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TRANSTUN Project: a Public-Private-Partnership to Enhance the Capacity of Emergency Response in case of CBRN Incident in Road Tunnels

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The TRANSnational TUNnel operational CBRN risk mitigation (TRANSTUN) project has been able to create a Network of stakeholders coming from more than 15 countries worldwide, draft a set of Operational Guidelines based on a tailored Risk assessment, and undertake a real-life exercise, involving more than 250 first responders from France and Spain, to increase the interagency and inter-country capacity of emergency response in case of CBRN events in real cross-border tunnels. Despite the high costs and the time required to organize a real-life exercise, only this kind of exercises allow to verify and test current operational procedures carried out by rescue teams, first responders and tunnel operators to deal with a chemical accident/event in a tunnel under stressful conditions. For these reasons, real-life exercises also represent a unique opportunity to highlight the gaps that emerged and the critical issues that need to be managed in the response to this type of event. In this work, the findings of the real-life exercise activity performed within the TRANSTUN project at the Bielsa-Aragnouet tunnel are presented. The main objective of this work is to analyse the real-life exercise performed on September 9, 2021 and lasted about 6 hours with the aim to assess safety and security procedures, optimal use of CBRN equipment, knowledge of decontamination processes and finally to evaluate the performance gains and operational capacity by measuring intervention time and the number of personnel required, comparing the different available technologies. The results of the evaluation process carried out at the end of the real-life exercise are reported in this study both in terms of quantity and quality (lessons learned and good practices) and represent an example of a testing methodology that can be used as a reference point for the management of similar activities in the future involving further cross-border tunnels as well.

1. Introduction

Road tunnels are transportation infrastructures often used to improve the Plano-altimetric junction of road sections, reduce slopes, sometimes even lengths (distances) and fuel consumption; however, the confined environment can represent a critical safety issue for users in the event of a relevant accident.
Relevant accidents, including CBRN ones, occurring in a tunnel may not only affect the users (potentially exposed population) inside the Infrastructure Itself, but it can cause also social and economic effects that may impact an area (region or state) because of the prolonged closure of the tunnel. These impacts can be associated with the reduction of passenger and freight mobility by causing, for instance, an increase in travel time due to the detour of traffic to alternative routes. Considering the importance and location of a tunnel, it is therefore necessary also to evaluate the potential impacts on the country's socio-economic system in case of an extended closure (Gehandler, 2015). The closure of a tunnel due to a major event disrupts the entire section, generating a detour of traffic to alternative and perhaps already congested routes. In this sense, the tunnel risk analysis plays an important role in assessing the vulnerability of the infrastructure to determine the possible effect on the entire transportation system after the closure of a road section. Therefore, knowing the technical and organizational specific characteristics of the tunnel of interest is essential to assess its resilience following

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a major event considering two main issues: i) the potential exposure to users ii) the effects resulting from the closure timeframe required to restore normal operational conditions. In tunnels the probability of an accident occurring and the likelihood of being injured is lower than in open-air road sections. However, when an accident occurs in a tunnel (e.g., a fire, dispersion of hazardous materials), the potential consequences are greater than in open-air sections because of its confined environment (Borghetti et al., 2019; Nævestad and Meyer, 2014). Since vehicle drivers drive more carefully in tunnels than in open-air sections, it is estimated that the probability of occurrence of an accident is about 50% than in open-air sections, (Nussbaumer, 2007; Caliendo and De Guglielmo, 2012; Bassan, 2016). According to that, main studies concerning road tunnel safety typically focus on fires involving vehicles and the release of hazardous goods since those scenarios can cause significant consequences for both the tunnel infrastructure and the overall transportation system (Mashimo, 2002; Vuilleumier et al., 2002; Caliendo et al., 2013).
Following the accident occurred in the Mont Blanc tunnel in 1999, which caused 39 fatalities and extensive damage to the tunnel structure, the European Community issued the Directive 2004/54/EC on minimum safety requirements for tunnels part of the Trans-European Road Network (TERN) and longer than 500 m.
The Directive regulates the safety of road tunnels, establishing minimum requirements and identifying risk analysis as the analytical method for estimating the risk level of each tunnel, that basically consists of identifying the answers to the following three questions (Kaplan and Garrick,1981; Kaplan, 1997):

- what could happen within the tunnel infrastructure?
- what is the probability of the event occurring?
- having established that the event occurs, what are its possible consequences?

The first question implies the definition of one or more hazardous scenarios. The second expresses the probability that a specific scenario would occur, while the last concerns the quantification of potential consequences caused from it.
Against this backdrop, the TRANSTUN project – Co-funded by the European Union Internal Security Fund Programme – represents a unique example of Public-Private-Partnership focused on increasing the interagency and inter-country capacity of emergency response in case of CBRN events in a real cross-border (road) tunnel. The project consortium is composed by partners from Italy, France, Belgium and Spain who, among others, have been able to undertake a real-life exercise held at the Bielsa-Aragnouet tunnel, which is a Cross-Border tunnel located between the north of the Huesca province in Spain and to the south of the department of Hautes-Pyrénées in France, in the Pyrenees mountains. This is a monotube and bidirectional tunnel 3,070 m long, 1,303 m of which is in Spanish territory and 1,767 m in French territory (see Figure 1).

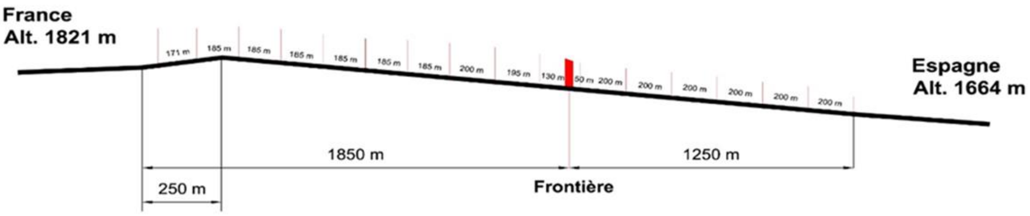


Figure 1: Tunnel cutting plan.

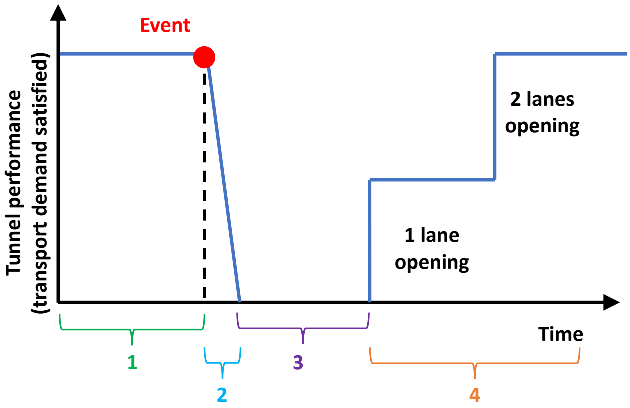
More than 250 first responders, from France and Spain, have been involved in testing their interagency and cross-country capacity of response against a CBRN terroristic event. The Prefecture des Hautes Pyrenees, the Gendarmerie Nationale des Hautes-Pyrénées, the SDIS65, and the Guardia Civil contributed to both organising and playing the exercise, while more than 50 experts representing 8 EU countries attended the event as technical observers.
Main objectives of the TRANSTUN exercise were the following:

1. To assess and improve the operational response of Tunnel Operators to CBRN events.
2. To implement and test the procedures best suited to the CBRN risk (ventilation, evacuation, etc.).
3. To test CBRN detection solutions.
4. To test the CBRN protection equipment essential for an appropriate response.

The TRANSTUN exercise represents the first case of EU real-life exercise concerning the CBRN threat against cross-border tunnels. Compared to previous exercises focusing on emergency situations in tunnels, TRANSTUN focused on the direct involvement of the Tunnel Operator, including the reference Safety and Security Managers responsible for ensuring the operativity of the infrastructure affected by the incident. Furthermore, it was essential to also consider the binational responsibility and cooperation as a peculiar requirement for cross-border tunnels. Thus, we could assume it paves the way for the implementation of further exercises involving other cross-border tunnels to replicate the TRANSTUN experience according to specific requirement.

2. The Emergency Management approach in case of an incident in the Transport system

Emergency management within transportation and mobility systems is a closely related concept to resilience. In technical scientific literature, several scholars have addressed the issue of resilience in the transportation infrastructure following a relevant event (Reggiani, 2013; Mattsson and Jenelius, 2015). There are several definitions of resilience, including those related to the scope of this study; one of which can be "*the ability of an entity - e.g., asset, organization, community, region - to anticipate, withstand, absorb, respond to, adapt to, and recover from a disruption*" (Carlson et al., 2012; Borghetti et al., 2021). With this regard, Figure 2 shows the trend and components of resilience with reference to a transportation system after a major event.



1	2	3	4
Preparedness	Mitigation	Response	Recovery
Activities taken by an entity to define the hazard environment to which it is subject	Activities taken prior to an event to reduce the severity or consequences of an hazard	Immediate and ongoing activities, tasks programs and systems that have been undertaken or developed to manage the adverse effects of an event	Activities and programs designed to effectively and efficiently return conditions to a level that is acceptable to the entity

Figure 2: Components and trends of the resilience of a transportation system.

The performance of a transport infrastructure, in this case a tunnel, can be evaluated by considering some parameter of efficiency such as, for instance, the percentage of traffic satisfied. The recovery time of an incident within a tunnel may be longer than a common accident because of the confined environment and thus, the difficulty of access and maneuvering by emergency responders. In case of the extended closure of a tunnel, domino effects can occur resulting, for instance, in high levels of congestion on the roadway network surrounding the event area. With this regard, it is important to inform drivers about the tunnel closure as soon as possible allowing them to take alternate routes and avoid becoming trapped and increasing congestion in the area where the event occurred. When an accident occurs, it is important to consider the socio-economic impacts as well: it is difficult to estimate the cost of delays due to the consequences of the accident, because in general, not only the loss of user time must be considered, but also the delayed delivery of goods, missed appointments, missed flights at airports, personal inconvenience, and frustration. Factors that can mostly influence the response time following a traffic accident are: location, time, direction of movement, type of accident, weather conditions, number and type of vehicles involved, number and location of lanes involved, number and type of responders required at the scene, and traffic queues (Haule et al., 2019, PIARC, 2008). Regarding traffic and mobility management, when a major event occurs requiring an extended tunnel closure, Standard Operational Procedures (SOP) should be considered. For example, identifying in advance and activating promptly practicable alternate routes can reduce traffic demand on the route and prevent users from approaching the incident area. Identifying feasible alternate routes is not always easy; this task requires the preparation of specific traffic management plans especially for heavy vehicles for which there may be restrictions related to mass and shape limits that could restrict passage on certain routes (e.g., the presence of a bridge or bottleneck). In those cases, different alternative routes might be dedicated to light and heavy vehicles. Finally, another issue related to the management of a tunnel hazardous event concerns the presence of emergency teams located close to tunnel entrances able to respond quickly. For instance, several international studies confirm the effectiveness of the teams for fire management but also to support tunnel users during the evacuation process by quickly providing useful information on the direction of the nearest emergency exit to be reached. Thanks to the specific knowledge of the tunnel infrastructure main characteristics, emergency teams can support the intervention of other rescue teams (e.g., firefighters) by providing detailed information about the evolution of the scenario and the facility also ensuring a continuous communication with the control center (Beard and Carvel, 2005; Borghetti et al., 2020; Kim et al., 2010).

3. The importance of Real-life exercises to test current procedures and outline gaps and criticalities to be managed

"*The realistic training is important because it teaches us how to help civilians and save lives if an event like this happens*" (Alfredo Hernandez, U.S. Army, November 2019). Despite the accurate preparation and training of rescue teams to intervene in CBRN fields, only live exercises allow to test current operational procedures and highlight the gaps and criticalities that need to be addressed. The reference scenario for the TRANSTUN real-life exercise had a focus on the chemical risk, but the methodology used to deal with this risk can also be replicated for other CBRN threats. Several objectives were set in conducting this real-life exercise. They concerned operational response tests to Chemical events both to assess and improve the performance of the solutions adopted and to implement and test the procedures best suited for dealing with the CBRN threat (ventilation, evacuation, etc.). In addition, both detection devices and Personal Protective Equipment (PPE) currently in use were tested to assess their effectiveness in CBRN response. The main goal defined for the Pilot Infrastructure (Tunnel Bielsa-Aragnouet) was to find and test a viable solution for increasing the protection of users in case of a CBRN emergency, allowing proper evacuation, as well as a ventilation solutions able to deal with dispersion and contamination. While the applied strategy seems clear for smoke caused by fires, the impact of Chemical substances dispersions makes more difficult to take a sound decision without assessing in advance eventual issues that might arise following that dispersion. For instance, it would be essential to know as soon as possible the type of chemical(s) involved in order to determine the most suitable decontamination procedure to be implemented. With this regard, the tunnel operator should be able to recognise the possible presence of gases which are not usually present in the tunnel (such as those caused by vehicular traffic, pollutants, etc.). If specific chemical detection instruments are used (detecting specific molecules) or even better, instruments trying to detect exactly the kind of substance (much more sensible) , the possible interferences should be well understood. To overcome these difficulties, simpler instruments could be used (e.g., the same ones used for CO, N, O_2, etc.) and carried out by an "indirect" interpretation: if oxygen drops too low, it is a sign that some other gases are present. However, a first level of alarm is sufficient to directly alert firefighters or other emergency services since, for instance, professional first responders will know in advance that they should assess the presence of unknown substances in the air.

4. Findings from TRANSTUN real-life exercise

TRANSTUN live exercise at Bielsa-Aragnouet tunnel showed a significant level of response capabilities by French and Spanish First Responders. Among them, Law Enforcement officers and firefighters' participation was outstanding in quantity and quality but suffered from a lack of Medical Emergency resources. First, it was important to isolate the scene to mitigate the consequences and identify the various intervention areas defining the Hot/Warm/Cold zones, outside the tunnel head (French side) and strengthen cooperation between tactical and rescue forces. The most urgent measure is the victim extraction out of contaminated area since casualties are going to stop breathing toxic chemicals and many affected people are going to improve their health status (mainly those with less dose). Despite the lack of ambulances and medical doctor on site, the intervention of the gendarmerie and firefighters enabled to secure the victims remaining inside the tunnel, providing them a hood mask (called evacuation mask), and move the others who had left the tunnel to a collection point within the hot zone for decontamination (see Figure 3). The victims were classified according to severe or mild symptoms, provided with Personal Protective Equipment and some of them were covered up with emergency blankets.

Figure 3: Victim's Collection Point outside the head of the Tunnel (French side).

These casualties were not decontaminated until Technological Risks Fire Unit Deco Container reached the staging area outside the tunnel and container was set up as shown in Figure 4.

Figure 4: Arrival of the Deco unit and preparation of decontamination tents.

A great disposition of means and personnel has been ensured, but the three specific tasks reported below have not been properly managed:

- The location of the decontamination shelter for the stretchers was in the wrong position because it made it impossible for other units to enter the scene;
- Many wounded people were left unattended for a long time when they were on the scene;
- Several mistakes have been recorded about the decontamination activity, including the wrong use of the slope (all the contaminants went into the valley below), a lot of cross-contamination (the operator offering the last check and assistance touched the naked skin of the rescuer taking off his clothes) and throwing the used PPE into the barrel (creating clouds of contamination) as shown in Figure 5.

Figure 5: Various stages of the decontamination process for rescuers.

The use of PPE by the tactical forces and rescue teams was adequate to deal with the chemical threat even if some general procedural errors were made by First Responder. However, as shown in Figure 6, they did not use first aid gloves on the victim, and when the decision was made to use the emergency mask, the staff did not use precautions to also cover the arms with raincoats (usually aggressive chemicals also permeate the skin not only the respiratory tract).

Figure 6: Intervention of First Responder.

Chemical incidents are characterized by inter-agency intervention, such as Law Enforcement, Fire Fighters, and Medical Emergency Responders, and possibly Explosive Ordinance Disposal, Civil Protection, Water Cycle, and so on. Usually, an Advanced Command Post (ACP) is set up on the spot where the Incident Commander (IC) manages the emergency with the remaining representatives of the services. During the live exercise, the ACP was not identified in Warm Zone from where the IC should control the entire Zone, as well as movements inside and outside. Operations were managed by a permanent Tunnel Control Centre in the Spanish side and a Command Post in the French side through a fire brigade communication and command truck located on the road close to the head of the tunnel.

5. Conclusion

Based on results achieved through the implementation of such a complex real-life exercise, it has been immediately clear how much essential is ensuring the regular organisation of exercises not just to practice Tunnel Operators procedures but also to test their synergies with relevant first responders. Further value added by TRANSTUN was the implementation of a “real-life” exercise, which means the players were not aware of the scenarios they would have to deal with as well as they started their intervention from their real headquarters only after receiving a corresponding emergency call. The latter approach was essential to test the real timing of response of emergency services in a peculiar environment (cross-border tunnel in the middle of Pyrenees), allowing to outline current gaps and then to discuss potential re-distribution of resources as well as the re-formulation of roles and responsibilities fundamental to enhance the capacity of response of multiple relevant actors in an integrated manner. Results achieved by TRANSTUN can be considered a modular and flexible operational approach that can be replicated in several contexts involving the CBRN risks and road/rail tunnel safety and security.

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