Road Safety Near a Landfill Assessment in Europe

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In Europe, many governments are struggling with the ambitious target of zero road deaths by 2050. On the other hand, they are facing remediation of illegal waste dumps, subject to European infringement procedures and involving a lot of workers and heavy materials transportation. In Italy, a specific department was started in 2017 to carry out the remediation of 200 illegal landfills of urban/industrial solid waste. According to the Italian legislative framework on construction site management, risk assessment should also include risks for the external context caused by the working site.

road accidents | landfill | remediation site | road safety | occupational road safety | cluster analysis

1. Introduction

The World Health Organization's (WHO) statistics point out that road accidents cause about 1.3 million people to die each year, with inevitable impacts on public health services [1]. In Europe, statistics on road accidents show a slight reduction in serious road injuries in recent years, but the goal of "Vision Zero" in 2050 is still far away [2]. Consequently, target 3.6 of the UN Agenda 2030 on road safety can be considered a milestone to reach sustainable development [3][4].

Among road safety issues, accidents involving people while working represent a matter of serious concern for transport companies [5][6]. The probability of workers being injured while driving vehicles is a risk that is likely to be higher in developing countries, where adequate infrastructures and safety training are still scarce [7]. Road safety involving workers is a complex problem that needs safety models to take into account road crashes [8]. However, this issue also needs to be addressed also in developed countries, where the use of emerging technologies in vehicles, as well as the sprawling of micro-mobility operators, have caused new challenges for road safety regarding the risk management model in a new dynamic society [9].

Over the years, several studies warned about the need to improve safety for drivers of heavy vehicles [10][11][12]. Moreover, some researchers demonstrated that construction sites, especially the ones located on roads, can be responsible for changes in territorial safety [13][14]. In fact, work zones or the high concentration of heavy vehicles can expose both workers and road users to accidents, thus requiring specific procedures for traffic management.

Furthermore, due to European infringement procedures, several EU Member States have also been struggling with the remediation of illegal waste dumps. Just to illustrate this concept, in Portugal, a research project was financed to evaluate risks caused by the construction and demolition of illegal waste dumping [15]. In Italy, a specific department was started in 2017 to carry out the remediation of 200 illegal landfills of urban/industrial solid waste [16]. According to the Italian legislative framework on construction site management [17], risk assessment should also include risks for the external context caused by the working site. However, the legislator has not provided specific methodologies to cope with such an issue and, above all, with road safety near a remediation site.

2. Main Methods and Datasets Related to Road Safety Assessment

According to the Decade of Action 2021–2030 promoted by the United Nations [18], road safety needs to be addressed through a holistic approach. In fact, this will result from the interaction of several factors related to infrastructural conditions, the environment, users' behavior and vehicle safety [19]. In this section, a narrative focus on the main methods and datasets related to road safety assessment is provided.

2.1. Road Safety Assessment Methods

After some dangerous events that occurred in the 2000s regarding high-stakes infrastructure (e.g., fires in the tunnels of Mont-Blanc (1999), Gotthard (2001) and Frejus (2004)), Directive 2004/54/EC promoted the application of risk analysis as a supporting decision tool in Europe. However, Directive 2008/96/EC gave a greater impulse to promote road safety by identifying the following main phases for the trans-European road network [20][21]:

- Road safety impact assessment: a comparative analysis of impacts of new roads/modifications on the safety of the entire road network in the preliminary planning step;
- Road safety audit: a systematic safety check of the design features of road infrastructure;
- Road infrastructure safety inspection: a random check of defects requiring maintenance due to safety reasons;
- Network safety management: this is aimed at ranking road safety and identifying road lines with a high rate of accidents.

Recently, road safety management approaches have changed, which started when countries decided to guide themselves by setting quantitative targets for evaluating fatalities due to road crashes [22].

In such a legislative framework, specific procedures to carry out the abovementioned activities were not identified. Hence, the scientific literature that has been collected over the years contributes to such aspects.

As regards road safety assessment, many research contributions considered the implementation of risk analysis models to comply with the regulations imposed [23]. For example, Lombardi et al. [24] discussed the use of fault tree analysis (FTA) and event tree analysis to identify the hazard/damage chain of the starting event (of an accident). Other researchers focused their attention on the use of models aimed at addressing specific hazards in selected types of road infrastructures. Haddad et al. investigated the state of the art related to the critical ventilation velocity and back-layering conditions in tunnels in the case of fire [25]. Others [26] investigated the issues of risk analysis in railway transport.

It is worth mentioning the attention placed on emergency planning and resilience capacity of infrastructures in the scientific literature [27][28][29]. For example, Rasulo et al. provided a model to assess the seismic resilience of a road network and, above all, of road bridges, which are considered the most vulnerable element to earthquakes [30]. Rohr et al. addressed the development of a model that evaluates the systemic interrelations of emergency services (e.g., firefighting, rescue teams and ambulances) and their dependencies on road networks [31]. Kong et al. [32] analyzed the multihazard and the consequent effect on infrastructure resilience: the resilience of the infrastructural system relative to two events, in fact, is lower than its resilience relating to a single one and also change regarding the speed for the repair of the infrastructure.

Data mining techniques recently addressed road safety with cutting-edge approaches. According to Raval et al., data mining is aimed at extracting new patterns and correlations from huge amounts of data [33]. Moreover, it shows great flexibility: in fact, it includes machine learning, artificial neural networks, etc., thus addressing several kinds of data. This is the reason why such techniques were recently used in many research topics (e.g., accidents at work [34] and environmental issues [35]).

Regarding road safety, some applications are related to the classification of national big data, open access local data and data collected by GPS sensors installed on vehicles. Such applications are aimed at identifying hazardous situations related to the use of selected infrastructures/vehicles in order to promote preventive measures for territorial road safety.

2.2. Databases for Road Accident Analysis

At an international level, researchers agree on considering road accident databases powered by national road authorities as the most reliable sources of data on road accidents [36]. In fact, such data are collected from different raw sources (e.g., police, local administration and surveys of law enforcement) and show details that are useful for research purposes at a national level [37][38].

However, as reported by Chand et al. [39], interesting results were also yielded from other data sources. They include open access datasets [40], technology installed on road infrastructures and GPS sensors installed on vehicles for safety purposes [41][42].

Furthermore, some researchers could argue that another valuable source of data is social media (e.g., Facebook and Twitter). In recent years, opinion-mining techniques, i.e., the ability to extract significant correlations from textual information, allowed for risk perception assessment in several fields (e.g., cultural heritage [43], customer satisfaction [44] and industrial safety [45]). Dai et al. developed a research work concerning road safety in the state of Washington, starting from the analysis of tweets posted between March 2015 and February 2019 [46].

In **Table 1**, a summary of the main features of road accident databases is reported.

Table 1. Main road accident datasets.

Data Sources	Main Features
Databases with restricted access [37][38][47]	Organized according to several formats (e.g., CSV and geographic readable formats) and they take into account different sources of data on road accidents (e.g., police reports, municipal data and road operators data). Events are described through synthetic variables in order to be comparable at a national level and due to privacy reasons.
Open access data [40][48]	They are released according to the provisions of Directive 2019/1024/EU (Open data directive). They can be organized according to comma-separated values (CSV) and/or vector geographic formats. They include variables identified by short text or numbers. The number of variables can change according to local administrative needs. Details depend on the amount of information included in the initial source (e.g., police reports) and administrative borders.
On-board technology [41][42]	Technology installed on new vehicles to provide their localization. Data are sent to a control room to give assistance in case of an emergency.
Infrastructure technology [49]	Radar, cameras, unmanned aerial vehicles, etc., that provide real-time information on traffic and potential causes of road crashes. Resolution can be decided by the infrastructure's operator according to several factors (e.g., common users, average speed and infrastructures conditions)
Social media and newspapers [46]	Information is reported in short texts on social media and may include the author's personal point of view. Through opinion mining techniques (e.g., natural language process), data from both social media and newspapers are further elaborated to perform risk perception assessments. Analyses are consistently dependent on language knowledge.

At a European level, the Council Decision of 30th November 1993, n.704 (further modified by Regulation 2003/1882/EU) introduced a Community Database on Road Accidents (so-called CARE) resulting in death or injury (i.e., crashes *"between road users involving at least one vehicle in motion on a public highway normally open to traffic and causing the death of and/or injury to one or more of the road users"*). However, this decision let Member States decide their own collection standard. The European Commission has further recommended the Common Accident Dataset Standard (CADaS) since 2011, which includes 73 variables and 471 values. However, the implementation of a unique standard is currently not mandatory in European countries [50].

In most cases, Italian datasets on road accidents are organized to collect the information reported in **Table 2**. More factors can be evaluated by local authorities according to specific territorial conditions.

Table 2. Main information on road accidents in Italian datasets.

Accident Categories	Accident Factors
General information	Accident code (AC), number of people and vehicles that crashed
People injured	Name and surname, sex, age, driving license, working condition (at work/while commuting)
Time and place	Province, location, geographical coordinates, hour, year
Consequences	Death, fractures, hospital conclusions
Road infrastructure	Road code (RC), pavement, weather, road safety signs, point km
Vehicles	Type(s) of vehicles, power

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