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Methodological aspects for modeling the environmental risk of transporting hazardous materials by road

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ABSTRACT

The main objective of this paper is to establish the procedures necessary to the development of a model for the environmental risk assessment of accidents involving Transporting Hazardous Materials by Road (THMR). Quantifying the environmental risk is useful in identifying areas with a high risk of accidents, which can be later discarded as main routes; orienting efficient emergency response operations; and assessing policies aimed at reducing these risks. Taking this into consideration, this study endeavors to identify the methodological aspects make possible the assessment of the impacts that arise from accidents involving the transportation of hazardous materials by road and to implement such methodological aspects in a Geographic Information System (GIS).

Introduction

Over the last few years there has been growing concern regarding the transportation of Hazardous Materials (HM), specially due to rise in the consumption of HM, which results in an increase in road transportation of these goods. Additionally, there is the issue raised by the dominance of transportation of hazardous materials by road (THMR) over other transport modes. For instance, 63% of hazardous materials are transported by road in Brazil (CETESB, 2005), and more than 90%, in the USA (Pedro, 2006; Panwhar et al., 2000). Other issues concerning the THMR in Brazil include the amount of built up areas along roads and vehicle fleet age (Nardocci and Leal, 2006). This increases the risk of the THMR for society and environment. Owing to this, there is a demand for environmental research to assess the risk involved in transporting hazardous goods, in order to reduce the risk and minimize damage caused by accidents involving the transportation of this kind of material.

Two kinds of models to assess risks involving hazardous material can be found in the literature: static and dynamic models. Static models analyze the risk at a fixed place, for example in an industrial plant (Planas et al., 2006). Considering that THMR is a mobile risk, since the material is constantly being moved through the environment, dynamic models are the most appropriate ones.

Additionally, dynamic models offer two kinds of analysis: those that include only the social risk, without considering the environmental variable, represent the most frequent analyses with risk and are determined by the road characteristics and the exposed population; those that involve both the social and the environmental risk, and therefore have become an important tool for management and decision making as they are more comprehensive.

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Table 1
Chemical products hazards. *Source:* Adapted from Martínez-Alegría et al. (2003).

Flammability	H_I	Toxicity	H_T	Reactivity	H_R	Oxidation	H_{GO}
Non-flammable: the material does not burn	0	Minimal risk	0	No reaction	0	Non-combustive or moderate oxygen contribution may ignite nearby combustible materials	0
May ignite other combustible materials and/or release inflammable gases in a reaction	1	Dangers deriving from fumes, vapors released during the decomposition of the material. Radioactive materials with a low level of radiation	1	Stable, but becomes unstable on-heating. Containers may explode when heated	1	Very powerful combustive: react violently or explosively with many materials	1
Needs to be pre-heated to burn, may smoulder but will not burst into flame easily	2	Moderately dangerous: burns, irritation. Radioactive materials with moderate level of radiation	2	Possible violent chemical changes at high temperatures. Explosive polymerization on heating			
May burn rapidly and/or ignite on making contact with air or humidity	3	Very dangerous: may produce severe lesions. Radioactive materials that may produce a high level of radiation	3	Explosive reaction to initiating source, high ambient temperature, overheating, friction. Explosive reaction on contact with water and combustibles			
Highly inflammable: Inflammable gases, liquids and solids; pyrophosphoric materials	4	Toxic and EXTREMELY DANCEROUS. Materials that may cause death	4	Capable of detonating in ambient conditions. Mass explosion hazard. Materials that form explosive mixes with air			

Table 2
Criteria under consideration for expert panel. *Source:* Adapted from Nicolet-Monnier and Gheorghe (1996).

Targets	Listed criteria
Environment	• Physical environment: hydrography, soil texture, topography, land use, etc. • Biotic environment: vegetation, fauna, etc.
Population	• Town's location, population density, economic activity surrounding the road
Road	• Functional: type of track, Daily Average Volume (VDM), traffic profile • Geometrics: horizontal curve, vertical curve, linear stretch, level crossing, ramp slope, etc.

In the dynamic models involving only the social risk, in order to characterize the road, various factors can be considered. Fabiano et al. (2002) considered the inherent factors such as: tunnels, railway bridges, high gradient, downward slopes, neighborhood characteristics and traffic conditions. According to the method used by Carotenuto et al. (2008) and Bonvicini and Spadoni (2008), the characterization of the road can be carried out by the probability of accidents happening in the road segment studied while hazardous goods are being transported. Verter and Kara (2001) point out that in order to determine the risk involved in transporting hazardous goods by road, the probability of a traffic accident varies according to the road's features, such as the number of lanes.

There are also more complex systems which take into consideration the road's features, the exposed population, the characteristics of the goods being transported, as well as weather conditions. In order to determine the risk of THMR, Bubbico et al. (2004a) included the accident rate related to the road's features, the weather conditions and the population density related to the area's characteristics. Afterward, Bubbico et al. (2004b) developed a risk analysis for road and rail transportation of hazardous goods using a GIS to manage land information in conjunction with a data bank of the goods. Nathanail et al. (2010) determined the social risk for transporting hazardous materials through tunnels, a method applied to Attica Tollway, an urban road in Athens, Greece. For the development of the model, the authors considered: the tunnels' features; the type of hazardous material; the traffic characteristics; the probability of accidents involving THMR; and the population at risk (the number of people living within a certain distance along the route).

In dynamic models that include the environmental variable, models by Lepofsky et al. (1993), Martínez-Alegría et al. (2003), Pedro (2006) and Tixier et al. (2006) were found. Lepofsky et al. (1993) carried out the management of accidents and risk assessment in THMR using GIS in various case studies on Californian roads. The developed model related the probability of accident occurrence, the probability of leakage of hazardous goods being transported and the consequences of such leakage, measured by the exposed population and financial damage to environmentally sensitive areas.