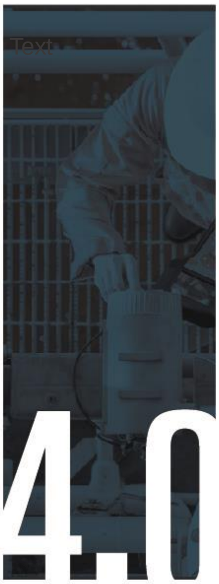
Gotthard Tunnel
Sketch and section …..



The accident in the Gotthard tunnel

The accident happened in Gotthard Tunnel in 2001
It is **October 24, 2001**. A truck takes the southern portal into the Gotthard tunnel. The driver is drunk. The vehicle skids shortly after one kilometre from the tunnel entrance.
0939: a heavy vehicle swerves and, after bumping into the tunnel wall on the right, invades the contraband lane 1.1 km from the South entrance of the Gotthard tunnel and collides head-on with another heavy vehicle that proceeds on the lane north-south route.
0940: the first telephone alarm arrives at the Police Command Operations Centre. At that moment the traffic light that stopped the vehicles at the south entrance of the tunnel was red due to a vehicle that exceeded the height allowed. The traffic police patrol, which was already at the entrance to the control tunnel, immediately went into action.
09.44: it starts the intervention device of the Local Emergency Team.
1018: the vault of the gallery in correspondence of the accident site yields (the temperature inside reached 1200 ºC).
10.30: the first SMEPI (Staff member of first responders) is established at Airolo (south entrance of the tunnel).
13.15: 6 dead persons were found by Uri's fire-fighters on the road, north of the accident.
14.15: the NOC (group of interface with organizations in partnership) is established.
17.00: 1st press conference in the presence of 100 journalists and TV networks all over Europe.

The accident in the Gotthard tunnel



The day later:
Inspection of the Scientific Police.
Continuation 24/24 of the extinguishing of the fire.
Evacuation of the 10 corpses and transport to the morgue.
2nd press conference.
Visit of federal political authorities
Start of medical examinations of corpses.
Early warning for the intervention of the DVI-Team (Disaster Victim Identification)
Identification and recognition of 2 persons.
Two days later:
Start of technical surveys of the Scientific Police with external specialists
252 people reported missing via hotline
Calls from 18 embassies and consulates
3rd press conference
Legal medical activity for the 10 victims recovered (the 11th victim was found completely charred a few days later)
Need to verify the presence of toxic materials
Identification and recognition of 3 other persons
Nine days later:
Conclusions of activities by the Scientific Police
Authorization to remove vehicles and destroyed parts by the judiciary.
Fifty-eight days later (21st December 2001):
Tunnel was reopened to traffic.

Adopted Methodology

Critical Infrastructures

Definition by Wikipedia

Critical infrastructure is a term used by governments to describe assets that are essential for the functioning of a society and economy

Resilience of Smart Critical Infrastructures

Definition by Linkov et al

Resilience of an infrastructure is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruption.

Resilience management goes beyond risk management to address the complexities of large integrated systems and the uncertainty of future threats, as it includes risk analysis as a central component.

Risk analysis depends on characterization of the threats, vulnerabilities and consequences of adverse events to determine the expected loss of critical functionality.

Adopted Methodology

Resilience of Smart Critical Infrastructures (SCI)
Definition by SMART Resilience Group

Modern critical infrastructures are becoming increasingly “smarter” (e.g. cities).

Making the infrastructures “smarter” usually means making them smarter in normal operation and use: more adaptive, more intelligent…

But will these ***Smart Critical Infrastructures*** (SCIs) behave equally “smartly” and be “smartly resilient” also when exposed to extreme threats, such as extreme weather disasters or terrorist attacks?

If making existing infrastructure “smarter” is achieved by making it more complex, would it also make it more vulnerable?

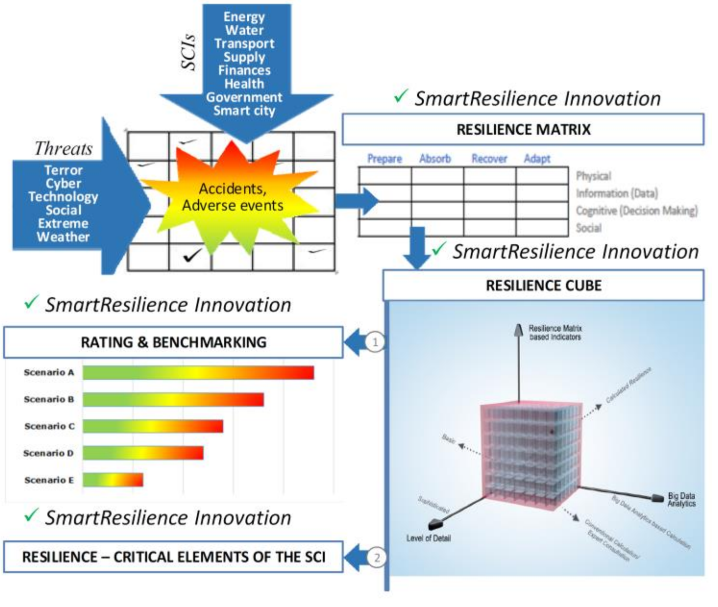
Would this affect resilience of an SCI as its ability to anticipate, prepare for, adapt and withstand, respond to, and recover?

These are the main questions tackled by this proposal.

OMAINTEC 7

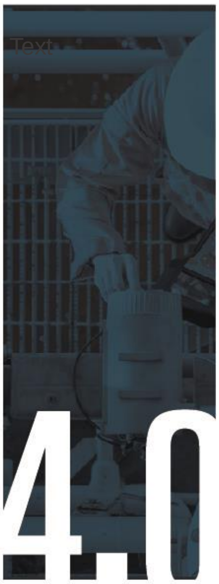
Adopted Methodology

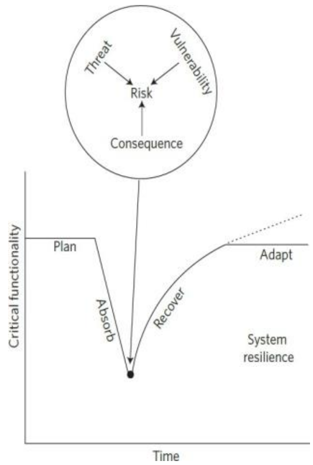
Resilience of Smart Critical Infrastructures (SCI)



OMAINTEC 8

Adopted Methodology



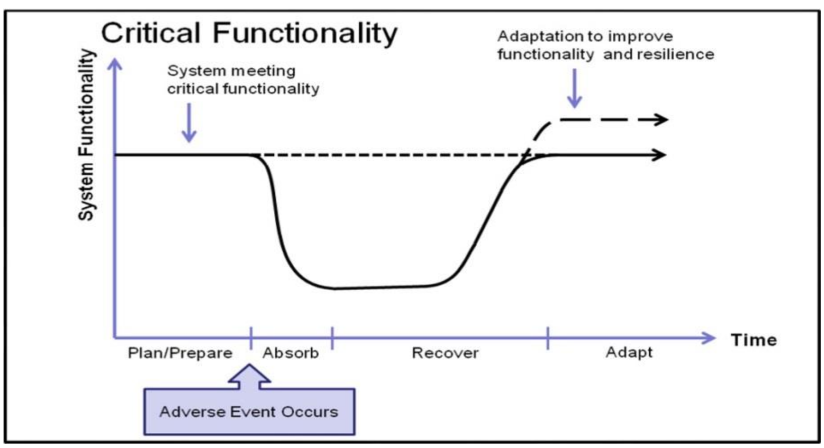


Risk in a system is interpreted as the total reduction in critical functionality and the resilience of the system is related to the slope of the absorption curve and the shape of the recovery curve — indicating the temporal effect of the adverse event on the system.

The dashed line suggests that highly resilient systems can adapt in such a way that the functionality of the system may improve with respect to the initial performance, enhancing the system's resilience to future adverse events and the concept of resilience stresses upon these aspects.

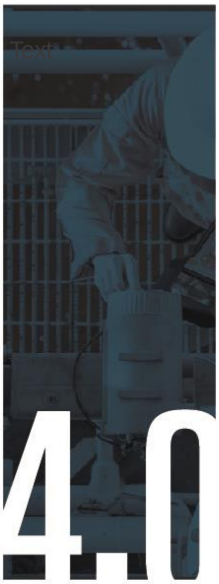
Adopted Methodology

Several scientific disciplines characterise the functionality as a more or less smooth V-curve or U-curve. This has also been done within critical infrastructure resilience.

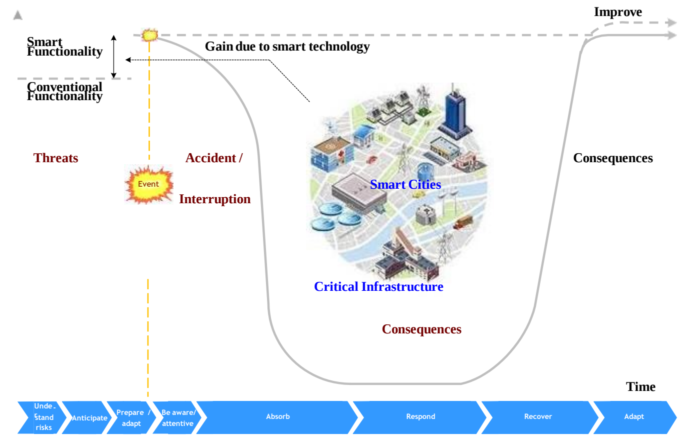


Critical infrastructure system functionality curve (by Linkov et al.)

Adopted Methodology



In SmartResilience, this curve is not of main interest as a measure of resilience. Resilience is measured indirectly through the status of the resilience dimensions/phases using resilience indicators. In addition, the four resilience dimensions/phases in the figure below (plan/prepare, absorb, recover and adapt) have been extended to seven resilience dimensions/phases.



Lessons Learned

After the previous event in Mont Blanc Tunnel

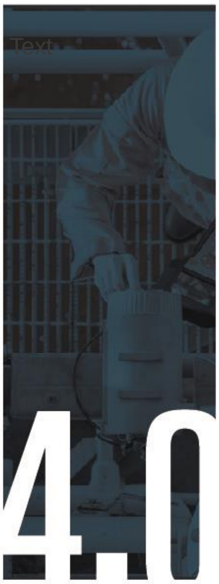
The fire of the Mont Blanc Tunnel occurred on the morning of March 24, 1999, inside the tunnel of the same name. The event cost the lives of 39 people.

The tunnel was closed for three years and reopened only for cars on 9 March 2002, after extensive repairs and renovations (the vault, heavily damaged, was completely rebuilt). These were the main interventions adopted after the fire:

- the creation of fire niches every one hundred and fifty meters,
- the creation of SOS niches every hundred meters alternating on the two lanes,
- a first-aid station was built in the centre of the tunnel, with a vehicle equipped to extinguish the flames and a group of fire-fighters permanently on site,
- construction of shelters connected to an independent evacuation tunnel (under the carriageway),
- construction of a unique control room.

This tragic experience and the consecutive actions allowed to reduce the effects of the accident in the Gotthard tunnel and get a much lower recovery time (from three years to less than two months).

Lessons Learned



From the event in Gotthard tunnel

Since the event, some actions were implemented, such as for example:

In Europe, the Implementation of the European directive 2004/54 / EC, which was then taken up by Switzerland, which determines technical and organizational aspects related to the tunnels, as well as the need to have safety documentation;

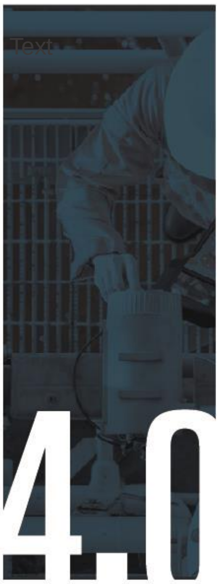
In Switzerland, the implementation of Directive USTRA 19004 highlights the importance of carrying out the correct risk analysis in the initial design.

Lessons Learned

How to design tunnels

- In case of new constructions, the adoption of two separate tunnels is suggested.
- As for existing tunnels:
    - Safe zones placed at a distance not longer than 200 metres;
    - Lighting to lead to safe zone placed near the pavement and special flashing lamps on the entrance of each safe zone;
    - Reinforced false ceiling to prevent collapses and guarantee the functioning of fume extraction and ventilation;
    - Higher capacity fans for fume extraction and ventilation;
    - Fume detectors, thermal cameras and web cameras placed;
    - Distributed wi-fi and GPS antennas all along the tunnel;
    - Many other gadgets.

Lessons Learned



How to organize the access of dangerous transports

- List of forbidden materials

How to design vehicles (i.e. criticalities of turbo-compressors, …)

How to check the efficiencies of vehicles

- Before the accident, there was only the control of maximum height;
- After, the previous control of documentation in the customs and thermo-cameras analyses before entering and sample controls on trucks.

Lessons Learned

How to inform (motorists)

- For Swiss people, information through media and education to earn driver's license
- For foreigners, information before passing customs

How to train (truck drivers)

- Actually in Switzerland, it is required a special license only for the transport of dangerous substances.

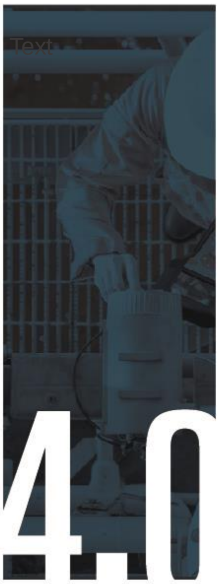
How to monitor systems (input controls –control of maximum heights, dosage of access and minimum distance among vehicles, exceptional transports permitted only during the night and with temporary closure of the tunnel, etc.)

How to train teams (maintenance, rescue, ...)

- Fundamental requirement is the coordination of the different teams and carrying out joint exercises.
- A special requirement regards communication: to North people speak German, to South Italian, even if there are all Swiss.

How to organize support structures (such as hospitals, mortuary rooms, collection areas for research findings, etc.)

Lessons Learned



There are many lessons learned by the accident in Gotthard tunnel, but the most important could be considered the following.

- Tunnels crossing mountains, such as most other critical infrastructures, are strategic and are investment that will be designed, built, maintained and made updatable with the evolutions of technology and lifestyles.
- Communication between the different systems involved in the use of infrastructures is essential to guarantee operational continuity and the possibility of recovering from situations that are difficult to predict but not impossible.
- The opportunities created by the introduction of new technologies must not undermine the continuity of systems that are already sufficiently performing.

References

- Wikipedia: https://en.wikipedia.org/wiki/Critical_infrastructure
- Proceedings from the event" Gottardo 24 ottobre 2001. Imparare dalla tragedia / Gotthard 24th October 2001 – Learning from the tragedy", held in SUPSI with the speeches by:
  - Daniele Albani, Safety Officer of Cantonal Roads - Construction Division
  - Antonio Perugini, Deputy Prosecutor General of the Canton Ticino
  - Andrea Mordasini, Safety and Security Officer for several European tunnels, member of BoD in Lombardi SA
  - Luca Ceresetti, Responsible for the Lombardi SA Safety and Security sector
- Smart Resilience Indicators for Smart Critical Infrastructures (https://www.ivl.se/download/18.4a88670a1596305e782dd/1484131256606/E001.pdf)
- Linkov, I. et al. (2014). "Changing the Resilience Paradigm." Nature Climate Change 4(6):407 – 9. Retrieved (http://www.nature.com/doifinder/10.1038/nclimate2227)
- Resilience Assessment Framework http://www.smartresilience.eu-vri.eu/Resilience-Assessment-Framework

claudio.rolandi@supsi.ch