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Protection of transport infrastructures against major accidents in land use planning policies. A decision support approach

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ABSTRACT

Users of transport infrastructures nearby hazardous plants may represent important populations potentially impacted by a major accident. Toulouse catastrophe in 2011 has been an illustrative example as it strongly impacted highway users. Therefore, transport infrastructure users (Roads and railways mainly) represent a population to be protected within a land use planning policy as it is the case for inhabitants.

Accordingly, this paper presents a decision support approach aiming to help local stakeholders identifying the most cost effective measures to protect transport infrastructures from major accidental consequences. The suggested approach takes in account both technical and participatory constraints with the aim of offering an equal chance to all involved stakeholders to understand the issues under discussion and formulate opinions and values.

After a description of the French regulatory context, the major technical difficulties related to transport infrastructures protection will be described before introducing the main technical choices adopted by the team. Finally, a decision support procedure is described and a real case study presented.

This work is strongly embedded in the French regulatory context. However, we believe the decision support structure as fully adaptable to other regulatory contexts.

1. Introduction

Land use planning has been a pillar of industrial risk management policies in Europe since the second Seveso directive 96/82/EC in 1996 and its revision in 2012 (Seveso III) have confirmed this status (4). Very synthetically, European policy on land use planning around hazardous plants is strongly oriented toward the future by dealing with modifications of existing installations, sitting of new ones or new developments of land uses (Seveso II directive, article 12). The reader may find in (Lenoble, Antoine, Bolvin, Kooi, & Ujit de Haag, 2010; Basta, Neuvel, Zlatanova, & Ale, 2007; Christou, Gyenes, & Struckl, 2011) and (Grooijer, Cornil, & Lenoble, 2010) a more extended description of this policy and its applications in various European countries.

However, the Toulouse (France) catastrophe in 2001 did put the spots on the need to consider also heritage of past policies where proximity between dense populations and industrial hazards was accepted (MEDDE, 2006). Risk acceptability being a social and dynamic construct (Renn, 1998; Short, 1984), it evolves through time: what has been accepted in the past may be rejected in the future, especially after a big catastrophe as it was the case in France (IRSN, 2012) or more recently in Fukushima (Prati & Zani, 2012).

Therefore, France decided to take a step further in risk prevention by adopting the 699-2003 Act on technological and natural risks prevention. Regarding the industrial risks part of the law, regulators insisted on the need to define, around some hazardous plants[1], land use planning processes that integrate safety criteria in future projects acceptation, besides correcting existing situations where cohabitation of hazards and vulnerable stakes is no more acceptable. Practically, this may lead for instance to expropriate either the hazardous site or some of its neighbors, whether they are inhabitants or other economic activities (MEDDE, 2006).

The local public decision processes aiming to achieve those objectives are the *Plans de Prévention des Risques technologiques*[2] *(PPRT)*. With respect to national acceptance criteria and technical

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[1] Plants classified by Seveso regulation as highly dangerous (Tier up) regarding the type and quantities of hazardous substances stocked or involved in the production processes.
[2] Technological Risk Prevention Plans.

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directives, those participative processes provide local stakeholders with the opportunity of discussing the most adapted local equilibriums between safety on one hand and social and economic development on the other hand (Mazri, Chantelauve, & Chevalier, 2010). There are about 420 distinct PPRT processes planned for the whole France.

One of the key issues raised by those decision processes is how to deal with existing and future transport infrastructures (roads, railways) located in risky areas. Protecting transport infrastructure users is a complex problem for mainly two reasons. The first one is the linear character of those infrastructures making it possible for the same risk scenario to generate various consequences levels for different linear segments depending on their respective distances with the accidental source. The second is the usual large set of social and economic stakes usually associated to decisions on transport infrastructures (Lakshmanan, 2011).

This paper will present an original and pragmatic approach aiming to support decision making on transport infrastructures protection given the PPRT context. In the next sections, we will be equally interested in describing the technical related issues we have been dealing with and the policy making related ones that present, in our opinion, interesting insights to the community of decision support providers in public risky contexts.

2. The PPRT framework

As specified earlier, PPRT are public decision processes aiming to both correct existing unacceptable territorial configurations and shape future territorial evolutions regarding industrial risks. It would go far beyond the objectives of the present paper to provide the reader with a full description of the specificities and evolutions introduced by the PPRT in the French regulation on land use planning. An extensive description is provided by Lenoble and Durand (2011) and Taveau (2010). We will thus focus on salient elements regarding the issue of transport infrastructure protections. We will proceed to the presentation of the PPRT framework according to its technical, organizational and financial features.

2.1. Technical features of PPRT

Risk is usually understood as a combination of a probability and the scope of consequences (Duijm, 2009) despite the various meanings the concept of probability may carry (Aven, 2013). Accordingly, Risk can be defined through Formula (1) below:

$$\text{Risk} = P \otimes C = P \otimes I \otimes V \qquad (1)$$

P: One year frequency associated to a given accidental scenario.

C: Severity of consequences regarding the stakes under consideration (human, ecological, material…).

I: Intensity of one or several effects generated by the scenario. For instance: Heat flows in case of thermic effects, Toxic concentrations in case of toxic releases…

V: Vulnerability of stakes under consideration regarding the intensity level.

In the PPRT framework, risk is defined in a slightly different way according to formula (2):

$$\text{Risk} = P \otimes I \otimes K \otimes V = A \otimes V \qquad (2)$$

A: Stands for 'Aléa' and defines the frequency that a dangerous phenomenon creates effects of a given intensity and over a determined time period at a given point of the territory (MEDDE, 2006). In addition to the classic frequency criterion, Aléa are characterized according to the two following additional criteria:

Table 1
Seriousness scale of consequences according to French regulation (MEDDE, 2006).

	Very serious consequences	Serious consequences	Significant consequences
Disastrous	>10	>100	>1000
Catastrophic	1–10	10–100	100-1000
Important	<1	1-10	10-100
Serious	0	<1	1-10
Moderate	0	0	<1

-I: A description of the various potential effects (overpressure, toxic, continuous or transient thermic) and the modeling of their respective intensity propagation. For instance, a Boil over will generate both overpressure and transient thermic effects for which different modeling will be performed.

The variations of intensity levels for each effect are set according to three thresholds:

- *Very serious consequences threshold (LC 5%)* define zones within which at least 5% lethality is expected regarding the intensity level.
- *Serious consequences threshold (LC 1%)* defines zones where lethal effects may impact less than 1% of the population.
- *Significant consequences threshold (LC 0%)* defines zones where no lethality is expected but still irreversible injuries are likely to happen.

Depending on the number of people impacted in each zone, a qualitative assessment of consequences seriousness is performed according to the matrix detailed in Table 1 below.

- K: An appreciation of the time duration required for each effect to reach vulnerable stakes starting from its detection. This *kinetic* criterion aims at assessing the opportunity to deal with a given scenario through an emergency planning procedure (if the kinetic is slow) instead of a land use planning one (in case of fast kinetic).

Those scenarios are aggregated in order to elaborate individual risk[3] maps dividing the territory into concentric *Aléa* zones ranging from very high to very low (see Fig. 5 for an example). Once such zones are established the planning proceeds as follows:

a. Within the risky areas identified in the previous step, an inventory of stakes is elaborated. The term stakes is here only focused on human safety and no consideration is given to material or ecological damages. Schools, habitations, economic activities or transport infrastructures are examples of stakes considered in the PPRT because of their human frequentation.
b. *Aléas* and stakes maps are superimposed and when necessary, vulnerability assessments are conducted to evaluate the ability of some constructions to protect their users regarding the *Aléas* level impacting them.
c. Depending on the variety of *Aléas* and vulnerability combinations, the following decision alternative are made available:
   - *Aléas* reduction through adapted technical or organizational measures aiming to reduce either the frequency or the intensity associated to one or several accidental scenarios.
   - Mandatory expropriation and compensation of the plant generating the risk or of one or several of its neighbors impacted by unacceptable risk levels.

[3] The term individual risk is defined here as the risk to an actual or hypothetical individual related to single or multiple event (Johansen & Rausand, 2014).