Deterministic scenario analysis

Why accident scenarios influence travel choice decisions

TRAIL Research School, Delft, November 2006

Author(s)

Ir. Sandra IJsselstijn
Delft University of Technology, Faculty Technology, Policy and Management, Section Transport Policy and Logistics' Organisation
DHV, Section Transportation Planning

© 2006 by S. IJsselstijn and TRAIL Research School
Contents

Abstract

1 Introduction..................................................................................................................1

2 Deterministic Scenario Analysis ........................................................................1

3 Dealing with risks..................................................................................................2

4 Accident scenario: Runway overrun Onur Air ...............................................4

5 Accident scenarios influence travel choice decisions ................................6

6 Conclusions........................................................................................................7

Acknowledgement(s)....................................................................................................7

References.................................................................................................................7
Abstract

The last decades, a lot of research has been done into travel choice behaviour in road transport. However, the influence of safety incidents on travel choice behaviour has not been studied very often, not even in the aviation industry. In general, there is an influence of disastrous scenarios on travel choice behaviour. This is shown by the accident of an Onur Air aircraft at Groningen Airport Eelde on 17 June 2003. This paper describes why accident scenarios influence travel choice decisions.

This paper is written as part of a PhD study regarding the role of a deterministic scenario analysis in the decision-making processes concentrating on transport and infrastructures. A deterministic scenario analysis is essentially a decision-making support tool that can be used for the assessment of safety of infrastructure projects. However, deterministic scenario analyses can be used for all kinds of safety assessments, including travel choice decisions. Accident scenarios describe accident processes of potential or actual sequences of events in time as a dependent variable, in a specific context and operating environment.

This paper also shows two fundamental ways in which people comprehend risks: the ‘analytic’ system (quantitative) and the ‘experiential’ system (qualitative). Both ways have to be taken into account during decision-making processes, because experts and the public (laypeople) have different perspectives of risks. People prefer quantitative or qualitative information depending on their position in the decision-making process. The different types of information needed during decision-making processes ask for different types of risk analyses. When people do have little knowledge about the likelihood and effects of an accident, a deterministic scenario analysis is the best method for gaining insight into risks. Together with (more well-known) quantitative risk analyses, a deterministic scenario analysis combines the analytic and experiential aspects of scenarios that fit the dual nature of risk decision makers.

Keywords

Safety, accident scenario, risk, decision-making, travel choice decisions
1 Introduction

During the last years, more distant destinations, like Turkey, are coming up for Dutch citizens to spend their holiday. This is partly the result of low budget air transport companies, like Onur Air, that make cheap flights possible and, thus, make Turkey as a holiday destination more attractive. But what happens when a cheap travel company is involved in several safety incidents?

The last decades, a lot of research has been done into travel choice behaviour in road transport [e.g. Van Wee & Maat 2003]. However, the influence of safety incidents on travel choice behaviour has not been studied very often, not even in the aviation industry. In general, there is an influence of disastrous scenarios on travel choice behaviour. For example, after the terrorism attack on 9/11, a temporary setback in booking rates in the worldwide aviation industry was seen [Reformatorisch Dagblad 2002]. This paper discusses why accident scenarios influence travel choice decisions.

The following section explains the PhD. study (concerning a deterministic scenario analysis) where this paper is part of. Section 3 describes different ways of dealing with risks during decision-making processes. In section 4, an example of an accident scenario is shown. Section 5 discusses why accident scenarios, like described in section 4, influence travel choice decisions. This paper ends with conclusions.

2 Deterministic Scenario Analysis

This paper is written as part of a PhD study regarding the role of a deterministic scenario analysis in the decision-making processes concentrating on transport and infrastructures. Because experiences with infrastructure projects show that quantitative risk analyses are not always a satisfactory approach for safety decision-making [Helsloot & Rosmuller], a deterministic scenario analysis is being developed as a complementary analysis.

A deterministic scenario analysis is a qualitative approach that can be used for the assessment of safety of infrastructure projects. In the analysis, a limited number of critical accident scenarios are developed describing accident processes of potential or actual sequences of events in time as a dependent variable, in a specific context and operating environment [IJsselstijn et al. 2006]. With these critical accident scenarios, infrastructure projects can be evaluated and possible safety bottlenecks can be identified.

The research objective of the PhD. study is to develop a deterministic scenario analysis in order to improve transport safety of infrastructure projects during the decision-making process. Research questions are:

- How should the scenarios of a deterministic scenario analysis be defined scientifically?
- How should a deterministic scenario analysis be positioned in the decision-making process of infrastructure projects?
- How should a deterministic scenario analysis be worked out to become practically feasible?
During the last few years, the relevance of deterministic scenario analyses as an additional safety decision-making support tool is more and more being recognized:

- In 2003, the National Institute for Public Health and the Environment developed a risk policy-making strategy ‘Coping rationally with risks’ [RIVM 2003] that focuses on the layered structure in decision-making and the position of different types of risk analyses, including a deterministic scenario analysis, in decision-making.

- Simultaneously, the Ministry of Transport, Public Works and Water Management, the Ministry of the Interior and Kingdom Relations, and the Ministry of Housing, Spatial Planning and the Environment developed a policy document concerning tunnel safety [Projectteam Tunnelveiligheid 2003]. This policy document focuses on a methodology containing probabilistic risk analyses as well as a deterministic scenario analysis to gain insight into the safety performance of a tunnel.

- In 2004, the Parliamentary Inquiry Committee Duivesteijn [Committee Duivesteijn 2004] identified several phases of policy decision-making processes with deficiencies in risk assessment procedures. New policy-making support procedures and notions for multi-level decision-making are needed, because of the multi-actor context. A deterministic scenario analysis can be such a procedure for safety decision-making.

Although in this PhD. research a deterministic scenario analysis is developed for the assessment of safety of infrastructure projects, deterministic scenario analyses can be used for all safety assessments. For example, the safety of different modes of transport can be assessed before deciding how to travel. But also the safety of different travel companies can be assessed. This paper will discuss why accident scenarios influence such travel choice decisions.

### 3 Dealing with risks

Flying is one of the safest modes of transport. The probability of being killed in an aircraft accident is much smaller than in a car accident or train crash [Ministry of Housing, Spatial Planning and the Environment 1989]. However, a lot of people are anxious to fly. This could be the result of another way of dealing with risks.

In the last decades, more and more attention has been focused on risks to life and health. This may be traced back to three factors [Hovden & Larsson 1994]:

- People receive more information about risks through media.
- People have greater knowledge of and more critical attitudes towards risks due to education, higher standards of living and welfare.
- The actual risks, to which we are exposed or expose ourselves, have changed due to new technologies.

Although risks are more and more discussed, there is no generally agreed definition of risk. For example, Vlek & Stallen [1981] themselves list six (mathematical) definitions of risk that are all common in the literature:

- Risk is the probability of a loss;
- Risk is the size of the possible loss;
Why accident scenarios influence travel choice decisions

- Risk is a function, mostly the product of probability and size of loss;
- Risk is equal to the variance of the probability distribution of all possible consequences of a risky course of action;
- Risk is the semi variance of the distribution of all consequences, taken over negative consequences only, and with respect to some adopted reference value;
- Risk is a weighted linear combination of the variance of and the expected value of the distribution of all possible consequences.

Slovic et al. [2004] distinguish two fundamental ways in which human beings comprehend risk: the ‘analytic system’ and the ‘experiential system’ (see Table 1). The ‘analytic system’ uses algorithms and normative rules, such as probability theory, formal logic, and risk assessment. This system is characterized by ‘risk as analysis’. The ‘experiential system’ is intuitive, fast, mostly automated, and not very accessible to conscious awareness. This system is characterized by ‘risk as feelings’ and focuses on affect. “Affect means the specific quality of ‘goodness’ or ‘badness’ (1) experienced as a feeling state (with or without consciousness) and (2) demarcating a positive or negative quality of a stimulus.” [Slovic et al. 2004]

Table 1: Comparison of the ‘analytic system’ and ‘experiential system’ [Slovic et al. 2004 adapted from Epstein 1994]

<table>
<thead>
<tr>
<th>Analytic System</th>
<th>Experiential System</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Analytic</td>
<td>• Holistic</td>
</tr>
<tr>
<td>• Logical: reason oriented</td>
<td>• Affective: pleasure-pain oriented</td>
</tr>
<tr>
<td>• Logical connections</td>
<td>• Associationistic connections</td>
</tr>
<tr>
<td>• Behaviour mediated by conscious appraisal of events</td>
<td>• Behaviour mediated by images from past experiences</td>
</tr>
<tr>
<td>• Encodes reality in abstract symbols, words, and numbers</td>
<td>• Encodes reality in concrete images, metaphors, and narratives</td>
</tr>
<tr>
<td>• Slower processing: oriented towards delayed action</td>
<td>• More rapid processing: oriented towards immediate action</td>
</tr>
<tr>
<td>• Requires justification via logic and evidence</td>
<td>• Self-evidently valid: ‘experiencing is believing’</td>
</tr>
</tbody>
</table>

However, as Slovic et al. [2004] state, “it can not be assumed that human beings can understand the meaning of and properly act upon even the simplest of numbers such as amounts of money or numbers of lives at risk, unless these numbers are infused with affect”.

Nowadays, it is more and more recognized that the analytic system and the experiential system are complementary ways in which human beings comprehend risk. Finucane et al. [2003] have characterized the interaction between the analytic system and the experiential system as ‘the dance of affect and reason’. “While human beings may be able to do the right thing without analysis, it is unlikely that we can employ analytic thinking rationally without guidance from affect.” [Slovic et al. 2004]
Both ways in which human beings comprehend risk have to be taken into account during decision-making processes, because experts and the public (laypeople) have different perspectives of risk [Slovic 1999]. Hendrickx [1991] proved that risk assessments are based on both frequency information (analytic system) and scenario information (experiential system). People prefer one of these types of information depending on their position in the decision-making process.

The different types of information needed during decision-making processes ask for different types of risk analyses [RIVM 2003]. Decision-making processes deal with different environments and different types of uncertainty. The National Institute for Public Health and the Environment (RIVM) defines several classes of decision-making contexts. In their turn, they define different types of risk analyses.

### Table 2: Positioning of various risk analysis methodologies [Beukenkamp & IJsselstijn 2006]

<table>
<thead>
<tr>
<th>Knowledge about likelihood</th>
<th>Knowledge about effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td>Conventional design:</td>
</tr>
<tr>
<td></td>
<td>Quantitative Risk Analyses</td>
</tr>
<tr>
<td></td>
<td>Data uncertainty</td>
</tr>
<tr>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>Technological design:</td>
</tr>
<tr>
<td></td>
<td>Simulation / Modelling</td>
</tr>
<tr>
<td></td>
<td>Method uncertainty</td>
</tr>
<tr>
<td>Multi-actor decision-making:</td>
<td>high</td>
</tr>
<tr>
<td>Fuzzy Logic / What-If analysis</td>
<td></td>
</tr>
<tr>
<td>Decision-making uncertainty</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>Precaution:</td>
</tr>
<tr>
<td></td>
<td>Scenario analysis /</td>
</tr>
<tr>
<td></td>
<td>Citadel approach</td>
</tr>
<tr>
<td></td>
<td>Scenario uncertainty</td>
</tr>
</tbody>
</table>

Depending on the level of knowledge about likelihoods and effects, other methods for decision-making are needed (see Table 2). When people have a lot of knowledge about the likelihood and effects of an accident, they can use quantitative risk analyses to calculate the risk. However, data uncertainty, the result of assumptions and estimations made when not all of the quantitative information needed is available, can make quantitative risk analyses unreliable.

When people do have little knowledge about the likelihood and effects of an accident, a deterministic scenario analysis is the best method for gaining insight into risks. (The citadel approach does not gain insight into risks, but focuses on which parts of a system should be protected.) With a deterministic scenario analysis, the nature of uncertainty moves from data uncertainty to scenario uncertainty. Developing a wrong or incomplete set of accident scenarios can result in a too positive or negative risk assessment.

Depending on the level of knowledge about likelihoods and effects, other methods for decision-making are simulation, modelling, fuzzy logic and what-if analysis.

### 4 Accident scenario: Runway overrun Onur Air

Accident scenarios of a deterministic scenario analysis can be developed in two different ways:
Why accident scenarios influence travel choice decisions

- a prospective way of specifying scenarios, which means that the scenarios are derived from a decomposition of the system. Already at the time of design, engineers have insight into the structure and the content of the system and can define intended and foreseen complexity, interactions and interfaces. At that time, the accident scenarios can be used as a conceptual design tool to remove hidden deficiencies before they lead to accidents. These scenarios can be characterised as a ‘technical construct’.

- a retrospective way of specifying scenarios, which means that the scenarios are reconstructed from accident analyses of existing analogous events. During these analyses, learning from proven deficiencies in order to prevent their recurrence becomes possible. These scenarios can be characterised as a ‘technical reconstruct’.

This section shows an example of an (retrospective) accident scenario. The accident scenario describes the runway overrun of an aircraft after the rejected take-off. The next section will discuss why accident scenarios like this influence travel choice decisions.

Onur Air is a Turkish charter company that carries passengers from Amsterdam Airport Schiphol, Eindhoven Airport, Rotterdam Airport, Maastricht Aachen Airport, Groningen Airport Eelde and Enschede Airport Twente to several destinations in Turkey. On 17 June 2003, a MD-88 (Boeing McDonnel Douglas) was ready for take-off for the flight from Groningen Airport Eelde to Maastricht Aachen Airport with final destination Dalaman. However, the crew rejected the take-off at a late stage, as a result of which the aircraft overran the runway threshold.

![Figure 1](image_url)

Figure 1: After the rejected take-off, the aircraft came to a stop approximately 100 meters beyond the runway threshold.

After the aircraft collided with the landing lights and underground concrete structures of the landing light system, it came to a standstill in soft soil, with serious damage as a result.
The investigation of the Dutch Safety Board [2006] shows that “the crew initially rejected the take-off when the stabilizer warning sounded. When carrying out a check the crew did not find any peculiarities, although they were present. After this short interruption the take-off was resumed and this time, when the (repeating) sound alert signal went off, the signal was ignored.” According to the Dutch Safety Board, the take-off should not have taken place with this signal.

The Dutch Safety Board also found other operational flaws. For example, the actual center of gravity during take-off was far more forward than assumed by the crew due to a higher passenger mass and a wrong distribution of fuel. As a consequence, the horizontal stabilizer was not set at the required position for take-off.

After the aircraft came to a stop, the evacuation was started. According to the Dutch Safety Board the most important findings regarding the evacuation are: “the cabin crew did not give enough evacuation instructions and not all the available cabin exits were used. This hindered the evacuation. Furthermore, most of the passengers stated that the crew spoke English in an insufficiently clear manner.”

In this accident, no fire occurred and none of the occupants sustained any serious injuries. According to the Dutch Safety Board, the combination of underground concrete structures and soft soil increases the risk of fire hazard in case of a collision (the aircraft fuel, the risk of ignition of sparks and the hot engines). However, the risk of the hot engines contacting the ground was reduced, because the MD-88 is a type of aircraft of which the engines are not located under the wing but on the rear side of the fuselage. This is why this accident did not lead to serious consequences for the passengers and crew.

5 Accident scenarios influence travel choice decisions

The previous section showed an example of an accident scenario concerning an aircraft of Onur Air. Because this was not the only incident where an Onur Air aircraft was involved, it looked like a more structural phenomenon. Last July, for example, another incident occurred with an Onur Air aircraft landing at Rotterdam International Airport [Elsevier 2006]. The result was a fall back in bookings, resulting in 20 instead of 60 flights per week between the Netherlands and Turkey [nu.nl 2005]. This fall back was, at least partly, the result of a reduction of public confidence in the company’s safety performance, because the described events speak to the imagination of risk bearers. So, there is a relation between incidents and travel choice behaviour. Although this fall may have serious consequences at a company level, this scenario did not cause a loss of confidence in the aviation sector as such: the total number of bookings increased [cubi.nl 2006].

The relation between incidents and travel choice behaviour can not only influence which travel company is chosen, but also which mode of transport or which route is chosen. With a deterministic scenario analysis, the risks of different alternatives can be assessed. Based on the risk assessment, people can make a decision.
That imaginable accidents or even the perceived risk of occurrence has in general its influence on consumer choice behaviour is a well-known phenomenon in the consumer product area on deficient products. For example, the factory owner of Exota lemonades was almost put into liquidation, because on television was shown that the bottles of Exota lemonades could explode. Although the explosions were faked, the sales of Exota lemonades fall back [Elsevier 2005]. It looks like that this phenomenon can be expanded to services in air travel choices.

6 Conclusions

This paper described the importance of a deterministic scenario analysis. A deterministic scenario analysis is essentially a decision-making support tool that can be used for the assessment of safety of infrastructure projects. However, deterministic scenario analyses can be used for all kinds of safety assessments, including travel choice decisions. Accident scenarios describe accident processes of potential or actual sequences of events in time as a dependent variable, in a specific context and operating environment. Together with (more well-known) quantitative risk analyses, a deterministic scenario analysis combines the analytic and experiential aspects of scenarios that fit the dual nature of risk decision makers.

Acknowledgement(s)

This paper is written as part of a PhD study regarding the role of a deterministic scenario analysis in the decision-making processes concentrating on transport and infrastructures. The author wishes to thank the organizers of the TRAIL Congress 2006 for the invitation to write this paper, Transumo for supporting this PhD research, and the (daily) supervisor John Stoop (PhD) of Delft University of Technology for his critical and valuable suggestions after reading the draft and final version.

References


RIVM (2003). *Coping rationally with risks*; RIVM 251701047


