Road transportation of dangerous goods quantitative risk assessment and route comparison

Philippe Cassini, Nelson Rodrigues

INERIS

INSTITUT NATIONAL DE L'ENVIRONNEMENT INDUSTRIEL ET DES RISQUES

ROAD TRANSPORTATION OF DANGEROUS GOODS QUANTITATIVE RISK ASSESSMENT AND ROUTE COMPARISON WITH QRA MODEL

P. CASSINI and N. RODRIGUES

Institut National de l'Environnement Industriel et des Risques
Direction des Risques Accidentels
B.P.2
F-60550 Verneuil-en-Halatte
Tel: 33 3 44 55 64 95
Fax: 33 3 44 55 65 92
email: philippe.cassini@ineris.fr

Transportation of Dangerous Goods (TDG) by road creates risk for the people present on and along the routes (road users and surrounding population). To minimise them is it better to have TDG going through a city or on the contrary by a longer detour through less populated areas ? The choice is not always easy. It may become very difficult when the detour goes through tunnels. There, accidents may have developments and consequences very different from what might happen on an open air route. To make the right choice it becomes necessary to use a QRA (Quantitative Risk Assessment) approach dealing with the accident Scenarios likely to occur, their probability and possible consequences. It may be useful to identify the DG (Dangerous Goods) classes which contribute most to the risk and examine the interest of non-uniform strategies i.e. different routing for certain DG.

Studies for real sites

INERIS has determined the risks due to TDG for real sites where traffic could go either through a city or an alternative route including a tunnel. To perform these studies, INERIS has devised and used a method for determining curves of yearly frequency against number of fatalities corresponding to the risks due to TDG on each route. These curves are hereafter mentioned as “ F/N curves ”. This method is very flexible and may be used in very various configurations.

To practically use it, it is necessary to gather, during a first stage, data concerning :

- density of population in the concerned geographical area (possibility to take into account diurnal or seasonal variations),
- traffic of all vehicles and foreseeable routes (possibility to take into account diurnal or seasonal variations),
- traffic of DG : nature of contents and holders, global annual traffic, foreseeable evolutions,
- meteorology in the concerned geographical area,
- layout of the open-air routes (which are divided in “ segments ” with constant probability of occurrence of each scenario),
- if it applies, dispositions taken for the design and equipment of the tunnels.

A complete risks assessment due to the TDG would require the consideration of all the possible meteorological states, all the possible accidents with all the types of vehicles completely or partially loaded. A such assessment is totally impracticable and simplifications were introduced. The model developed and used by the INERIS is based on the exam of 10 scenarios (table 1) concerning a restricted number of dangerous goods.

Two scenarios relative to fires of Heavy Goods Vehicles (HGV) and not transporting goods were used because they represent a serious risk in tunnel and because their probability of occurrence is higher than that of scenarios involving dangerous goods.

Scenario Nr:	Description	Capacity of tank	Size of breach (mm)	Mass flow rate (kg/s)
1	HGV fire 20 MW	-	-	
2	HGV fire 100 MW	-	-	
3	BLEVE of LPG in cylinder	50 kg	-	
4	Motor spirit pool fire	28 tonnes	100	20.6
5	VCE of motor spirit	28 tonnes	100	20.6
6	Chlorine release	20 tonnes	50	45
7	BLEVE of LPG in bulk	18 tonnes	-	
8	VCE of LPG in bulk	18 tonnes	50	36
9	Torch fire of LPG in bulk	18 tonnes	50	36
10	Ammonia release	20 tonnes	50	36

Table 1**: Main characteristics of the 10 selected scenarios**

Determination of the occurrence probabilities and effects

The Organisation for Economic and Co-operation Development (OCED) and the World Association of the Road (PIARC) launched a common research program concerning the Transport of Dangerous Goods (TGD) in road tunnel. The objectives of this program are the settling of a quantitative risks assessment model (QRA model).

For the open air routes, models exist to calculate the physical consequences of scenarios. The consideration of possibilities of evacuation and stake under cover, and the use of equation of probit (Equation which allows to deduct the physiological consequences, from the knowledge of the physical consequences of an accident), allow to calculate the percentage of deaths and/or injuries.

In tunnel, the techniques usable with the open air route do not apply in general. So a specific processing is necessary to determine: The zones of the tunnel which are affected, the effects which overflow of the tunnel and create risks outside.

A specific tool called the "Pre-conditioner" was developed for that purpose. Because of the complexity of the treated problems and the number of possible configurations of ventilation (longitudinal, semi-transverse or transverse, tunnels containing one or two pipes), it uses a simplified modelling.

The adoption of measurements appropriate to tunnels (concerning the traffic, the drainage of flammable liquids, the capacities for the construction of the tunnel, the surveillance...) can reduce the frequency of the accidents, their gravity, the delays of detection. Some of these measures are taken into account in the Pre-conditioner and the QRA. It is so possible to investigate their influence on curves F/N.

Theses studies are very complex. It is therefore impossible to avoid simplifications. The first one being that risk level is evaluated by examination of only a limited number of scenarios corresponding to a very small number of DG. In the same way, collection and prevision of site data are sometimes roughly performed. It is for example difficult to predict 10 or 15 years in advance what will be global traffic, DG traffic and seasonal changes in surrounding population densities.

Minimising risk between several alternative routes

In case where DG may be transported by different routes, the method enables to determine the risk that would result from TDG for each route if it were the only one chosen for the DG traffic (DG traffic forbidden on the other routes). Interpretation of results relies on comparing the various F/N curves pertaining to the routes or on comparing the various associated “ mathematical hopes ” (Each F/N curve gives a mathematical hope which represents the area located under the F/N curve. It indicates the yearly number of fatalities when the accidents of every severity are summed up and is expressed in fatalities per year).

This comparison leads to a certain conclusion in the case of F/N curves that do not intersect (as shown on **figure F1**).

It is also possible to get intersecting curves, but with significantly different mathematical hopes (as shown on **figure F2**), and this even when uncertainties are taken into account. Once more, a conclusion is at hand.

When F/N curves intersect and lead to close mathematical hopes, the method does not help in the decision process except give indication that the comparison of risks linked with DG is not discriminating and decision might be made on other criteria.

Judging of the acceptability of risk on a route.

It is possible to judge of the acceptability of the risks due to TDG on a route by comparing the F/N curve with acceptance criteria in case such criteria are available and accepted (**Figure 3** shows a fictitious use of such criteria).

Societal risk may also be judged on a local basis using iso-contours like those appearing in **Figure 4** . These contours indicate for each area the statistical probability level to get fatalities. These probabilities take into account the population densities and their eventual daily and seasonal variations.

It is also possible to compare individual risk for the surrounding populations with individual risk acceptance criteria.

Conclusion

QRA of risks due to TDG helps in decision making when routes have to be chosen for DG transit and one wants to minimise resulting risks. It also enables to situate the risks due to TDG against other kind of risks (fatalities due to banal traffic accidents i.e. no DG involved for example). It requires complex studies. A method and practical tools have been produced and used for real site cases.

Nevertheless, further work has still to be carried out in order to make these evaluations easier, more accurate and indicate the magnitude of the uncertainties.

Finally, the transportation of dangerous goods can be made by different ways of transportation (railway, road...). The current researches of the INERIS, aims to develop an assessment risk model due to the transportation of dangerous goods by the railway and to create an interface common with the “road tool” and with the “railway tool” to improve the user interface and connect these two " road " and " railway " tools. The objective is to allow calculation of risk on a route, independently of the environment (tunnel or open area), and independently way of transporting (railway, road or combined road-rail transport).

List of figures :

Figure F1 Example of non intersecting F/N curves.

Figure F2 Example of intersecting F/N curves with different mathematical hopes.

Figure 3 Example of comparison of a F/N curve with an acceptance criterion.

Figure 4 Iso-contours of societal risk due to dangerous goods traffic on an open air route (taking into account the population layout).

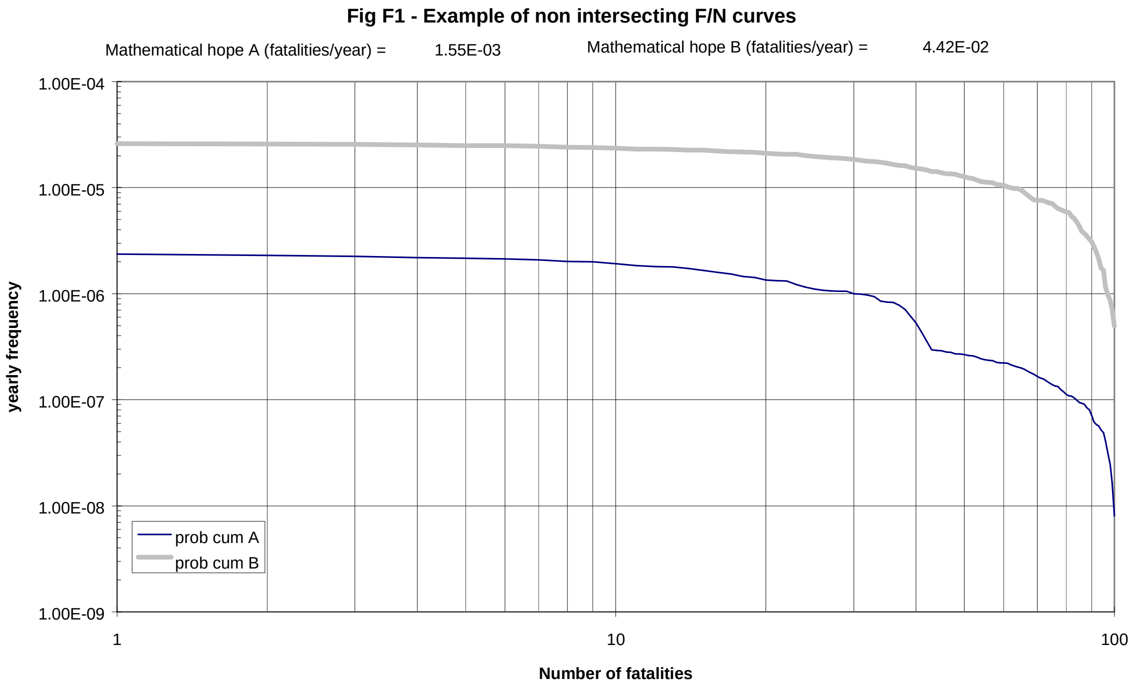


Fig F2 - Example of intersecting F/N curves with very different mathematical hopes

Mathematical hope A (fatalities/year) = 1.86E-03 Mathematical hope B (fatalities/year) = 4.48E-02

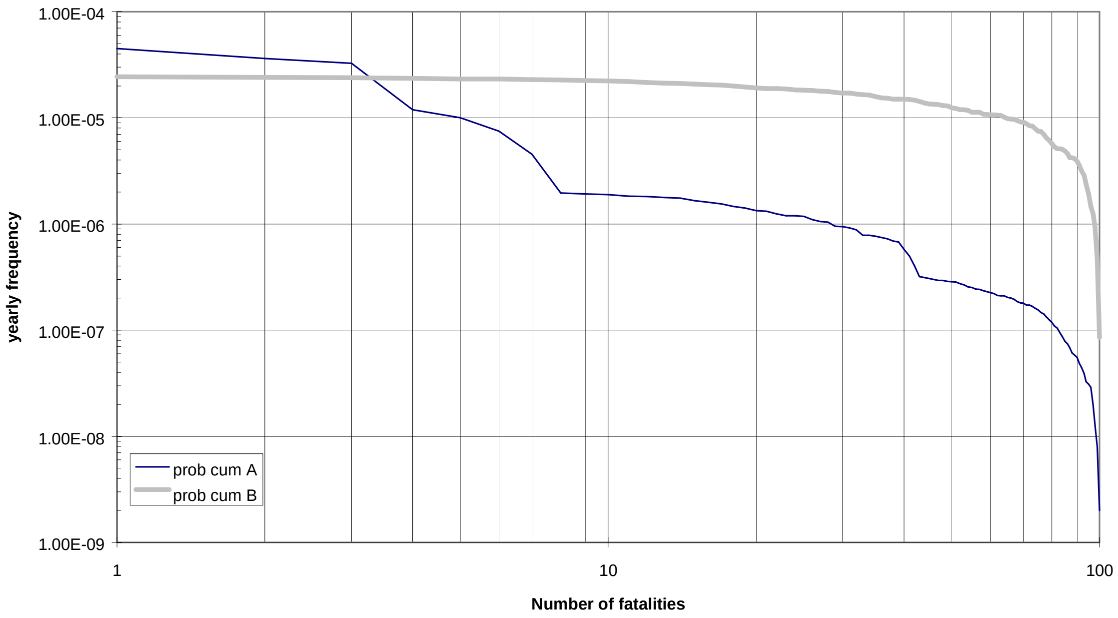
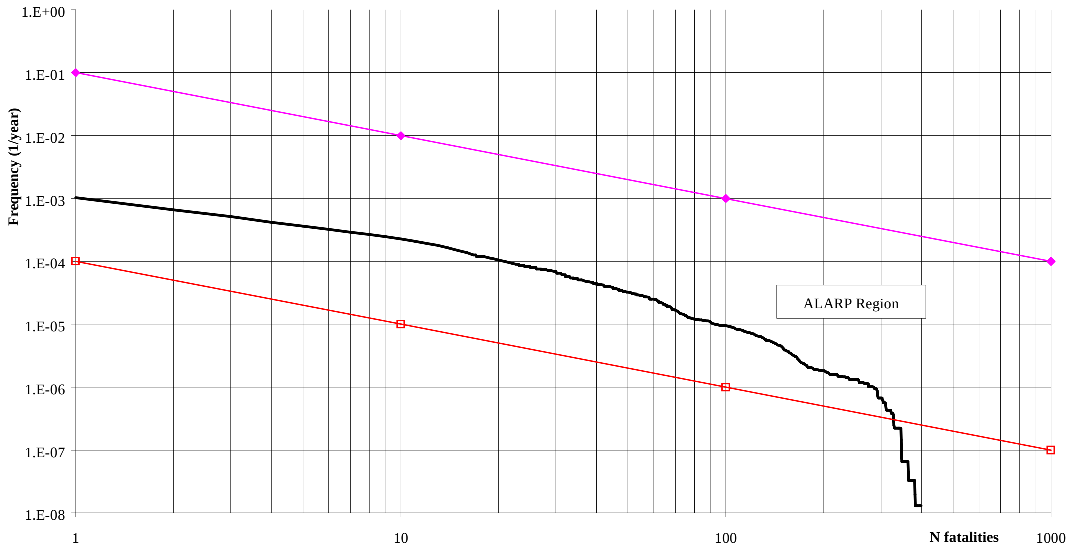


Figure 3 : Comparison of a F/N curve with an acceptance criteria



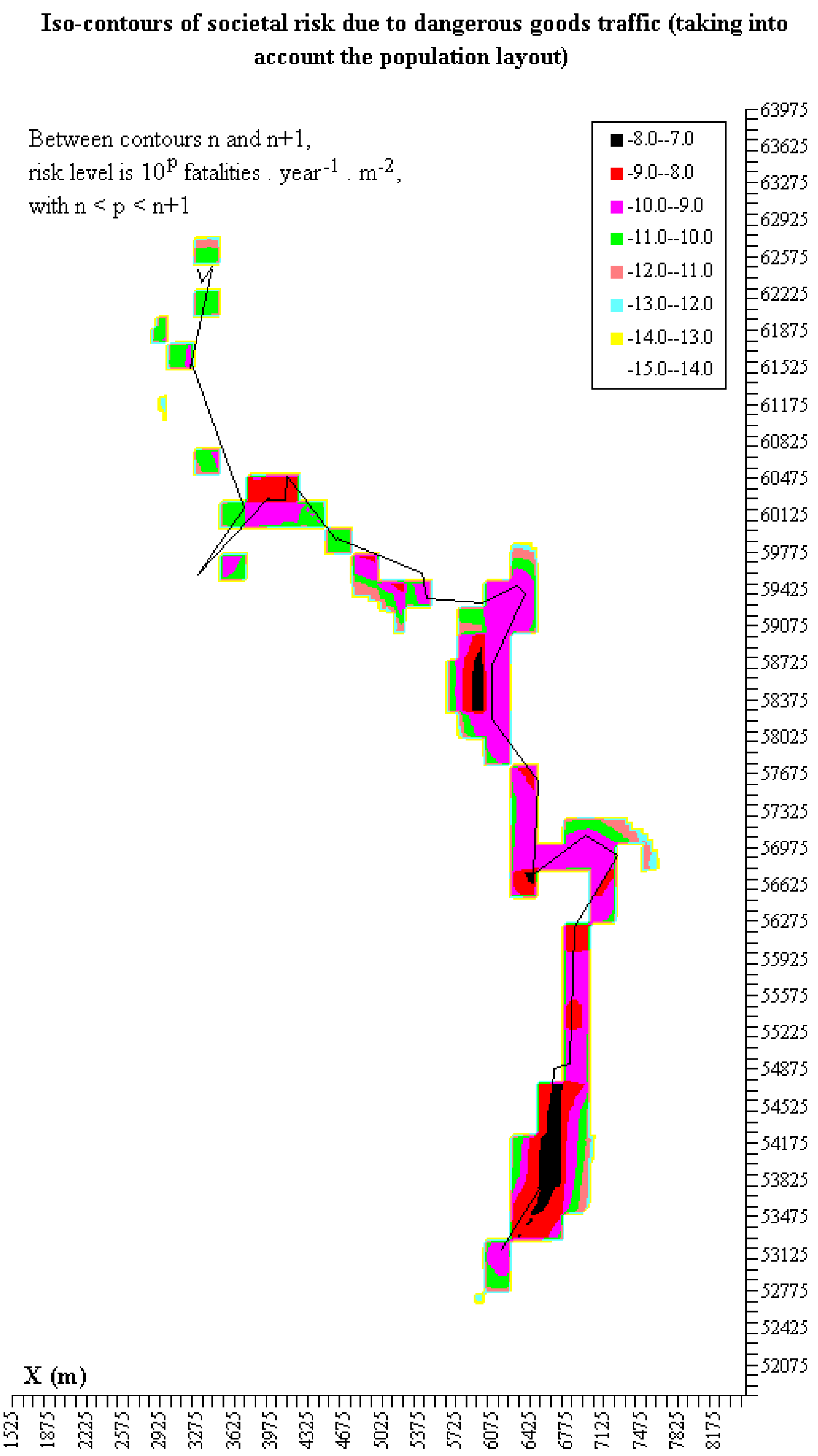


Figure 4 Iso-contours of societal risk due to dangerous goods traffic on an open air route (taking into account the population layout).