Rapid transit network design and risk aversion

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Abstract. Rapid transit network design is highly dependent on the future system usage. These spatially distributed systems are vulnerable to disruptions: during daily operations different incidents may occur. Despite the unpredictable nature of them, effective mitigation methods from an engineering perspective should be designed. In this paper, we present several risk averse measures for risk reduction in the rapid transit network design problem based on a set of finite scenarios to represent the disruptions’ uncertainty. As a counter-parts of the typical risk neutral strategy, some measures that are presented are aiming to minimizing the impacts of the worst scenario in the network operation, and another additionally, takes into account different risk reduction profiles. Some computational experience is presented.

Keywords: Rapid transit network design, disruption management, stochastic, risk aversion.

1 Introduction

Rapid Transit Network (RTN) design is highly dependent on the future system usage [1, 2]. Such networks are urban mass public transportation systems which operate in metropolitan areas and feature frequent train services. When designing a new network, the infrastructure designer must account for the fact that passengers will use the new network if the trip total cost is lower than the current options: when facing a new Rapid Transit Network design (RTND) there is usually another transportation system already operating in the area where the RTN is to be built or extended. The RTND problem aims at maximizing the demand coverage by the new network subject to design and budget constraints, all while considering demand decisions when evaluating different alternatives [4, 1].

Spatially distributed systems are vulnerable to disruptions: during daily operations different incidents may occur. Despite the unpredictable nature of them in terms of location, time, and magnitude, effective mitigation methods from an engineering perspective should be designed. Dealing with these uncertainties is a key ingredient for providing a resilient network for daily operations. The more the network is able to absorb these disruptive negative effects, the more resilient the network is. In order to find resilient network designs, different research techniques such as deterministic static, two-stage stochastic optimization and robust optimization may be applied, among others. Solutions may be recovered after data perturbation and the recovery of the system may not be as expensive as the introduction of robustness concepts. This concept is the recoverable robustness [2].

This work presents a model for designing a rapid transit network considering the network reliability under the point of view of recovery robustness and risk theory. The model is a balance between the traditional approaches of transport demand coverage and the recovery of disruptions [5, 3].

We present a new approach to the RTND problem where the uncertainty is related to the passenger service demand disruption. It is represented by a finite set of scenarios. The novelty of this approach is the introduction of risk aversion in the network design. It consists of a set of risk averse measures as a counter-part of the probably most popular strategy, as it is the risk neutral one, where the uncertainty
is explicitly considered in the constraint system. One of those risk averse measures, we have so-called it, VaR2 is a variant of the classical Value-at-Risk (that we have so-called it VaR1), where the risk reduction of the total cost due to the service disruption over the scenarios is performed based on a modeler-driven set of profiles. For each of those weighted profiles the minimum regret excess cost on the related threshold is performed and, additionally, a bound should be satisfied on the expected excess cost over the scenarios, besides explicitly considering the uncertainty in the constraint system. Due to space limitation, we have left for the extended version of the paper the treatment of new risk averse strategies as the expected conditional VaR and the expected conditional measure for a mixture of the first- and second-order stochastic dominance strategies.

2 Summary of the results

Several risk averse measures for risk reduction in the rapid transit network design problem under the disruptions’ uncertainty are presented. We can observe in our provisional computational comparison, where the risk averse strategy VaR2 has been taken as our measure of reference, that the traditional RTND and Expected Value (EV) strategies are the worst ones for any of two goodness indicators. The minmax strategy produces a high violation of the expected cost excess over the different thresholds that have been analyzed for the disruption cost, although it gives the non-disruption cost as VaR2. Similar conclusion can be reached for the risk neutral strategy where a 6.5% decrease in the non-disruption cost induces so high above violations that it cannot be accepted as a strategy of choice. VaR1 strategy is the champion of the case that we analyze. Notice that, by allowing a slightly higher deviation of the disruption cost versus the non-disruption cost in just one scenario, it results that the non-disruption cost is smaller than the cost for VaR2 (and some other strategies). Additionally, it does not violate the bounds on the expected excess of the given thresholds on the disruption cost in a more deeper way than the same VaR2.

References


