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Based on Experiences of Recent Major Disasters

The disaster on the A14 in Bologna: a missed multidisciplinary approach to road safety

P. Villani*,
* Politecnico di Milano - Department of Civil and Environmental Engineering, Italy
paola.villani@polimi.it

Abstract

Explosion in Bologna, on the urban stretch of the A14 motorway. A tanker crashes violently on a truck with a trailer that caught fire immediately. After four minutes, a devastating explosion causes the bridge to collapse. In this accident, a multidisciplinary approach would have avoided structural damage to the viaduct and prevented 145 victims of wounded burns. The incident was filmed by the motorway cameras, but the attention of the traffic authorities is only for the initial collision, the tanker truck that gave the first truck carrying solvent barrels, and that immediately caught fire. Part of the pavement of the engineering structure - a road with two lanes and a paved safety band - collapsed and under the vehicles were crushed and others caught fire. In four minutes many drivers on the highway are put in safe positions, but a multidisciplinary and remote technical intervention, thanks to improvements in new technologies for road safety - could have led to a different conclusion and limit the damage caused by the accident

Figure 1 On the A14 Bologna motorway the rear-end collision, the first explosion and shortly after the second

1. Accident description

It's 1.50 pm on 6 of August 2018 on the Italian highway A14 Bologna Casalecchio motorway junction at km 4.000 northbound branch to Bologna's North bypass motorway – when a tanker truck carrying 30 thousand litres of LPG (Liquefied petroleum gas) causes a rear-end collision with a articulated lorry that carries solvent drums in flatbed. The barrels blow up and ignite due to of the truck impact against the New Jersey barrier. In the motorway control room the focus is firstly on this initial buffer. Fortunately, there are few vehicles in transit at 13.50. The buffered truck driver - already enveloped in flames - understands that a minimal initial leakage of LPG can cause a gigantic explosion and therefore alert everyone. Police officers quickly swept away all the vehicles that came. And eight minutes later the expected explosion actually occurred and determined the collapse of the road deck, damaging the buildings immediately surrounding and injuring 145 people.

Figure 2 Accident concentration zone

2. Traffic Data and Road Description

In the accident section the roadway has two lanes in each direction and emergency lanes. A new jersey barrier separates different motorway roadway from the roadway of the "Bologna's North Ring Road" which has two lanes in each direction and many merging sections.
Summertime 90,000 vehicles per day drive over the A14 (Imola Junction Interconnection only 6.57 km long towards Ravenna Direction), 72.296 light vehicles, 20.868 heavy vehicles (July 2018 data). About half of it is on this link of the A14 where the incident occurred. Depending on the time of year 22% - 34 % total vehicles are heavy. This stretch of A14 motorway junction is flanked by the Bologna's Ring road.

3. Causes

The Bologna accident allows to investigate the causes that produced the second explosion. The images document what happened in a few minutes: in this short period of time many drivers were saved but further damages, as you can see, could have been prevented by a different technical intervention leading to a different epilogue and limit the damage of what was a normal rear-end collision. This stretch of A14 motorway junction is in an urban environment. Under the motorway there are shops, car dealers, roads and parking lots although they do not comply with the Regulation in force that requires, "clear zone" [Note 2] precisely for safety, with distances from the road axis never less than thirty meters.

Figure 4 Second explosion in which, in a few minutes, the first rescuers have already eliminated the traffic

The rear-end collision occurred on a section of the urban viaduct, the traffic is intense in the motorway lane only heading north direction. The images show that there is a queue of more than ten trucks, no one respects the safety distance and none operates the four flashing direction indicators to indicate a traffic jam. The driver of the LPG tanker braked as can be seen in the images of the cameras. Therefore it is possible to assume that brakes were malfunctioning.

Figure 5 The second explosion seen from a car stopped in motorway lane

First responders worried about diverting traffic because the risk of explosion was high. Even the truck drivers went away on foot just over a hundred metres in length because they understood that the explosion was simply a matter of time. The control center has activated the procedures and firefighters converge in this area. In a few minutes they will be at the scene of the accident.

But no one who observes the fire from the cameras remotely thinks that it is necessary to understand a energy detachment in the Borgo Panigale heritage district: LPG (CAS Number 74-98-6 $CH_3CH_2CH_3$) has a higher density than air, so it goes down. And right there - under the bridge of the A14 viaduct - there was the cause of the blast.

Figure 6 Smoke after the second explosion

Downstairs, the air below is unbreathable, as in all car parks in summer, when the evaporation of benzene is easily perceptible even by those who pass through
Below - the electric cables abounded. And these are not those of car dealerships, nor those of traffic light systems, which still work as shown in the published photos.
Below the viaduct electric cables abounded. But they certainly didn't belong to the Motor Dealers nor were connected to the traffic lights, since the photos show that they work well even after the deflagration. Here, under the bridge of the viaduct there was here under the eyes of all, the cause of the explosion.
If only someone had wanted to look. If only someone had thought that this could be a trigger cause. But you know, doing post-hoc analysis is always easy.
At the moment, between the chaos, the smoke, the first fire, the vehicles that arrive and those on fire, everything is thought of and one does not think about what could have happened. And that - on time - after few minutes - it happened. Here - under the bridge of the A14 - a sort of clockwork bomb hung from a thread.

Figure 7 The second explosion also caused the cars blast under the bridge

The explosion of the tanker was felt throughout the area, blew up the windows of shops and homes, the huge blast caused the explosion of cars in the two dealers under the bridge.
Before continuing the examination of the incident, two words on the ignition triggers due to electrical causes: occur as a result of the occurrence of one of the following phenomena: external heat sources, development of heat by Joule effect, development of high energy due to a electric arc [1].
In this case of Bologna, the heating due to the overlying fire may have caused the loss of insulation of the cables and may have caused an electric arc between the cables hanging on the bridge of the A14.
The majority of heating problems are always caused by a pre-existing fire and it is conceivable that here the cables were affected by the heat of the above fire due to the impact between the heavy vehicles and the initial fire of the substances transported and spilled. But this fire at overpass was moving downwards considering the nature of LPG. (Critical Point 96,75 °C = 206 °F).
Secondly, it is the interest to see how a accident can evolve and become something completely unexpected over. Even if different occurrence, each accident is a unique,

unrepeatable, there are some situations in which the heating of the cables can unexpectedly evolve what was the initial cause of the fire.

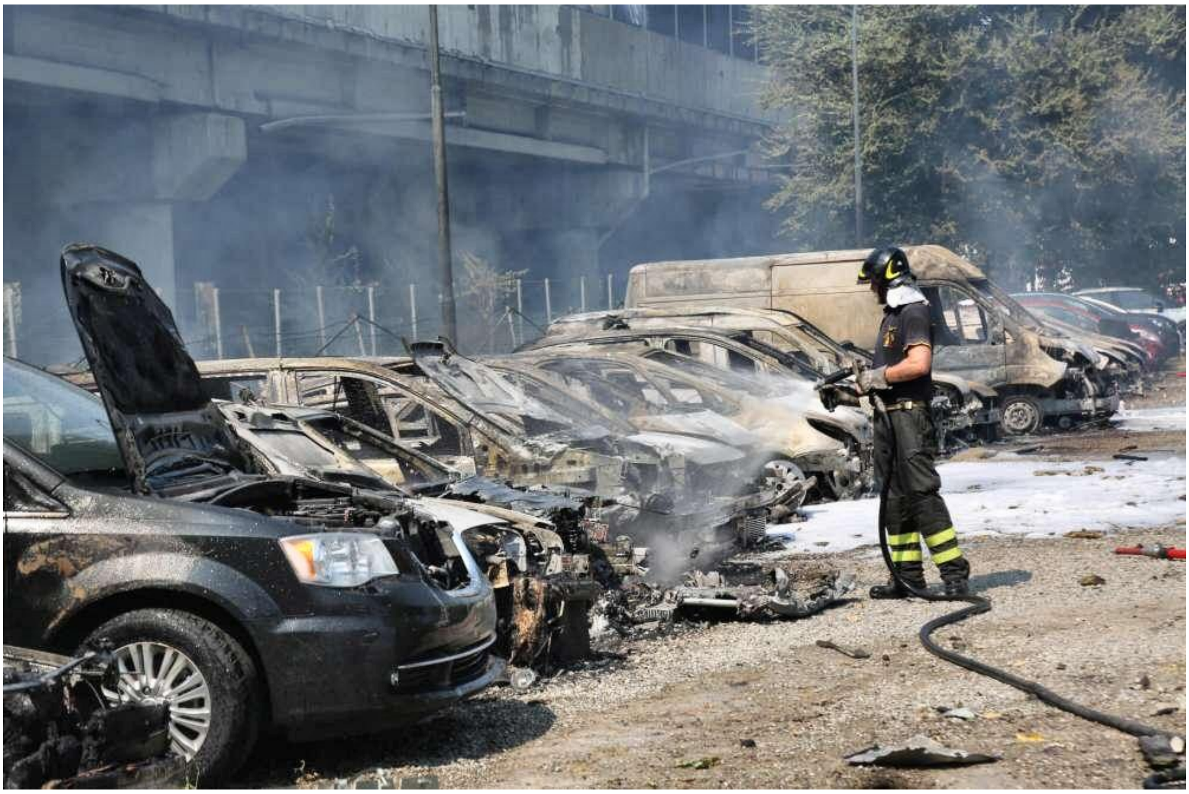

Figure 8 Firefighters extinguish car fire under highway bridge

Figure 9 Combustion of cars of two concessionaires located under the road bridge

This first fire on the roadway of the A14, involved the underlying electrical systems that, once hit by fire, have released a large amount of energy at high temperatures and that is why everyone reported having heard a loud roar.
And the fire - initially contained - flared up with a very strong explosion - which caused much more damage than initially due to the collision. It is therefore necessary to ask whether this fire was of an electrical nature in order to better understand the causes of what was determined in Bologna on 6 August 2018..

Figure 10 Debris of carbonized vehicles under the road bridge

4. Available evidence

Whoever wanted to engage in specific analysis to determine if the phenomenon of the Bologna explosion was really an electric arc will be able to note that a projection of high energy sprays are visible in some debris of carbonized vehicles, as well as - another proof is the explosion and the pressure determined by the shock wave that struck the window frames in the area.

Figure 11 The road viaduct after the explosion

5. Emergency response

The first aid arrived in a few minutes: firefighters truck . Under the viaduct, in the streets below there were many vehicles in transit and people on foot, by bike or motorbike. The Agents were busy clearing the area while the explosion occurred that resulted in 145 injured. From a tank truck carrying LPG, a very tall column of smoke appeared, visible from all over the city for hours, until the firemen tamed the flames with the helicopter.

Figure 12 Area affected by the explosion

6. Causative factors

It is necessary to ask whether the fire - if an immediate detachment of the tension in the area in question was made - could not be better tamed and the explosion could then be avoided, which then occurred. To ask whether all the classic techniques used in the confined spaces have been put in place in order to prevent the initial fire from absorbing energy and deflating due to an electrical problem. Another factor that has certainly contributed to the devastating explosion is most likely due to the air that was charged with benzene, released in this summer of scorching heat [35 °C = 95 °F] - from vehicles parked both sides of the infrastructure - whether in the dark spaces below. Abusive parking as is well understood from the images displayed in diachronic sequence.

And the vehicles below and of which very few traces remain have contributed to increase the power of the deflagration.
In fact, electric fire, as assumed for the Bologna explosion, may be the result of a combination of several factors that must be considered together and which are mutually competing causes for the devastating fire.

Figure 13 The power cables of the filament line, cables with 600 V voltage, will have been affected by the fire and this led to the explosion.

7. Explosion for electric arc

The arc discharge can be caused by the action of the flames, when they attack the live conductors and damage or carbonize their insulation.
The composite scheme does not omit the first cause (the fuel tanker truck collide with articulated lorry) but aims to understand what determined the catastrophic explosion - well aware that the investigative action on any event contributes - if shared and made public - to understand the dynamic of an accident and represents an opportunity to oppose all possible and similar event in the future.

8. Accident investigation conclusion

In this case we should consider - before proceeding with the introduction of restrictive rules for freight transport - if there is something that can be put in place to prevent a similar occurrence, examining in this specific event in Bologna, both the proximate causes, that caused the explosion, both the mechanism by which the same event was determined, causing so much damage.
Compulsory causes and without which it would have occurred in any case, but certainly in different forms and with less impact. We don't forget as causative factors the following repeated explosions can be linked back to the Regulations on the Clear Zones [Note 2].
It is essential to exchange best international practices to prevent road disasters based on the main experiences of disasters, can be explained by analyzing all the factors that lead to an increase in accidents, factors that must be considered by road infrastructure managers..

[Note 1]
The electric arc is a phenomenon that occurs following a shock that occurs when the voltage between two points exceeds the limit of the dielectric strength; if the conditions are opportune, a plasma is formed which conducts the electric current until the upstream protection does not intervene. Being in the proximity of an electrical arc is quite dangerous; here are some data to understand how dangerous it is: • pressure: at a distance of 60 cm from an electrical arc associated with a 20 kA arcing a person can be subject to a force of 225 kg; moreover, the sudden pressure wave may cause permanent injuries to the eardrum: • arc temperatures: about 7000 - 8000 °C; • sound: electrical arc sound levels can reach 160db, a shot gun blast only 140db.

[Note 2]
In Italy the Clear Zones depend on the road type and - for the highway category - they can never be less than 30 meters (98 feet).
In Spain, the security zones are equal to three different zones: "legal servitude", "affectionate" and "non-construction" zones located beyond the "adjacent public domain zone". In this area of the adjacent public domain, there are two strips of land, one on each side of the carriageway, eight meters wide on high-capacity roads and three meters on conventional roads, measured horizontally from the outer edge of the leveling and perpendicular to it. Similarly, the legislation establishes, besides the adjacent public domain, other protected areas, which, although not owned by the government, are protected.
After the adjacent public domain, there are the following areas: legal servitude, affection and non-construction. The "legal servitude zone" of the roads consists of two strips of land, one on each side of the same, bounded internally by the adjacent public domain zone and externally by two lines parallel to the outer edges of the levelling, and a distance of twenty-five meters on high-capacity roads and eight meters on conventional roads, measured horizontally and perpendicularly from the edges mentioned.
In this zone, the new building cannot be carried out and there are only uses compatible with road safety and therefore with prior authorization from the competent authority of the Road Administration: each different use will not be authorized. The "zone of affection" of the roads consists of two strips of land, one on each side of the same, delimited internally by the legal servitude zone and externally by two lines parallel to the outer edges of the earthworks and distant one hundred meters on high-capacity roads, 50 meters on conventional roads and 25 meters on the rest of the roads, measured horizontally and perpendicularly from the edges mentioned..
The "no-build zone" of the roads consists of two strips of land, one on each side, bounded internally by the outer edges of the carriageway and externally by two parallel lines of the said ridges and one hundred meters distant in high-capacity roads. , fifty meters in the conventional roads of the autonomous network and twenty-five meters in the rest of the roads, measured horizontally and perpendicularly from the edges mentioned. In summary, the distances from the security zones are as follows (correspond to legal service areas):
- High-capacity roads (motorways, expressways and expressways): 25 m
- Rural roads (rest of the network): 8 m

In the United States the width of the "clear zone" or "clearance zone" varies according to traffic volume, speed and embankment slopes. Matches and procedures for determining the width of the safety zone and are described in the AASHTO (American Association of State Highway and Transportation Officials) Roadway Design Guide AASHTO Roadside Design Guide provides guidance to help highway agencies develop their own standards and policies for determining the widths of clear zones along roadways based on

speed, traffic volume, roadside slope and curvature. But the recommended clear zone ranges are based on a width of 30 to 32 feet (approximately 10 mt) for flat, level terrain adjacent to a straight section of a 60mph highway with an average merely daily traffic of 6000 vehicles. For steeper slopes on a 70 mph roadway AASHTO set to the Clear Zone range increases to 38 to 46 feet, and on a low speed, low volume roadway the Clear Zone range drops to 7 to 10 feet. For horizontal curves AASHTO set the Clear Zone can be increased by up to 50 percent.
For expressways, arterial high speed roads and rural service roads with a reference speed greater than 60 km / h, specific values are given. For slow speeds, less than 60 km / h, service roads or local roads: minimum width of 3 m. The AASHTO Road Design Guide provides guidance for road agencies to develop their own standards and policies to determine the width of Safety Zones along roads according to speed, traffic volume, slope and of the curvature of the road. But the recommended buffer strips are based on a width of about 10 meters (30 to 32 feet) in the case of flat, flat ground adjacent to a straight section of a highway with a maximum speed limit of 60 miles per hour. (96 km / h) with average daily traffic of only 6000 vehicles. For the steepest slopes on a 70 km / h road, the AASHTO establishes that the buffer zone is increased to 14 meters (38-46 feet), while on secondary roads, characterized by low speeds and high volumes. reduced traffic, the size of the respect band falls to 2-3 meters (7-10 feet). For horizontal curves, AASHTO declares that the band of respect can be increased up to 50%.
The Clear Zone in France have the following measures width depending on the type of road or development:

- 4 m on existing roads,
- 7 m in new development,
- 8.50 m on roads with 2x2 lanes limited to 110 km / h.

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