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# A framework for robustness analysis of road networks for short term variations in supply

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ABSTRACT

There is a growing awareness that road networks, are becoming more and more vulnerable to unforeseen disturbances like incidents and that measures need to be taken in order to make road networks more robust. In order to do this the following questions need to be addressed: How is robustness defined? Against which disturbances should the network be made robust? Which factors determine the robustness of a road network? What is the relationship between robustness, travel times and travel time reliability? Which indicators can be used to quantify robustness? How can these indicators be computed? This paper addresses these questions by developing a consistent framework for robustness in which a definition, terms related to robustness, indicators and an evaluation method are included. By doing this, policy makers and transportation analyst are offered a framework to discuss issues that are related to road network robustness and vulnerability which goes beyond the disconnected definitions, indicators and evaluation methods used so far in literature. Furthermore, the evaluation method that is presented for evaluating the robustness of the road network against short term variations in supply (like incidents) contributes to the problem of designing robust road networks because it has a relatively short computation time and it takes spillback effects and alternative routes into account.



## 1. Introduction

There is a growing awareness that road networks, are becoming more and more vulnerable to unforeseen disturbances like incidents because of the fact that the level of congestion keeps growing. Furthermore, it becomes more difficult to recover from unforeseen disturbances since the spare capacity in the network reduces both in place and in time. The opportunity costs of vulnerability in the Netherlands can for example increase to more than 4000 million euro per year in 2030 (Snelder et al., 2008). This raises the question which measures can be taken to reduce the vulnerability or to increase the robustness of the road network and where and when these measures should be applied. Before these questions can be answered first some other questions need to be addressed: How is robustness defined? Against which disturbances should the network be made robust? Which factors determine the robustness of a road network? What is the relationship between robustness, travel times and travel time reliability? Which indicators can be used to quantify robustness? How can these indicators be computed? These latter questions are the questions that are addressed in this paper. In Fig. 1 the different steps

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**Fig. 1.** Steps that are needed to design robust road networks.

that have to be followed to make a robust road network design are summarised. This paper focuses on the first four steps of Fig. 1 (from context to evaluation method). The last three steps are however kept in mind, since the results of the first four steps should be applicable in network design.

The robustness of transportation networks is a relatively new research area. There are several definitions, but none of these are commonly accepted. Specific indicators for robustness are scarce and robustness against short-term uncertainties in supply and demand is, as far as is known to the authors, not yet explicitly considered in the network design problem. This paper aims to present a definition, indicator(s) and an evaluation method for robustness against short-term variations in supply. However, the method could be extended to short term variations in demand. Besides this, it aims to position the term robustness in relation to other terms like reliability. By doing this, the paper gives policy makers and transportation analyst a framework to discuss issues that are related to road network robustness and vulnerability. Furthermore, the evaluation method that is presented contributes to the problem of designing robust road networks against short time variations in supply because it has a relatively short computation time and it takes queue spillback effects and alternative routes into account. The short computation time is required because the network design problem is a complex problem which requires many network evaluations since there are many possible robustness measures that can be applied on many different locations.

In Section 2 of this paper an explanation is given of different terms that relate to robustness. The section thereafter explains how the robustness of a network can be assessed. Finally, in the last section some conclusions and recommendations are given.

## 2. An explanation of terms that relate to robustness

### 2.1. The context of robustness

Fig. 2 shows the relation between network characteristics and robustness and between robustness and reliable travel times.

The numbers in the figure refer to the order in which the figure should be read:

(1) Under regular circumstances (no disturbances), the network performance is determined by the regular demand and supply pattern.

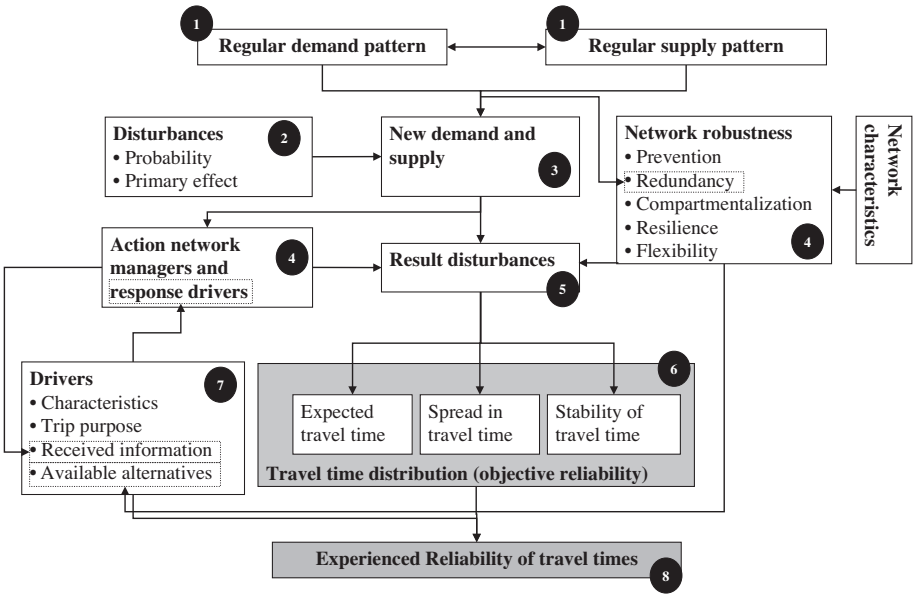


**Fig. 2.** Factors that influence the reliability of travel times.