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Resistance and resilience of systems

Critical infrastructure in mountain areas in the era of climate change – a multifaceted challenge

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Introduction

The presentation is inspired by the results of the European project "Smart Resilience" aimed at assessing and managing the resistance and resilience of critical infrastructures, i.e. their ability to cope with possible scenarios or adverse events that can potentially lead to significant damage and prolonged interruptions in availability.https://resiliencetool.eu-vri.eu/

SmartResilience

Smart Resilience Indicators for Smart Critical Infrastructures

Premise 1

Deductive method: it starts from general assertions to arrive at specific conclusions.

Inductive method: starts from specific observations to arrive at generalizations.

What's the matter?

The problem must be well identified.

Are there any tools that can solve the problem?

If so, how effective are they?

If not, how can I limit the effects of the problem?

Premise 2

RCA – ROOT CAUSE ANALYSIS

Maintenance is based on the search for the main causes of failure.

In the discussion, we will use the ISHIKAWA model at 8M:

- Machine;
- Measure;
- Material;
- Method;
- Manpower;
- Money (capital);
- Management;
- Milieu (environment).

Infrastructure

An infrastructure is the basic systems and services that a country or organization uses to work effectively.

Therefore, each country defines what critical infrastructure is:

- For some countries, power generation, rail networks, power grids, aqueducts, highways, rail networks, ports, airports, arms manufacturers, ...
- For other countries, sectors related to food, such as bread and milk, and health, such as vaccines, antibiotics and the health care system, are also strategic, hence the financing and control over companies in their respective sectors.
- For an industrial plant, infrastructures are those that allow the implementation of processes without entering into the production of products.

Infrastructure

Utilities

Usually, they are the energies distributed in the plant:

- Electricity (which usually runs all the following ones as well)
- Compressed air
- Methane
- Water (industrial, drinking, softened, demineralized, purified, sterile)
- Wastewater
- Telecommunications

Infrastructure

Facilities

We also include all those services that could compromise the proper functioning without being part of the production process.

Some examples:

- HVAC systems
- Fume treatment plants
- Cranes and overhead cranes
- Truck scale
- Staff access control
- …

Criticality

We will start from the definition of FMEA to define the criticality of a system.

Failure Mode and Effects Analysis (FMEA) is a structured way to identify and resolve potential problems, or failures, and their resulting effects on the system or process before an adverse event occurs.

What could be the cause that is able to generate an unpleasant event?

There are different types of events:

- **Events that have already occurred,** for which it is possible to analyse the causes, the preventive actions implemented and not implemented, the reactions and behaviours, the interventions and methods of absorption, the recovery times and costs, if the improvement actions were implemented subsequently.
- **Events that have never occurred but are reasonably conceivable,** for which there is no documented history. A typical example would be the fall of a meteorite of catastrophic proportions. We know that it happened, we have hypothesized the consequences and we can predict its occurrence in advance, but we have no experience in implementing measures to prevent or mitigate the effects.
- **Unthinkable but not impossible events,** and here we leave it to the imagination as long as there is the possibility of perceiving the impending risk.

Criticality

The FMEA tool is based on the definition of three factors:

Severity: An assessment of the consequences of an unwanted or undesirable event, from minor damage to catastrophic effect.

Probability: An estimate of the probability of the event occurring, from improbable (once every 1000 years, for example) to recurring.

Detectability: An estimate of the likelihood that a cause of a potential harmful event will be detected and corrected before reaching the person or property being protected

The method allows us to define a **Priority Index**, which is given by the product of the **Severity**, **Probability** of occurrence and **Detectability** rankings of the unwanted phenomenon with a necessary advance.

$$RPN = S \times P \times D$$

Criticality

What actions should be taken against the risks?

- **Risk avoidance** – Eliminate risk by stopping or modifying the activities that generate it. This can involve changing processes, canceling projects, or exiting high-risk markets/areas.

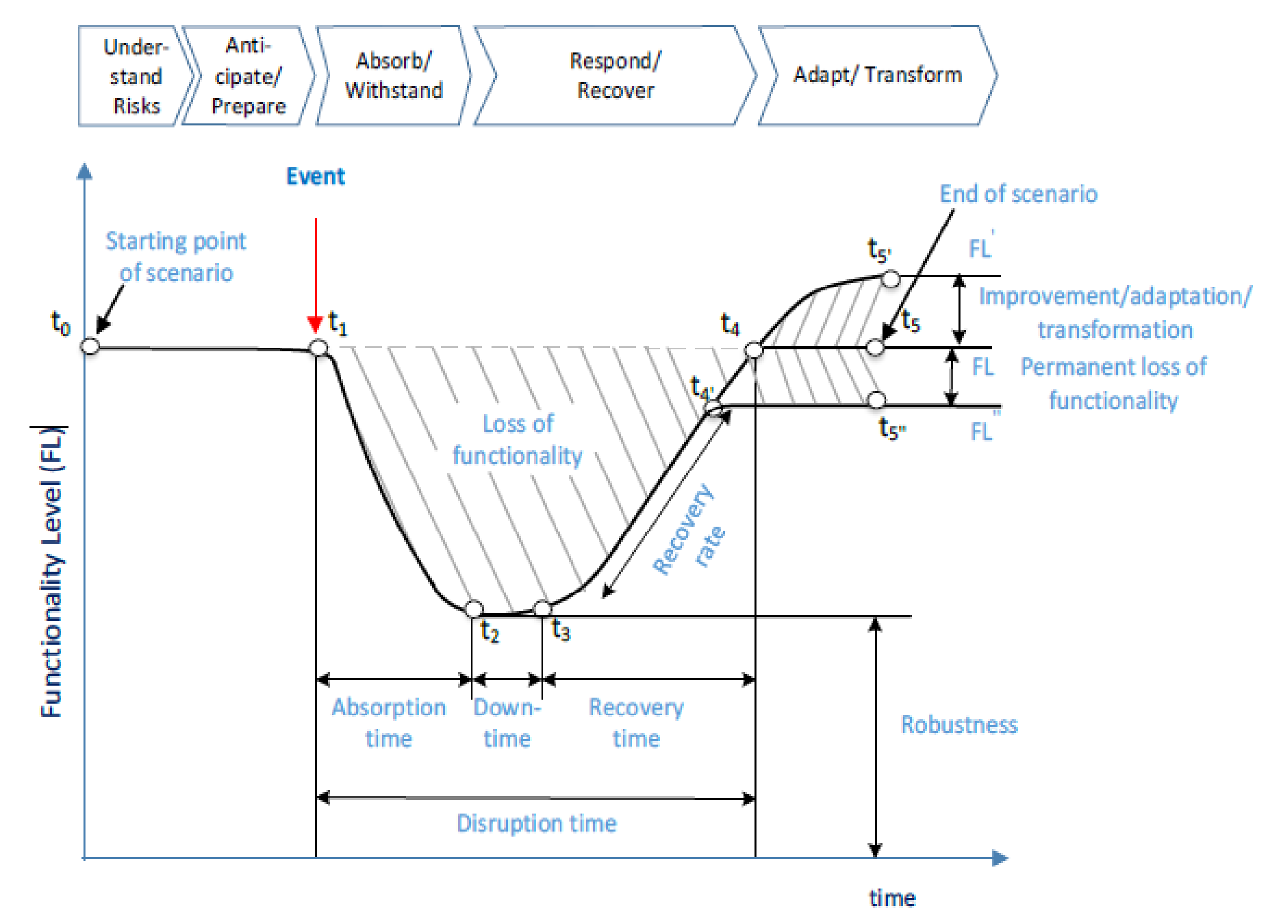
- **Risk reduction** – Take proactive actions to reduce the likelihood or consequences of a risky event. This could include improving security protocols, implementing new controls, training, etc.

- **Risk transfer** – Transferring part or all of the burden of risk to third parties, for example through insurance policies: outsourcing or contractual sharing of risk.

- **Acceptance of risk** – Acknowledge the existence of the risk but take no further action beyond periodic monitoring and contingency planning.

Basis of the analysis

In the analysis, the model of Resistance and Resilience is followed.



The functional level of a critical infrastructure in the time before, during, and after the incident. Taken from the "Smart Resilience" project.

To improve the situation, you could:

- Increase the functional level of the system in preparation for the event;
- Reduce the time due to the absorption of the blow;
- Reduce downtime
- Reduce the time needed to restart;
- Not to be satisfied with restoring the pre-existing situation but to learn from experience.

Basis of the analysis

It will be possible to implement:

Passive protections, such as barriers or devices to be included at the design level or changes to be made during the phases prior to production or service;

Active protections, such as monitoring or training staff to make appropriate decisions in cases that may occur.

Example

If the electrical substation is located near a ditch, it is preferable that it is positioned at least above ground level.

If the cabin is already located in a risk area, appropriate evacuation systems, either automatic or based on trained teams, must be monitored and set up.

Safety from natural hazards

Infrastructures

Natural hazards in an Alpine environment can be of different types and intensity, such as water hazards (floods, river floods, thunderstorms, water bombs, etc.), gravitational hazards (landslides, avalanches, landslides, rockfalls, etc.) or other hazards (tsunamis, earthquakes, etc.).

Some of these have the intensity to be able to seriously damage or destroy the infrastructure, making it partially or totally unusable, as happened in several points of the Maggia Valley.

An optimal risk mitigation methodology can be the one used in the field of occupational safety in which the STOP system (Substitution, Technical, Organizational, Personnel) is adhered to.

For this reason, correct planning in the planning phase can lead to the avoidance of the danger zone (Replacement) or to the introduction of risk mitigation measures such as protection valleys or rockfall protection nets (Techniques).

In view of the definition of these measures, however, the assessment of the risk areas is of fundamental importance, in order to understand whether the measure undertaken is economically sustainable.

Safety from natural hazards

Users

Some of the dangers considered, on the other hand, have a lower intensity such as not to damage the infrastructure itself but to have an impact on any users.

Also, in this case it is necessary to take all the necessary measures to protect users.

In addition to the above, in fact, additional measures such as traffic lights and traffic bans (Organizational) can have an effect on users.

Clearly, compliance with these measures, as well as users' understanding of the risks, are part of the mitigation measures (Personnel).

Surrounding environment

The infrastructure itself can become an element that can change the effects of any natural hazards.

It is therefore important to assess that the infrastructure and all the measures put in place to protect it do not modify the territory by creating dangers for the surrounding environment.

Safety from anthropogenic hazards

Infrastructures

Examples of citable anthropogenic hazards:

Culpable human activities:

- Road accidents (minor or major)
- Construction site accidents
- Industrial or human activity in the vicinity of the infrastructure
- Deficient projects
- Lack of maintenance
- Traffic problems
- Blackout

Malicious human activities

- Sabotage
- Events
- Wars

Safety from anthropogenic hazards

Users

It is necessary that the conformation of the road and its use (accidents and near misses) are constantly under control.

Therefore, different aspects of the design and operation must be constantly analyzed to ensure continuous improvement of the road.

Some of the tools used in Switzerland are the ISSI (Infrastructure Safety Tools) and the OPIR (Major Accident Prevention Ordinance) analyses.

ISSI tools are a collection of 6 standardized techniques that analyze the impact on user safety of the different variants of a preliminary project, the impact of the different elements introduced in the different design phases, the state of maintenance and operation to assess compliance with the standards, as well as the analysis of accidents, whether they are scattered on the different road axes or concentrated in specific black spots.

Finally, events of particular importance can lead to a reanalysis of the rules as happened in the case of a bus accident on a pier of a tunnel in Sierre, causing the death of several children.

This event caused an international sensation by defining new ways of designing tunnel accesses and road niches.

Safety from anthropogenic hazards

Users

…

OPIR Analysis), consists in the analysis of possible accidents caused by the transport of dangerous goods to the surrounding environment, whether it is a "human" environment (number of possible direct deaths), or environmental (pollution of aquifers or waterways). In this case, the system assesses the possibility that some explosion or pollution scenarios will cause damage to the surrounding environment on the basis of accidents.

Similarly, the surrounding environment, if industrial with chemical risks, can itself be a source of danger and must consider the surrounding road infrastructure as a target of damage.

SISI Alptransit Accident Report - https://www.sust.admin.ch/inhalte/BS/2023081002_GBT_Media_I.pdf

Safety from anthropogenic hazards

Surrounding environment

The infrastructure itself, however, is to be considered as an artificial element inserted in a larger environment.

So here it can become, for how it is made but also for the users who use it, a source of danger for the external environment.

These interactions are also to be considered in a multidisciplinary environment, in order to assess the risks and the necessary measures to be taken.

Here, as mentioned above, an OPIR-type event could create damage to those who reside on the side of the road or due to damage to the surrounding environment if it were to be polluted.

Safety from anthropogenic hazards

Surrounding environment

A further possible impact is represented by the event of the collapse of the Morandi bridge in Genoa where the collapse of this infrastructure involved 2 industrial warehouses under it, although fortunately none of the buildings located below it was damaged.

However, road infrastructures are often interconnected with other infrastructures, such as water collection (meteorological or industrial).

A further example of impact occurred precisely in the event of the collapse of the Visletto bridge (Maggia Valley), in which following the collapse, the canalization that passed through the bridge was torn, pouring the sewage content into the water of the river below, polluting it and making the water of much of the territory downstream of the event undrinkable.

Business Continuity – Security of connected zones

It needs focusing only on the impact that these hazards could have on the infrastructure itself and on the environment connected to it.

The road infrastructure is an element of transit, of passage, which serves to connect the most disparate places.

A complete analysis of the importance of this infrastructure must also evaluate any aspects at the "medium" and "maxi" level.

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
The event

Case of the Maggia Valley: the entire valley found itself confronted with a very complex situation of discomfort generated by the bad weather that raged in the region.

The first problem encountered was the impossibility of getting in touch, during the night, with the areas where the storm was in progress.

Arriving on the spot for the check, the intervention forces discovered that the road bridge had collapsed, the only access to an entire valley that winds, in addition to its side valleys, for more than 20 km.

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
The event

With the collapse of the same, the electricity supply of the entire valley, as well as the telephone lines that allowed the connection with the various people in the valley, had been compromised.

In an era connected via smartphone, but the absence of power to the entire valley also had the impact of the disabling of the entire mobile telephone network.

To continue, as already anticipated, the sewer connection was also compromised.

Moreover, there were a summer camp and a football tournament with concerts in the area:

So, it was also necessary to check and contact the people present in the valley to check that everyone was okay despite the various landslides that occurred during the night.

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
Disaster recovery

It required immediate prompt intervention, to ensure the safety of the entire population present on the site but also the functioning of the entire territory.

It was first necessary to at least partially restore the functioning of the infrastructure, and then bring it back to full capacity, improving the service and safety of the same.

Note: often the speed with which you can move clashes with bureaucratic procedures, which is why it becomes important to have "streamlined" procedures that allow you to adapt to emergency situations, but at the same time "solid" that allow you to ensure that you are following legal regulations.

Specifically, the intervention appeared to have been divided into several phases.

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
Sequence of activities

- Event detection and situation analysis
- Organize for the immediate intervention
- Securing the intervention/rescue axis and interventional planning in general
- Ensuring viability
- Restore service

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
Sequence of activities

Military Bridge installation

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
Sequence of activities

From the top of the photo:

1. ford,
2. footbridge,
3. collapsed bridge and
4. military bridge

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
Sequence of activities

At the same time as the partial restoration interventions, it was necessary to evaluate the situation and start by designing a solution that would be valid in the long term.

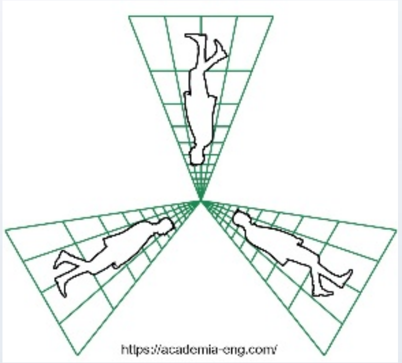
For this reason, a process of design, selection and assignment of mandates, that would normally last 4-6 years, was condensed into less than 1 year, allowing less than a year from the event to assign the works, with the aim of delivering the new bridge within a further year.

In the meantime, this bridge had to be designed with criteria that answered all the questions that arose in compliance with the steps explained above.

Case study: Flood in the Alps that destroyed a bridge and disrupted all related utilities
Lessons learned

In an environment characterized by constant change, be it technological or climatological, it is no longer just to be ready to intervene, but more ready to adapt, to learn from the past, not to replicate, but to change one's behavior in the management of events, in constant improvement in order to no longer follow decisions of the past that, in reality, they only worked in an environment that could no longer be replicated, since everything changes and situations can never be twice the same.

If you need more information



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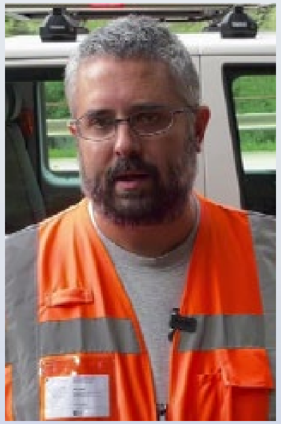

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