CBRN EVENTS IN THE SUBWAY SYSTEM OF ROME: TECHNICAL-MANAGERIAL SOLUTIONS FOR RISK REDUCTION

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ABSTRACT

The acronym CBRN stands for Chemical, Biological, Radiological and Nuclear. CBRN risks are those caused by chemical, biological, radiological or nuclear agents that can produce serious harm to persons and things. The accidents connected with this type of substances can be either due to man (industrial accidents, road accidents, human mistakes in manipulation and/or storage of materials, etc.) or natural causes, when the structures where these substances are produced or stored are damaged by natural events (earthquakes, flood, etc.). Sometimes, in cases of terrorism, man voluntarily causes this kind of incidents. In Italy, as well as in the rest of the world, subways are one of the critical infrastructures that are more at risk in case of a CBRN event. In this work, the authors will analyse the case study of the subway system of Rome and propose technical-managerial solutions to improve the response in case of release of CBRN agents. In order to evaluate the quality of the proposals, a risk analysis will be carried out, both before and after the application of the suggestions.

Keywords: *Chemical, Biological, Radiological and Nuclear (CBRN); Rome; safety; subway; terrorism.*

1. INTRODUCTION

A Chemical, Biological, Radiological and Nuclear (CBRN) release can be very hazardous, especially when happening indoor, in conditions of bad ventilation and in the presence of big crowds, such as in a subway. It is easy to remember the terrorist attack that took place in the subway of Tokyo, Japan, between 8:00 and 9:00 am on March 20th, 1995, which caused the death of 12 people and the intoxication of over 5,000. In that occasion, the chemical agent Sarin was released during the rush hour, when more than 10 million people were on the trains of Tokyo's underground lines. In the area between the government departments and the harbour, chaos and terror immediately grew; there were victims experiencing unconsciousness, vomiting, sore throat and blindness. The rescue was fast, with the three stricken lines being promptly closed, while hundreds of ambulances intervened together with the support of 6 helicopters to rescue the injured. Among the casualties was the vice head of the Kasumigaseki station, who asphyxiated a few instants after removing a wrapper, dripping the agent, from a train. That morning, Tokyo saw the collapse of a certainty; the myth of the safest city in the world. For the first time in its history, it knew terrorism (Murakami, 2000; Tu, 2000).

In Italy, the current prevention, control and operation system does not include an effective response in case of accidental release of CBRN agents inside the subway system of Rome. Considering the history of the city, institutions, monuments and innumerable events that populate the city and subway every year, it represents a public transport infrastructure in the city of Rome with a very high risk level.

At present, the subway system is highly vulnerable as:

- The operations of first rescue are not always carried out by trained CBRN first responders;
- The zoning is not optimised for CBRN events;
- It is not possible to prevent this type of events and, often, the warning is belated.

For these reasons, it is necessary to propose solutions that can meet higher safety requirements and can bring benefits in terms of:

- Rapidity of response;
- Enhancement of safety for the first responder teams and for the persons injured;
- Better management of the event and decongestion of the traffic in the surroundings of the scene.

In this work, a method to carry out a preliminary assessment of the risks connected to an unconventional event has been developed. This has lead to the achievement of a preliminary risk analysis applied to a hypothetical CBRN attack inside the subway system of Rome, in order to prove the quality of the proposed solutions.

2. CREATION OF A FIRST RESPONDER CBRN UNIT AND DEPLOYMENT OF CBRN TEAMS ON THE SUBWAY SYSTEM

From the analysis of the Italian national response system, it can be seen that the first rescue teams are formed by operators belonging to security forces and, often, they are not trained to face CBRN events. Therefore, these teams can encounter two main problems:

- Risk of contamination for the operators of the team caused by the lack of proper protective equipment that are usually only provided to fire fighter teams;
- Risk of adoption of wrong rescue actions due to the lack of specific skills in CBRN matters.

In consideration of the importance of these problems, it is believed that the formation of special teams trained to deal with CBRN events, with the task of performing first rescue operations together with security forces, can be a good solution. The CBRN teams should meet at least the following requirements:

- Be made up of at least 4-5 firemen with proper CBRN expertise;
- Be provided with the necessary personal protective equipment, such as:
  - Protective suits (category III type 1a-ET) to enter the red zone, where these teams are asked to work (DOA, 1995);
  - Protective suits (category III type 2) to be used in the warm zone for the decontamination of the operators (DOA, 1995);
  - Filtered masks and re-breathers for the rescue of the victims.
- Wear the protective equipment from the beginning of their action (DOA, 1995);
- Be provided with specific detectors for CBRN agents;
- Be able to carry out first zoning and demarcation of the hot zone, taking into account safety approximation;
- Be ready to intervene in case of non-CBRN events;
- Have at disposal special premises for the decontamination of the operators;
- Be in command in the hot zone before the arrival of the other responders;
- Pay attention to possible second explosive devices;
- Take into account that the aggressors can be among the casualties;
- Warn all the other rescue teams.

It is important that these teams are deployed in a proper manner on the territory in order to optimise the response time.

This was applied to the case study of the subway system of Rome. An appropriate deployment of the CBRN teams along the subway (Figure 1 and Table 1) was defined to guarantee a fast and effective operation.

Teams 1A - 4A and 1B - 2B are assigned with 8 - 10 firemen (alternating in three 8-hour shifts). The central team was assigned with twice the number of firemen (16 - 20) as compared to the other teams in order to command two different squads in case of attacks on both subway lines. The collocation of the teams and the lengths of the subway covered by any of them were chosen in order to allow the arrival on the scene in a short time (approximately 10 - 15 minutes), by moving on the surface roads, wherever the event happens. This feature permits the rapid deployment of forces prepared to deal with CBRN emergencies protecting, and, at the same time, the members of the security forces, that in Italy are not well equipped and trained for this kind of events but are usually the very first responders. Moreover, this solution allows for first aid to be provided to a larger number of victims and minimises the diffusion of the contamination.

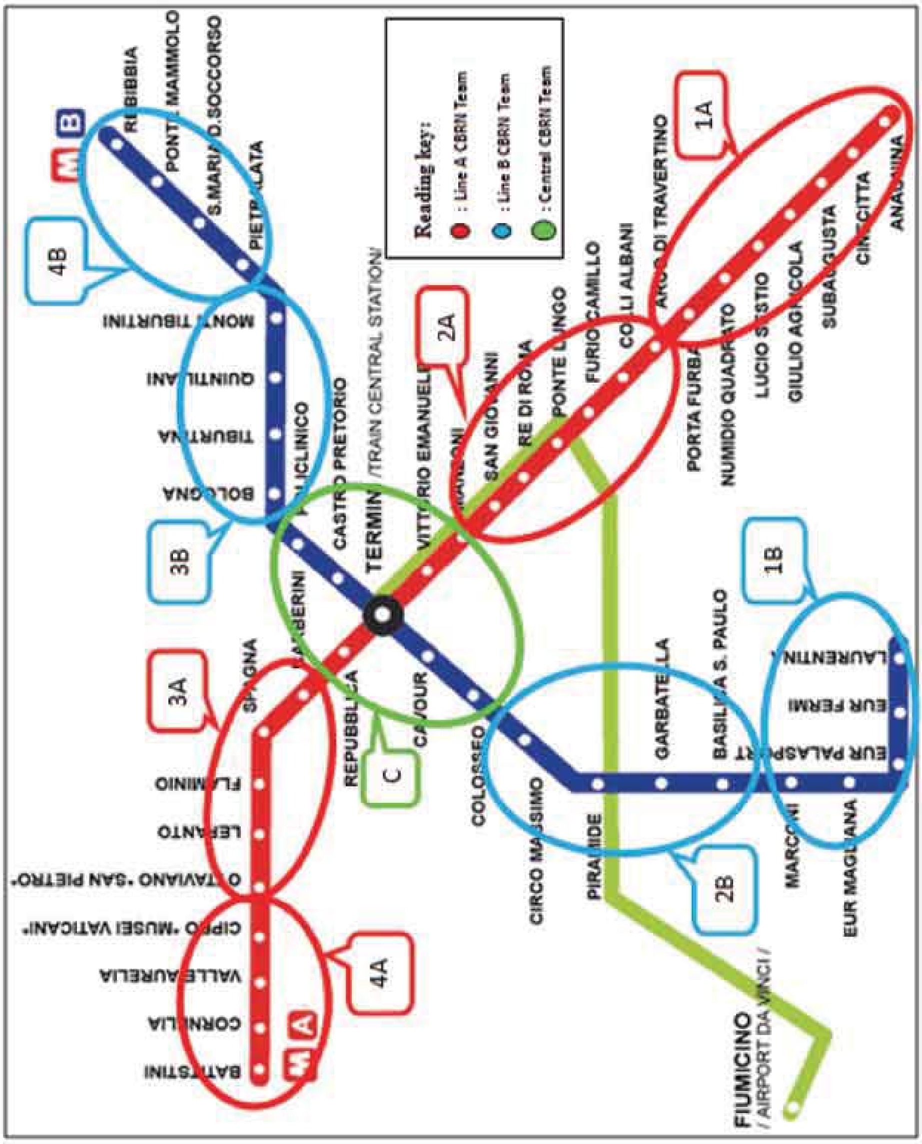

Figure 1: The subway system of Rome and areas covered by the CBRN teams.

Table 1: Deployment of the CBRN teams along the Roman subway system.

CBRN Team	Location	Range of Action
1A	Between the Subaugusta and Cinecittà stations	Line A: Between the Anagnina (terminus) and Arco di Travertino stations
2A	Close to the Ponte Lungo station	Line A: Between the Colli Albani and San Giovanni stations
3A	Between the Spagna and Flaminio stations	Line A: Between the Barberini and Ottaviano stations
4A	Close to the Valle Aurelia stations	Line A: Between the Cipro and Battistini (terminus) station
Central	Close to the Termini station	Line A: Between the Manzoni and Repubblica stations
		Line B: Between the Colosseo and Policlinico stations
1B	Close to the Eur Magliana station	Line B: Between the Laurentina and Marconi stations
2B	Close to the Colosseo station	Line B: Between the Basilica S. Paolo and Circo Massimo stations
3B	Close to the Tiburtina station	Line B: Between the Bologna and Monti Tiburtini stations
4B	Close to the Ponte Mammolo station	Line B: Between the Pietralata and Rebibbia stations

3. IMPROVEMENT OF EMERGENCY ZONING

Emergency zoning (Figure 2) is the determination of the different areas that characterise a CBRN event (DOD, 1998; Jarrett, 1999):

- Contaminated zone (Hot Zone);
- Possibly contaminated zone (Warm Zone);
- Safe zone (Cold Zone).

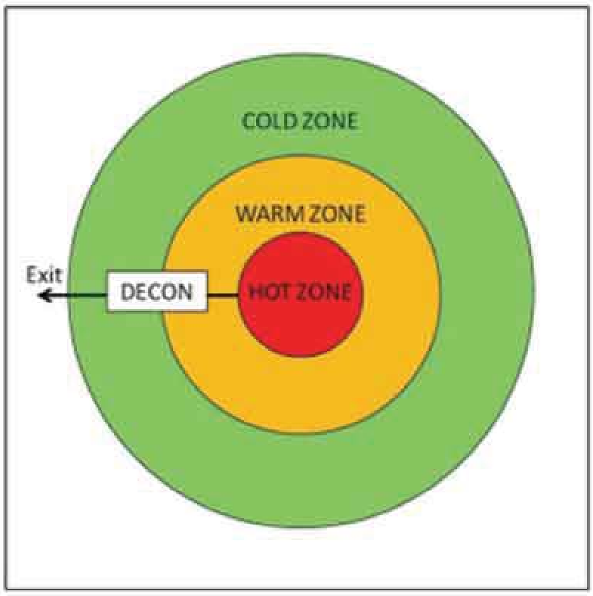

Figure 2: Standard emergency zoning.

After analysing the British response system for unconventional events, it has been decided to add one more zone to the standard emergency zoning. This new "pedestrian only" zone is delimited by a traffic barrier and is useful to prevent vehicles from entering the operative area. Furthermore, it has been considered advantageous to create a rendezvous point (RVP) and a sorting area (DOA, 1991; DOD, 1996). The advantages gained through this new configuration are:

- Traffic barrier:
  - The traffic barrier is placed so as to prevent the access of vehicles to the area of the operations;
  - Measures to avoid congestions of the traffic and guarantee that the arrival of rescue teams on the scene and surroundings, in case of emergency, can be easily undertaken;
  - The decontamination unit can be set up inside the pedestrian area in case of special requirements.
- Rendezvous point (RVP):
  - The RVP is to be located outside Hot Zone and will be under the control of the Police;
  - At the beginning of the rescue, all the emergency services will head to the RVP;
  - Any request that cannot be satisfied immediately by the person in charge of the RVP will be assigned to the sorting area.

- Sorting area:
  - This area (where it is appropriate to wear reflective coats) is located near the RVP and the hot zone. The precise location will be decided by the Head of Police and the Head of Fire Fighters after consultation. However, fire fighters do not take part in the operation in this area as it is under the control of the medical services.
  - The area is used for the arrival and departure of ambulances and other vehicles, and can also be used to recover the personnel involved. It can be maintained throughout the operation.

The new configuration of the emergency zoning is shown in Figure 3.

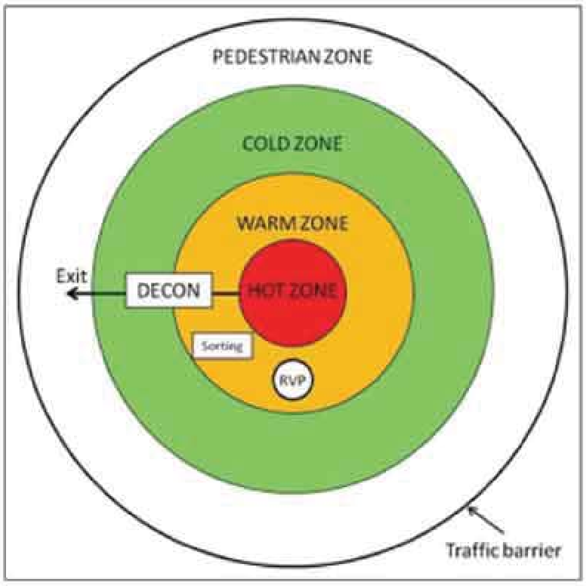

Figure 3: The emergency zoning after the suggested improvements.

4. SYSTEM OF DETECTION AND WARNING OF THE PRESENCE OF CBRN AGENTS

In order to further increase safety in case of an attack in the subway, it has been decided to add a system to detect CBRN agents that is, at present, missing. This detection system should be made up of:

- Real time chemical agents detector;
- Biological agents detector; since the real time detection of biological agents is not possible (CRPC, 2004), this system should collect air samples that are to be analysed remotely every 15 - 20 minutes;
- Gamma dosimeter or counter for radiological detection.

All the detectors have to be placed in a "detection apparatus" at the entrance of every subway station, on both sides of the staircase, and will be connected to an automatic warning system. The positioning of the apparatus is shown in Figure 4.

Figure 4: Positioning of the detection system.

The detection system will work using a threshold criterion. If an aggressor is trying to enter the subway with an amount of chemical, biological or radiological substances that is higher than the threshold, the alarm activates automatically. The system is placed on the entrance of the subway in order minimise the dispersion of the agent in case the aggressor tries to spread it anyway. The warning system has three main tasks:

i. Activation of an acoustic alarm to:
   - Alert the security personnel in the subway;
   - Alert the passengers entering the subway.

ii. Sending of a warning to the CBRN teams so as to:
   - Activate the CBRN team in charge of that station;
   - Activate all the required rescue procedures.

iii. In order to prevent the aggressor from entering the subway, a system of doors, with reinforced glass, placed at the end of the staircase that leads to the station (Figures 5 and 6), will automatically close. The activation of the doors will happen only in case of detection of chemical or radiological agents because biological agents cannot be detected in real time.

Figure 5: Position of the emergency doors.

Figure 6: Example of emergency door with reinforced glass.

Moreover, in order to enhance the safety of passengers in case an aggressor manages to bypass the detection system and enters the subway station to release the agent, a manual alarm is to be placed on the platforms. When the button is pushed, this alarm activates functions 1 and 2 of the previous list, while function 3 must not be activated, otherwise it would impede the access of the rescue teams and the evacuation of the people inside the station. The push buttons of the alarm should be placed every 10 to 20 m, at a height of 1.20 - 1.30 m from the floor (Figure 7) so as to make the use of them easy, in particular in case of very crowded platforms

(Figure 8). The buttons can also be placed inside the coaches, in order to facilitate the use of them and improve safety (Figure 9).

Figure 7: Positioning of the manual alarm buttons on the platform.

Figure 8: Easy use of the manual alarm buttons in case of crowded platform.

Figure 9: Possible positioning of the manual alarm buttons inside the train.

5. PRELIMINARY RISK ANALYSIS IN THE EVENT OF A CBRN ATTACK IN THE SUBWAY SYSTEM OF ROME

In this section, the risks associated with the hypothesis of a terrorist CBRN attack in the subway system of Rome before and after the application of the proposed solutions will be analysed. This analysis will be carried out in three phases:

- Identification of risk sources: This phase will help in the identification of the risks connected with the exposure to CBRN agents;
- Preliminary identification of the risks: This phase will have the dual task of identifying the risks both in absence and in presence of the solutions proposed;
- Preliminary assessment of the risks identified: In this phase, a preliminary assessment of the risks involving the "Total Risk", that is the risk that the attack will be perpetrated, causing an emergency associated with the presence of casualties, injured persons and a contamination that can potentially spread, will be carried out. In this phase, it will be considered, to simplify the calculations, that the risks identified are disconnected, so it is possible to estimate the Total Risk as the mean of the single risks considered.

5.1 Identification of Risk Sources

In order to identify the risk sources, a short but accurate description of the environment is necessary:

- Classification of the considered environment: Public environment – transport infrastructure;
- Structural characteristics: The rail tunnels are from 10 – 15 m to 80 – 90 m deep. This characteristic makes the subway an ideal target for attacks because of the small space available that hinders the escape routes of the victims and makes the dispersion of the agents more effective;
- Number of people that can be on the platform / in the train: This value changes from station to station and it can be up to a few hundred.

The main risk sources that have been identified are shown in Table 2.

Table 2: Identified risk sources.

No.	Risks	Causes
A	Safety	• Hazardous substances • Malfunction of the detection-warning system • Fire-explosion
B	Health	• Chemical agents • Biological agents • Radiological agents
C	Safety and health	• Not optimised organisation of the first responders • Not optimised deployment of the first responders • Not optimised emergency zoning

5.2 Preliminary Identification of the Risks

Table 3 shows the risks connected with an attack in the subway both in absence and in presence of the proposed solutions.

5.3 Preliminary Assessment of the Risks Identified

In order to assess the value of the identified risks, it is necessary to:

- Evaluate the probability of occurrence of any single risk;
- Evaluate the amount of harm.

It will be use:

- 4 probability scales;
- 4 harm scales.

Table 3: Risks connected with an attack in the subway system.

Risks Identified in Absence of Countermeasures	Risks Identified in Presence of Countermeasures
Contamination of the first responders (security forces) from CBRN agents	Contamination of the first responders (CBRN trained teams) from CBRN agents
Diffusion of the contamination outside the area of the event (standard zoning)	Diffusion of the contamination outside the area of the event (improved zoning)
Traffic congestion with the standard zoning	Traffic congestion with the improved zoning
Transport of CBRN agents in the absence of the detection-warning system	Unsuccessful detection of CBRN agents by the proposed system
Failure of the rescue in the absence of the automatic warning system	Malfunction of the automatic warning system
Delay in the rescue due to the deployment of the responder teams	Delay in the rescue due to the proposed deployment of the CBRN teams

Tables 4 and 5 indicate the criteria used for the assessment of:

- Probability occurrence P;
- Amount of possible harm H.

Once probability and harm are defined, the risk R is automatically calculated using the following equation:

$$R = P \times H \quad (1)$$

The result obtained is given a scale of the risk from 0 (no risk) to 16 (maximum risk). In order to transform this result into a percentage value, it is necessary to perform the following simple ratio:

$$16 : 100\,\% = x : y \quad (2)$$

x: estimated risk from Equation 1, extracted from Tables 4 and 5.

Y: percentage of risk calculated case by case.

Table 6 shows the values assigned to the risks identified in Table 3, using the proposed procedure, with the values taken from Tables 4 and 5. Figure 10 illustrates the significant reduction of the risks using the proposed countermeasures.

Table 4: Scale of probability *P*.

Value	Level	Definitions / Criteria
4	Highly probable	• There is a direct correlation between the observed failure and the occurrence of the hypothesised harm; • Harms already occurred due to the same observed failure in the same or similar environments; • The occurrence of the harm due to the failure would not cause surprise.
3	Probable	• The observed failure might cause a harm, even if not directly or automatically; • Some harm already occurred due to the failure; • The occurrence of the harm due to the failure would cause moderate surprise.
2	Unlikely	• The observed failure might cause a harm only in unfortunate circumstances; • Rare harms already occurred due to the failure; • The occurrence of the harm due to the failure would cause big surprise.
1	Completely Unlikely	• The observed failure might cause a harm in concomitance of other unlikely independent events; • No known harm occurred; • The occurrence of the harm due to the failure would cause incredulity.

Table 5: Scale of harm *H*.

Value	Level	Definitions / Criteria
4	Very serious	• Accident or acute exposure with lethal or total disability effects; • Chronic exposure with lethal or total disability effects.
3	Serious	• Accident or acute exposure with partial disability effects; • Chronic exposure with irreversible and/or partial disability effects.
2	Medium	• Accident or acute exposure with reversible disability effects; • Chronic exposure with reversible effects.
1	Minimum	• Accident or acute exposure with quickly reversible disability inability; • Chronic exposure with quickly reversible effects.

Table 6: Results of the risk analysis.

Assessment of the Risks Identified in Absence of Countermeasures	Assessment of the Risks Identified in Presence of Countermeasures
Contamination of the first responders (security forces) from CBRN agents: • Probability: – Level: Highly probable – Probable – Value: 3.8 • Magnitude: – Level: Very serious – Serious – Value: 3.5 Risk = *R1* = 13.3 ≅ **83 %**	**Contamination of the first responders (CBRN trained teams) from CBRN agents:** • **Probability:** – **Level: Unlikely – Completely unlikely** – **Value: 1.5** • **Magnitude:** – **Level: Very serious – Serious** – **Value: 3.5** **Risk = *R1* = 5.25 ≅ 33%**
Diffusion of the contamination outside the area of the event (standard zoning): • Probability: – Level: Unlikely – Value: 2.0 • Magnitude: – Level: Serious – Medium – Value: 2.5 Risk = *R2* = 5.0 ≅ **32 %**	**Diffusion of the contamination outside the area of the event (improved zoning):** • **Probability:** – **Level: Completely unlikely** – **Value: 1.0** • **Magnitude:** – **Level: Serious – Medium** – **Value: 2.0** **Risk = *R2* = 2.5 ≅ 16 %**
Traffic congestion with the standard zoning: • Probability: – Level: Unlikely – Value: 2.0 • Magnitude: – Level: Medium – Value: 2.0 Risk = *R3* = 4.0 ≅ **25 %**	**Traffic congestion with the improved zoning:** • **Probability:** – **Level: Unlikely – Completely unlikely** – **Value: 1.5** • **Magnitude:** – **Level: Medium** – **Value: 2.0** **Risk = *R3* = 3.0 ≅ 19 %**
Transport of CBRN agents in absence of the detection-warning system: • Probability: – Level: Highly probable – Value: 4.0 • Magnitude: – Level: Very serious – Serious – Value: 3.5 Risk = *R4* = 14.0 ≅ **87 %**	**Unsuccessful detection of CBRN agents by the proposed system:** • **Probability:** – **Level: Unlikely** – **Value: 2.0** • **Magnitude:** – **Level: Very serious – Serious** – **Value: 3.5** **Risk = *R4* = 7.0 ≅ 45 %**

Table 6 (Continued): Results of the risk analysis.

Assessment of the Risks Identified in Absence of Countermeasures	Assessment of the Risks Identified in Presence of Countermeasures
Failure of the rescue in the absence of the automatic warning: • Probability: – Level: Highly probable – Probable – Value: 3.5 • Magnitude: – Level: Very serious – Serious – Value: 3.5 Risk = *R5* = 12.25 % ≅ **77 %**	Malfunction of the automatic warning system: • Probability: – Level: Unlikely – Completely unlikely – Value: 1.5 • Magnitude: – Level: Very serious – Serious – Value: 3.5 Risk = *R5* = 5.25 ≅ **33 %**
Delay in the rescue due to the deployment of the responder teams: • Probability: – Level: Probable – Unlikely – Value: 2.5 • Magnitude: – Level: Medium – Value: 2.0 Risk = *R6* = 5.0 ≅ **32 %**	Delay in the rescue due to the proposed deployment of the CBRN teams: • Probability: – Level: Unlikely – Completely unlikely – Value: 1.5 • Magnitude: – Level: Medium – Value: 2.0 Risk = *R6* = 3.0 ≅ **19 %**

6. CONCLUSIONS

This work has focused on the improvement of the safety of the subway system of Rome in case of a CBRN event. The proposed solutions contributed to:

- Improvement of the first response system: By means of the creation of first responder CBRN teams and the proposal of a proper deployment. This was analysed using the case study of a CBRN attack in the subway system of Rome;
- Improvement of the emergency zoning: Based on the British system, it has been possible to suggest a new approach for the emergency zoning with the following advantages:
  - Reduction in the dispersion of the contamination outside the area of the event;
  - Reduction of the traffic inside the area of the event.
- Creation of an automatic detection and warning system: This system was elaborated for the special case of the subway system of Rome, but with

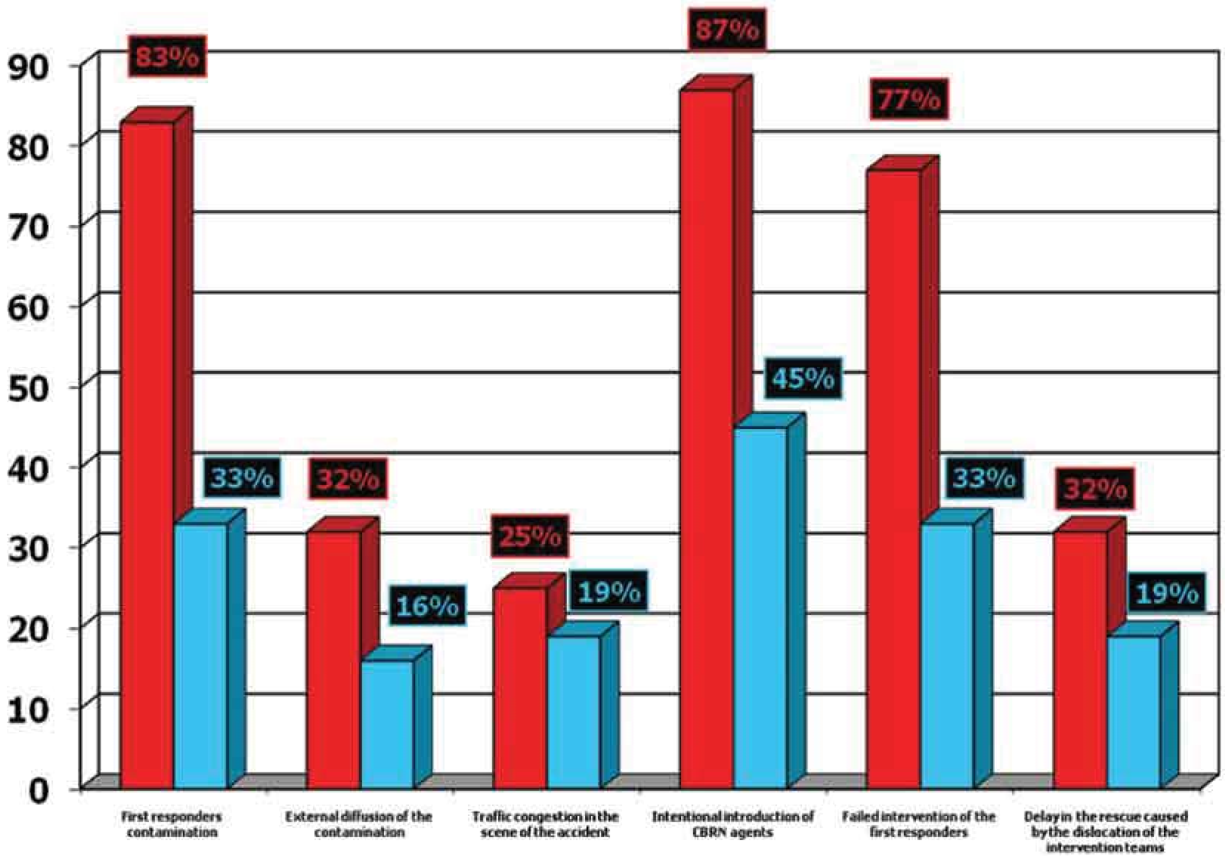

Figure 10: Comparison of the results of the risk analysis before and after the introduction of the solutions proposed.

proper modifications, it might be feasible for other sensitive targets in Italy;

- Study of a method to carry out a preliminary assess of the risks connected to an unconventional event: This method was applied to the case study, showing the effectiveness of the proposed solutions. There has been a reduction of the risks of about 30 %, calculated by the difference between the mean values of the Total Risk before and after the introduction of the solutions.

In conclusion, the aim of improving safety in case of a CBRN attack in a confined environment, such as the subway system of Rome, has been achieved.

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