Improving Knowledge of Risk in Dangerous Goods Transport

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Abstract

In order to increase safety as far as dangerous goods transport is concerned, the DESTINATION project has been developed since 2010 in the framework of the Italy/Switzerland Operational Program for Transfrontier Co-operation 2007-2013. The project was born to satisfy the increasing needs of public bodies to share data on hazardous material land transportation and to develop instruments and methodologies to ensure territorial and environmental protection. The project aims to reach this purpose through the increased knowledge of the vulnerable subjects, people and environment, and of the transport activity itself, by using and defining an architecture of data acquisition based on "On Ground Units" (OGU) and "On Board Units" (OBU). These data will be used as an input for a new information system called GIIS (Global Integrated Information System), which manages a risk analysis model of the land transportation of hazardous materials to assess human and environmental vulnerabilities. The GIIS will provide a more effective management of land planning by providing authorities with the possibility of implementing a rational restriction to vehicles transporting dangerous goods within specific areas.

Keywords

Hazmat, Hazardous materials, Dangerous goods, Transport risk, Tracking, Tracing, Risk analysis.

DESTINATION

The assessment of the risk associated to dangerous goods transport is an issue of strategic interest, since in Europe a relevant quota of hazardous materials transport is carried out by road.

Control of dangerous goods has always been mainly related to productive plants, but in recent years at European level, studies, projects and researches focused their attention on the transport of these materials. The attention of projects focused on minimizing damages after an ADR accident occurs (Fanelli et al., 1999) and managing crisis situations (Pastorelli et al., 2010). Other fields investigated by projects concern the definition of risk criteria (Marchionni et al., 2008), the planning of ADR transports (Romano et al. 2010) and the monitoring of ADR vehicles (Benza et al., 2007).

The main legislative references for the regulation of the transport of dangerous goods are made by the ADR, for road transport, and by the RID, for rail transport. These agreements, however, merely regulate the transport of hazardous materials considering the requirements road vehicle carrying dangerous goods have to be compliant with, on-board devices and drivers' training. According to the laws and regulation in force, monitoring and controlling the route of vehicles transporting dangerous goods is not required, and the interaction vehicle-infrastructure-environment related to the route is not specified.

The consequence of this approach is the absence of measures to reduce transport risks, such as, for example, a rational restriction to the passage of transport of dangerous goods in areas with a ahigh population density, near sensitive locations or within areas with specific vulnerabilities for the environment.

The DESTINATION project generated from the awareness of this lack in legislation with the aim to create an instrument and a methodology to enrich the knowledge on Dangerous Goods Transportation (DGT) and on the anthropic and environmental vulnerability, in order to protect the territory.

DESTINATION aims at realizing a Global Integrated Information System (GIIS) to collect data from institutional partners and from a specific monitoring architecture based on OGU-Gates (On Ground Units) and on OBU (On Board Units). Gates and OBU will be connected to the GIIS through an interface to transmit data on ADR vehicles transits.

Based on this data, the GIIS will process risk maps of all the areas of the project defining the risk at a local scale, depending on user needs. Simulation features will also be available according to the needs of public and private stakeholders.

The project involves the Regione Piemonte (IT, Project leader), the Regione Lombardia (IT), the Valle d'Aosta (IT), the Provincia Autonoma di Bolzano (IT) and the Cantone Ticino (CH).

Data acquisition activity

A little information related to the transport of dangerous goods by road is available nowadays. Within the territory involved by the project, the only data available is either only related to too small areas, or connected to pilot researches, or it is excessively aggregated.

The main source of information is the "Conto Nazionale Trasporti" (ISTAT, 2004), a statistical publication by the Italian Ministero delle Infrastrutture e Trasporti, reporting aggregated data about the incoming and outgoing tons of dangerous goods, divided in wide categories, for each Italian region.

In order to obtain meaningful results for the GIIS, significant data for the territory involved by DESTINATION is therefore to be acquired. To reach the aim, a network of data acquisition and analysis of DGT will be provided, based on two different approaches:

- OGU-GATES (electronic gates) to detect the transit of vehicles transporting hazardous materials, able to register the alphanumeric code contained in the UN and Kemler orange panels, as required by the ADR;
- OBU (On Board Units) are electronic devices installed on the vehicles in order to trace transport routes as well as the type of substance.

OGU - Gates

Electronic gates will be placed on strategic road infrastructures for DGT and based on OCR technology for the registration of the UN and Kemler code. The gates will be placed according to the following criteria:

- Availability of installation support, with energy and data transmission connections;
- Roads notoriously used by DGT and connecting productive plants to the territories involved in DESTINATION;
- Roads of different categories.

Figure 1 - Locations of the Gates

The 27 Gates installed will communicate the data recorded to a central server that will carry out data and images processing and image transfer, in order to guarantee the tracking of goods in transit from the areas being monitored. The transmission of data between the gates and the central server will be based on the mobile network of leading national operators or using a wired network, if the locations identified are provided with a connection point to the fixed network.

OBU – On Board Units

In order to know the routes interested by DGT, OBU will be used to transmit information

from the vehicle via a GPRS connection as a string of text. This string is composed by the data pair "type" and "value", which indicate the type of event and its value (for example "transmission event of exceeding the speed limit" with its values). In this way the data model is expandable with all the events / type of information that the vehicles could transmit.
The minimum set of data to be transmitted consists in the vehicle’s position and in the type of substance. The system is intended to receive further information that can be sent by sensors, such as:

- Rollover and plugging sensors;
- Sensors monitoring load conditions;
- Sensors monitoring vehicles conditions;
- Automatic alarms resulting from accidents;
- Manual alarms activated by the driver.

Not all information can be automatically transmitted by OBU, and some must be entered manually, e.g. the type of substance. To ensure that both large fleets and individual transporters take part to the project two architectures are possible, according to the needs of the final users.
The first architecture considers that the information concerning the relevant substance, the code that uniquely identifies the travel and the information about the driver, tractor and trailer are included in the system in two alternative ways:

1. an operator performs the operation of back-office data entry via a web form which is directly made available by the GIIS;
2. the Information Systems of the transport company will send the information to the GIIS via a Web Service (WS).

As far as the second possible architecture is concerned, which is more suitable for individual carriers, the OBU itself must directly collect the input information entered by drivers. In this case a specific tool (keyboard or tablet) available for the drivers will be designed to enter data via USB or Bluetooth.

DGT Risk Analysis Model

After a survey of the geographical, anthropic and environmental data available among the partners to identify a common data set, a definition of the methodology of the DGT risk analysis was made possible.
The parameters to define DGT risks and their functional dependencies were defined considering the need of optimizing the implementation of the algorithm in the GIIS.
To determine the connection of each parameter to the elements of major interest, 4 "subscripts" were defined:

- arch road (*i*);
- ADR substance (*j*);

- incident scenario with a specific threshold and a consequential damage area (*k*);
- type and susceptibility of targets (*m*).

The general risk formula is the following:

$$R_{Dest} = \sum_i R_i = \sum_i \left(P_{is,i} \times \sum_j \left(P_{ADR,ij} \times \sum_k \left(P_{sc,ijk} \times \sum_m \left(Fp_m \times E_{ikm} \times S_{km} \times \left(1 - C_{ff,ikm}\right)\right)\right)\right)\right) \quad (1)$$

Where:

R_{Dest} = “Destination” cumulated risk (deaths/y), (damaged m^2/y), (€/y)

R_i = cumulated risk referred to the *i*-th arch (deaths/arch/y) (damaged m^2/arch/y) (€/arch/y)

$P_{is,i}$ = road hazard referred to the *i*-th arch (vehicles involved in accident/arch/y)

$P_{ADR,ij}$ = occurrence probability of a car accident involving a *j*-th ADR substance referred to the *i*-th arch (ADR vehicles involved in accidents/vehicles involved in accidents)

$Psc_{,ijk}$ = occurrence probability of a *k*-th incident scenario with a specific threshold and a consequential damage area (*k*), involving the *j*-th substance, on the *i*-th arch (incident scenario/ADR vehicles involved in accident)

$Fp_{,m}$ = presence factor of the potentially exposed target referred to specific temporal sets

$E_{,ikm}$ = *m*-th target potentially exposed to a *k* incident scenario with a specific threshold and a consequential damage area (*k*), involving the *j*-th substance, on the *i*-th arch (exposed inhabitants/incident scenario), (exposed m^2/incident scenario), (estimated € of damage/incident scenario)

$S_{,km}$ = susceptibility of the *m*-th target (deaths/exposed inhabitants), (damaged m^2)/(exposed m^2), (damage in €/estimated € of damage)

$C_{ff,ikm}$ = resilience/cope capacity of the *m* target potentially exposed to a *k* incident scenario with a specific threshold and a consequential damage area (*k*), involving the *j*-th substance, on the *i*-th arch (multiplicative factor from 0.10 to 0.20)

The structure of the formula gives users the possibility to obtain even partial intermediate useful results, such as, for example, the amount of exposed targets within an area.

Pis,i (Occurrence Probability of car accident)

The parameter $P_{is,i}$ represents the probability of each road element to be interested by a generic car accident. The P_{is} shall be calculated as follows:

$$P_{is} = Inc \times p_{terr} \quad (2)$$

where:

Inc = car accident occurrence (accidents/km/year)

p_{terr} = factor able to increase the value of *Inc*, considering possible domino effects related to the territory (landslides, floods, avalanches)

The *Inc* factor will be defined based on historical statistics, and a particular procedure will avoid the possibility that road links could be characterized by a value of 0 accidents.

P_{ADR} (Occurrence probability of car accident involving a vehicle transporting hazardous materials by road)

The use of Gates and even more of OBU is intended to obtain data about DGT routes in order to achieve more precise information about the traffic of DG vehicles and even of their involvement in road accidents.

Current statistics do not exhaustively specify any presence or absence of ADR vehicles in accidents. For this reason, for the time being, it is assumed that P_{ADR} is set equal to the ratio of traffic quota of dangerous goods transports to the generic traffic:

$$P_{ADR} = k_{inc,pes} \times k_{traff,ADR} \quad (3)$$

where:

$k_{inc,pes}$ = ratio of heavy traffic involved in car accidents to the generic traffic (heavy vehicles involved in car accidents/circulating vehicles involved in car accidents)

$k_{traff,ADR}$ = ratio of ADR traffic to heavy traffic (ADR traffic/heavy traffic)

DESTINATION focused its attention on 10 model substances which are considered strategic for the institutional partners involved.

P_{sc} (Occurrence probability of a scenario)

$P_{sc,ijk}$ represents the probability that, from a road accident involving an ADR vehicle, a loss of load and then a trigger occurs, resulting in a scenario with a specific threshold and a specific damage area (buffer).

This parameter is affected by the probability of release, depending on the type of container used (atmospheric or pressure tank) and on the extent of the loss and the trigger probability:

$$P_{sc}(p) = P_{pc} \times P_{inn} \quad (4)$$

where :

$P_{sc(p)}$ = probabilistic component of P_{sc} (incident scenario/accident ADR vehicles)

P_{pc} = probability of loss (ADR vehicles with loss/accident ADR vehicles)

P_{inn} = trigger probability (incident scenario/accident ADR vehicles)

DESTINATION focused its attention on 11 standard incident scenarios, including pool fire, flash fire, fire ball, jet fire, release in water and soil and toxic gases and vapour release.

Fp (Presence factor), E (Potential exposed targets), S (Potential exposed targets susceptibility) and Cff (Cope capacity)

The parameter E represents targets that are potentially exposed to the different scenarios.

The GIIS will have to calculate and display the DGT risk both for “human targets”, such as road users and resident populations, industries employees, hospital, school and shopping centre users and employees, and “non-human targets”, such as protected and agricultural areas, ground and surface waters and woods.

The consequences will be assessed through the overlapping of damage areas connected to the *k*-th with maps of exposure. The consequences for human targets will be expressed as the number of equivalent inhabitants, while for non-human targets it will be necessary to find a way to give them a common unit, such as, for example the equivalent m^2.

The parameter S represents the fact that not all targets that are potentially exposed could be really damaged, whereas the C_{ff} is defined as the resilience or cope capacity, which means the capability of the territory to face the damage reducing its negative consequences.

The parameter F_p is able to quantify the actual presence of targets considering different time sets (for example weekday or weekend).

GIIS features

The GIIS is intended to be a modular system, able to give features for preventive, passive and active safety. It will be structured according to the implementing rules of INSPIRE Directive, whose aim is to create a European Union spatial data infrastructure.

The first function implemented on the GIIS is the possibility for users to process and view DGT risk maps of the given areas, at different scales. Moreover, the user has the possibility to carry out simulations, e.g. inserting on the map the point where an accident could occur to verify impact areas, vulnerabilities and to evaluate the potential environmental and anthropic damage. It will be also possible to insert new structures, infrastructures, building areas as well as to assess how the DGT risk may change.

Results will be clear and understandable thanks to the use of different colours in order to display the different levels of risk.

In a second phase of DESTINATION new features will be implemented in the GIIS, especially in the field of travel information services. The information that will be transmitted to the ADR drivers involved in the project will regard weather conditions, traffic, parking areas, presence of other ADR vehicles on the same route.

Conclusions

DESTINATION and its final product GIIS shall provide with some support all the stakeholders (private and public ones) involved in hazardous material land transportation in all its phases.

The collection, organisation of data sets available and common among the partners, and their implementation with data related to monitoring activity with GATES and OBU will increase, on the whole territory, the knowledge of DGT as well as of territorial and environmental vulnerabilities.

A deeper awareness of DGT risks and of ADR vehicles routes will influence decision-making processes in urban planning, new infrastructures planning and management and route planning.

The project may also result in the definition of guidelines useful to influence the legislation on dangerous goods transportation by road, considering even issues that are still unanswered in some contexts, such as for example the classification of road tunnels requested starting from ADR 2007.

The GIIS, its functions and tools will be part of the official information systems of institutional partners. This condition will guarantee the use, the updating and the maintenance of the GIIS for years.

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