Designing Group Decision Making in Infrastructure Safety Planning

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Abstract
Infrastructure planning involves a multitude of concerns, where safety considerations generally range behind economic issues. We hypothesize that safety issues are insufficiently considered in infrastructure planning due to the lack of a shared view among the different safety experts, and that a carefully designed participatory group decision making method can support safety experts in reaching a shared view on the problem. To test our hypotheses, we developed a participatory methodology that helps infrastructure planners, emergency managers, and spatial planners converge their views on safety in infrastructure planning. The methodology integrates dynamically and interactively risk analysis and deliberation processes and it is integrated in a mobile multimedia group decision network system. In this paper we discuss the planned application of this method for the North-Eastern Connection of the transport route by rail linking Rotterdam to the German Ruhrgebiet.

Keywords: infrastructure planning, probabilistic safety assessment, group decision making

1. Introduction

Preference assessment and decision making knows limitations from a psychological, behavioral, axiomatic, and practical point of view [Beroggi, 1999]. These theoretical limitations motivated us to identify principles for an integrated analytic-deliberative process:

- Different types of safety experts must be involved in the process: safety is a concern for planners, fire brigades, emergency responders, infrastructure management, etc., all having different views on safety.
- Probabilistic risk analysis (PRA) must be integrated in the process: employing a deliberation process cannot mean to ignore data and risk analysis studies during the deliberation; however, the results of PRA must be presented in a way which is comprehensible to all safety experts.
- Each expert should only address aspects of safety for which s/he is competent for: for example, asking a fire brigade officer to include PRA results in his/her preference assessments for alternatives might result in objection or disinterest in the process; instead s/he should be free to choose the safety indicators with which s/he wants to assess the alternatives.
- Analytic and discursive elements must be integrated recursively in the process: separating the analysis from the deliberation part precludes experts to reinvestigate PRA results.

- Preference aggregation across the experts must be done from different point of views: instead of using just one aggregation method, several methods should be used and the experts should be confronted with the possibly different results.
- Preference aggregation across the experts can only serve as stimulant for deliberation and not as prescriptive measure: due to the limitations of all aggregation methods, any proposed aggregated preference order should be seen as a proposal which must be accepted by all experts.

A consequence of these principles is that a flexible preference structure should be devised which enables quick real-time processing of the stakeholders' preferences as part of sensitivity analysis.

2. A Participatory Safety Evaluation Approach for Infrastructure Planning

The approach proposed in this paper consists of four elementary building blocks that have to be conducted as a part of participatory transportation risk analysis (Figure 1). They consists of (1) systems and decision analysis, (2) probabilistic safety assessment, (3) multimedia support system, and (4) discursive alternative evaluation and decision making.

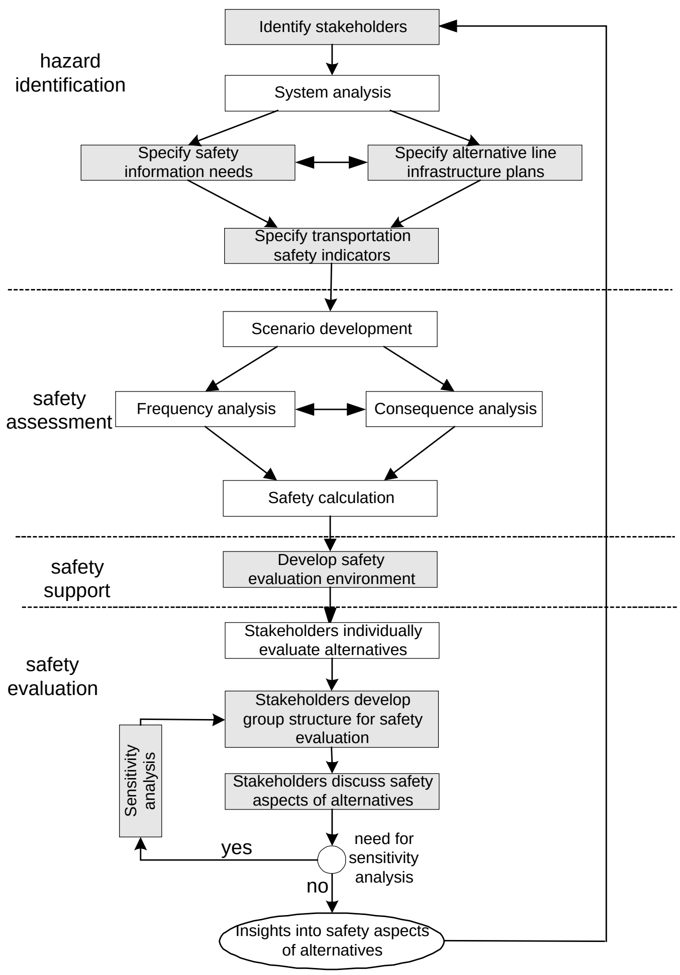

Figure 1:Safety evaluation approach for infrastructure planning [Rosmuller, 2001].

A central role in participatory group decision making takes on the *facilitator*, who should be an expert in infrastructure safety. S/he guides the whole safety evaluation process by combining technical knowledge with skills of moderating participatory meetings. The tasks of the facilitator include identifying the relevant decision-makers and experts, conducting or monitoring risk analysis studies, processing the results to meaningful information for less analytically skilled decision makers, and organize and guide the meetings where consensus decisions should be reached.

Systems and Decision Analysis

The first step of the participatory safety evaluation process is to appoint a facilitator, who should be an expert in risk analysis and have experience with participatory decision making processes. The initial activity of the facilitator is to identify the elements of decision and systems analysis [Beroggi, 1999], which refer to the decision makers, the objectives, the safety indicators, the alternatives, and the uncertainties. At least three stakeholders should always be present: infrastructure providers, spatial development authorities and emergency response organizations. The indicators for the three stakeholders are the following. The infrastructure provider use as indicators ‘expected death’ and costs. Spatial planning uses individual risk, societal risk and life-quality. Emergency response use ‘mobilization need’ and driving time.

Probabilistic Safety Assessment and Assessment of Additional Indicators

The identified line infrastructure alternatives are being assessed with the identified safety indicators. This process includes aspects of probabilistic safety assessment, but also the assessments of costs, environmental impacts, and economic considerations. The experts and decision makers and their organizations are encouraged to support or even to participate in these assessments.

Development of Multimedia Decision Support System

The results of the probabilistic safety evaluation must be integrated in a multimedia or Internet-based decision support system (DSS), which will be used during the participatory evaluation process with the safety experts. Special emphasis in the development of the DSS must be placed on the intuitively sound user interface, which can handle all aspects of multimedia information processing, including animation, audio, video, text, and analytic reasoning. Approaches to participatory expert decision making in safety planning have been addressed in the literature [Beroggi and Wallace, 1998]. Advanced systems rely on Internet technology which can be used in centralized and decentralized settings.

Discursive Safety Evaluation and Decision Making

The safety experts and decision-makers engage in a discursive safety evaluation and decision making process, in a centralized or decentralized setting. The facilitator welcomes the participants, explains the goal of the session, and clarifies the way of working in the session. The first task of the participants is to evaluate the alternatives using exclusively his/her transport safety indicators. Subsequently, they present their evaluations and rankings of alternative plans to the other experts.

Model sensitivity analysis is being investigated by using a compensatory weighted average utility-type model, and a non-compensatory ordinal preference model, such as proposed for Operational Risk Management (ORM) [Beroggi and Wallace, 1998; Rosmuller and Beroggi, 2000]. The ORM logic ranks the indicators in order of dispreference. Alternatives are discarded based on the most disliked indicator. The remaining alternatives are then evaluated on the nest most disliked indicator. As a result, only a small set of alternatives remains and is proposed as the alternatives which are least disliked.

With regard to the same ranking structure, alternative rankings will be available as a result of adjusting weights to criteria. With regard to using other ranking structures, alternative rankings will be available as a result of using other ways to aggregate individual evaluation. Subsequently, for alternative ranking structures, weights can be adjusted so that again alternative rankings may be generated. The decision makers discuss the rankings with regard to their interests, their evaluations and the weights as assigned to criteria to arrive at a shared view on the ranking of the alternatives.

3. High-Speed Freight Railway Project

The Netherlands are planning a dedicated high-speed freight railway from the Rotterdam Harbor area to a transfer facility called Valburg, in the eastern part of the country. A freight flow of about 17 million tons per year (of which 3,5 million tons concern hazardous materials) should be transported from Valburg northwards into North-West Europe. Initial plans indicated that a new railway called North-Eastern connection would facilitate the freight transport. We will discuss the four main parts of our participatory approach: hazard identification, safety assessment, safety support and safety evaluation.

<u>Hazard identification</u>

Six line infrastructures were identified as result of a preliminary systems analysis. Three of the six alternatives were rail alternatives, called Railway Deventer, Railway Zutphen, and Railway New; two highway alternatives, called Highway Veluwe and Highway Achterhoek, and one was a water alternative, called Water. Figure 2 shows a screen view of the six alternatives that will be presented to the experts.

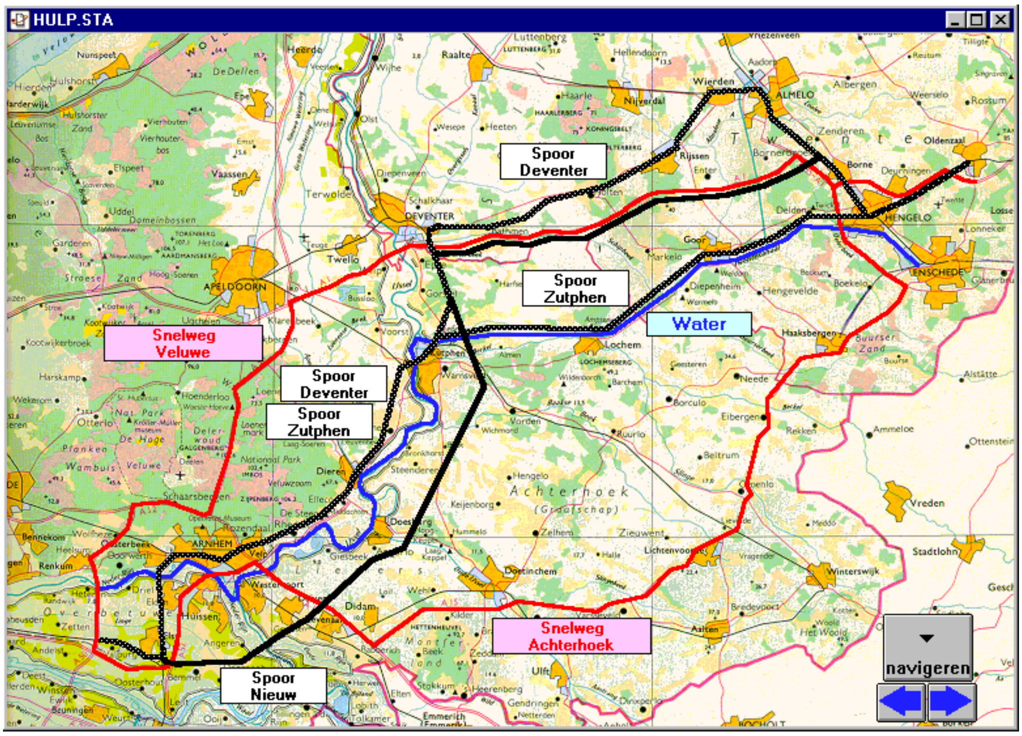

Figure 2: Six alternative line infrastructure plans.

We already emphasized that a large number of people have their safety interests as regard to line infrastructure planning. However, for practical reasons, we limit the number of stakeholders and their safety information needs. At least three stakeholders should always be present: infrastructure providers, spatial development authorities and emergency response organizations. The indicators for the three stakeholders are the following. The infrastructure provider use as indicators 'expected death' and costs. Spatial planning uses individual risk, societal risk and life-quality. Emergency response use 'mobilization need' and driving time.
Each of the perspectives will use its specific safety indicators to evaluate the alternatives. Spatial planners will focusing on individual risks, societal risks and life-quality, emergency responders will focusing on mobilization need and time, and infrastructure operators will focusing on risk profile and costs.

Safety Assessment

Now that the system is described, stakeholders and their safety interests are known, we can assess the risk indicators.

Spatial planning: individual risks, societal risks and life-quality

To assess individual and societal risks of the six alternatives, we will use the IPORBM software. This software is recommended by the Dutch authorities for risk assessment of hazardous material transportation activities for various type/route alternative line infrastructure plans. Where possible, we will make use of available data.

Individual risk

In the IPORBM software tool some data for generating individual risk have been prepared and are represented by default values.

Societal risk

To assess societal risks, data concerning the residential area surrounding the infrastructure needs to be specified. The software IPORBM will be used to assess societal risk curves using pre-defined calculation rules.

Life-quality

Several images of the three types of infrastructures (highway, railway and waterway) and the environment of the planned routes will be shown to the experts. This set of images provides a picture of a possible situation in the future where the type of infrastructure is constructed.

Infrastructure providence: User risk profile and costs

User risk profile

The user risk profiles will be assessed with a bootstrapping method using known user profile data.

Cost

The costs were assessed using existing costs estimates and judgments by experts of the department of public works of the Ministry of Transport.

Emergency response: mobilization needs and driving time

Mobilization needs
First, the emergency responders will be presented information concerning the possible physical phenomena of an accident (including the 1% lethal effect distance where in addition 50% of the present people gets injured). Next, these effect distances will be related to the necessary emergency response mobilization capacity. The emergency response mobilization need is only assessed for fire fighting organizations. For Highway Achterhoek, we will present the physical phenomena and the emergency response mobilization need.

Driving times
The assessment of driving times for the six alternatives for the Northeastern connection will be conducted in one single computation. This implies that we will not assess the driving times for six alternatives separately. To this end, a self-developed software tool will be used [Rosmuller, 2001]. The basis for this tool formed a road map of The Netherlands.

Safety support
Four computer interfaces are built: three to support the stakeholders in their evaluation of safety aspects of alternative line infrastructure plans, and one for the facilitator to aggregate the individual rankings. The stakeholders can fill out their preferences with regard to the alternative plans using the laptops. The facilitator supports this process by answering some general questions. The individual rankings are filled out in the facilitator computer interface, after which the aggregate rankings are presented and discussed.

Safety Evaluation
We will invite eight persons who in their daily practice are related to the Northeastern connection and its safety. One of the infrastructure operators is affiliated with Dutch National Railways, while the other is affiliated with the ministry of Transport, directorate Rijkswaterstaat direction East. With regard to spatial development we will invite residents and spatial planners. The residents are active in a local/regional group with interests in reaction of the Northeastern connection (RONA). One of the residents is the former chairwoman of the RONA; the other is actively involved in it. The spatial planners we will invite are affiliated with the Province of Gelderland and Overijssel who both had the safety aspects of the Northeastern connection under their supervision. A Northeastern connection will by definition go through both provinces. One of the emergency responders is affiliated with the regional fire-fighting brigade Stedendriehoek that covers the cities of Zutphen, Deventer and Apeldoorn. He was involved in evaluating safety aspects of a railway connection going through the region where his brigade was responsible for the emergency response. The other emergency responder is affiliated with the fire-fighting brigade of the city of Arnhem.

4.1 Direct Assessment of Hypotheses
As part of the direct assessment of the hypotheses, we will ask the participants, after the session, to rate the earlier presented six alternatives, on a scale, where 1 stands for total disagreement, 5 stands for neutral, and 10 stands for total agreement with the hypothesis.

Q1: Coverage of safety indicators only
We will ask the participants to assess if they felt comfortable discriminating the alternatives before they were offered to evaluate them with standard safety indicators. This question will be asked before and after the session; i.e., after the participants will have assessed the alternatives with the standard safety indicators.

Q2: Discrimination power of all indicators
The same question as Q1 will be asked with respect to all indicators, both before and after the session.

Q3: Shared view
To assess whether the proposed preference aggregation approach helps the participants to arrive at a shared view we will ask the participants, before and after the session, to judge how much aware they were of the safety interests of the other stakeholders.

Q4: Evaluation support
The judgment of the multi-media system concerns three elements including representation (image) of safety interests, the safety contents, and the user interface.

4.2 Indirect Evaluation of Hypotheses

Indirect evaluation of the hypotheses will be done by analyzing the data that will be automatically collected during the session. The rankings for each indicator and the overall ranking will be used for this purpose. The overall ranking will be computed with the ORM model, where individual risk is the most disliked indicator, followed by risk profile, up to life-quality being the least disliked indicator.

The stakeholders will be asked to assess the weights among the three stakeholders. This will be done in a pairwise fashion, in the sense that each stakeholder will have to assess the relative importance of spatial planning (SP) over emergency response (ER), SP over infrastructure provider (IP), and ER over IO.

Conclusions

We have proposed a participatory safety evaluation method that integrates probabilistic safety assessment with discursive safety evaluation by different groups of experts. The method will be applied in the line infrastructure project of a high-speed freight railway in the Netherlands. The purpose is to test four hypotheses referring to why safety experts often disagree in their judgments.

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Short Biographies

Nils Rosmuller works at the Dutch Institute of Fireservice and Disaster Management; he holds M.S. degrees in Public Policy & Administration and Technology and Management, both from Twente University (Netherlands), and a Ph.D. from Delft University of Technology.

Giampiero E.G. Beroggi is associate professor of policy analysis. He has taught classes in systems analysis, quantitative methods for problem solving, and risk management. His research deals with operational risk management, decision making, and conflict resolution.