INNOVATIVE TRANSPORT PRICING: DERIVING THE OPTIMAL PRICING SCHEME

A Multi-Objective Multi-Modal Dynamic Network Perspective

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ABSTRACT

In this paper we aim to provide a framework for finding optimal pricing strategies for multiple stakeholders, taking a multitude of externalities (congestion, safely, emissions, etc.) into account, and both private and public modes. Stakeholder preferences and interactions, a phase-wise implementation and the application to the Randstad area are explicitly considered.

KEYWORDS

Road pricing, optimal pricing scheme, stakeholders interaction, dynamic traffic assignment, network design

INTRODUCTION

Pricing measures in transportation have been heavily discussed in the past few years in the Netherlands. Several stakeholders are involved in the decisions on road pricing and the establishment of an optimal pricing scheme. Governments, road authorities (e.g. Rijkswaterstaat), the road associations (e.g. ANWB), environmental organisations, insurance companies, and travellers all developed their own opinions on pricing measures in transportation. These stakeholders have conflicting preferences, mutual influences and are hierarchically structured.

This study focuses on an integral evaluation of road pricing measures, and optimisation of the system as a whole. With integral we mean that both private and public transport is considered, and that all important stakeholders and objectives are analysed at the same time. This is different from the traditional approach, where typically only private (car) transport is considered, and only one stakeholder, namely the road authority aiming to for example mitigate congestion.

The study is divided in four sections of interest; (1) modelling travel behaviour in response to pricing measures; (2) modelling traffic flows on networks, including spillback effects; (3) computing impacts for travellers, road managers, the environment, etc; (4) building an optimisation procedure for determining optimal road pricing strategies for multiple stakeholders.

There are some important objectives to consider while constructing the model; (1) the model should become a tool that is applicable on the Dutch *'Randstad'* area, this implicates a large model size. (2) elaborating in the latter the arithmetical model elements should have acceptable computation times; (3) the phase-wise implementation of pricing schemes should be considered, this implicates that the model has to be flexible on the input since each phase leads to a different scenario with different input variables; (4) the model will have a multi-modal approach, interactions between modes should be considered explicitly.

PRICING MEASURES

Pricing measures in transportation exists in a large amount of forms and the freedom in designing is infinite. This section delivers an overview of the most important forms of pricing measures and poses some of its most important properties. The following list describes different types of pricing measures, it is comprehensive, but does not pretend to be exhaustive:

- **Kilometre charge:** The most relevant and heavily discussed pricing measure is the kilometre charge imposed by a government. Several researchers have conducted research primarily focussing on this type of pricing measure. Kilometre charge itself is rather comprehensive; a distinction is made on static (i.e. time and traffic flow independent) and dynamic (i.e. time and/or traffic flow dependent) charges and fees can be differentiated among user classes, vehicle types, geographical positions etc.
- **Fuel costs:** Governments can levy excise on fuel.
- **Insurance fee:** Insurance companies charge their customers generally with a fixed amount per month; another possibility is to charge them per driven distance or time.
- **Maintenance fee:** Road authorities have high maintenance costs for the road. They can charge the road users for their share in the dilapidation.
- **Emission fee:** Stakeholders that concern themselves with the environment (e.g. ministries of environment) can levy an emission fee.
- **Public transportation tickets:** Ticket prices are influenced by several stakeholders and usually based on the travelled distance and/or time.
- **Cordon charges:** Vehicles entering a cordon can be charged. In practice this is used by highly congested urban areas that want to divert visitors to others modes.
- **Toll (tunnel/bridge):** Some specific places in the infrastructural network can be tolled, reasons can be the high costs of the development or it can be a bottleneck of the network.
- **Parking charges:** Shortage of parking lots and the aim to exclude vehicles can lead to the well known measure parking charges
- **Sojourn time charges:** Vehicles that stay in a certain area for a certain time can be charged for the sojourned time in the area.
- **Vehicle tax:** Most governments can charge a vehicle tax; commonly a purchase and periodical tax are levied.

Three bases for charging can be distinguished: distance, time and space. Payment by distance is of major importance for this study, several pricing measures are based on the covered kilometres; implementation can be achieved link- or route-based. Payment by time primarily

considers parking charges; implementation can be achieved activity-based, the times are normally not available in conventional models. Space is the basis of tolls for example, it can also be the basis of a differentiation of pricing schemes; the implementation is link-based. It is not necessary that each pricing measures has a single basis for the levy, it can depend on several variables. Charges can also contain a fixed component; vehicle tax is an example of a pricing measure that just consists of a fixed amount.
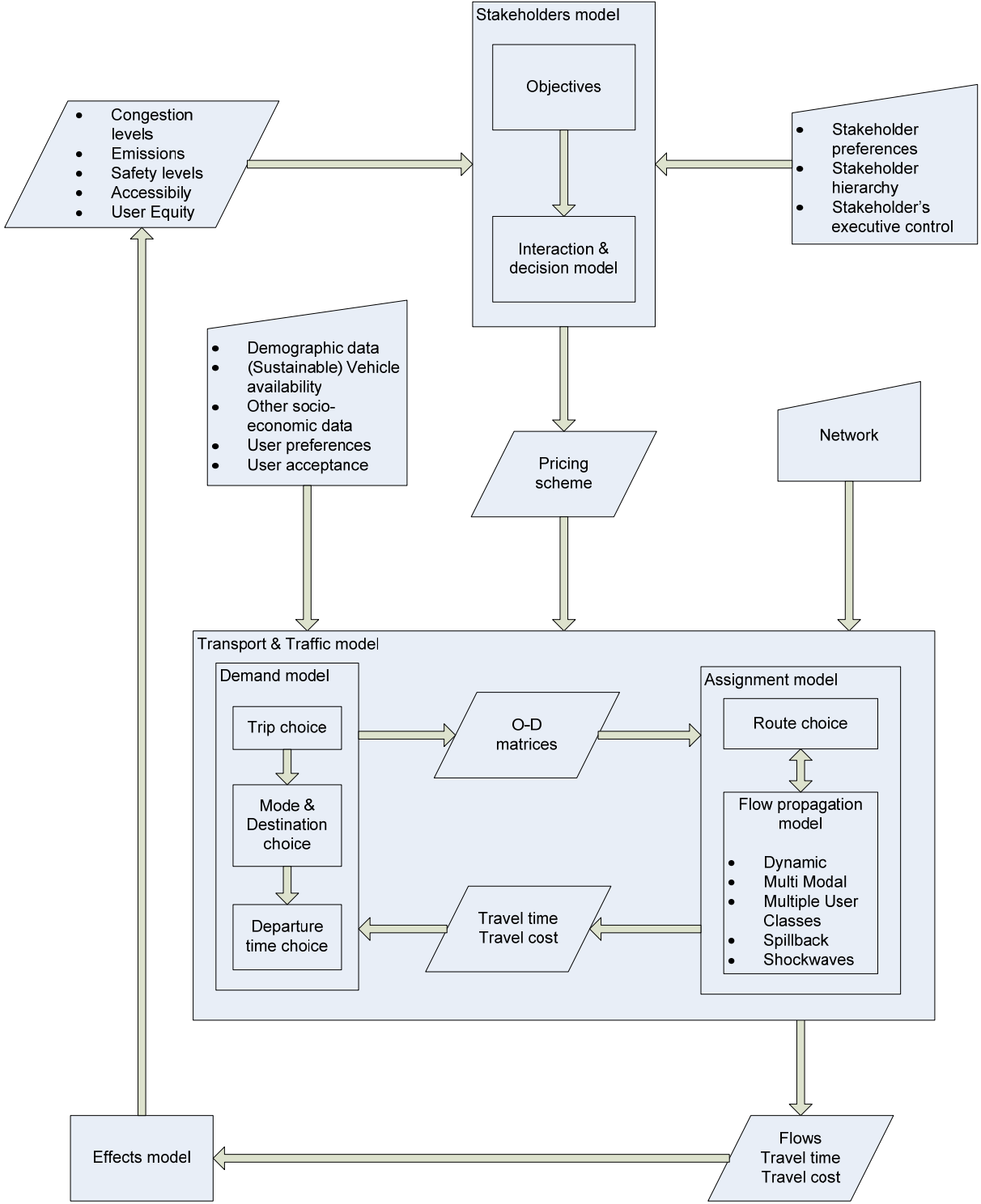

Figure 1: Schematic model set up

MODEL SET UP

The different pricing measures stated in the previous section and stakeholder preferences and interactions are the main element of the proposed model set up. They are supplemented with a transport and traffic model, this combination leads to a comprehensive model to consider pricing measures and their implementation. The model will be described by means of an explanatory figure. Consider figure 1, a schematic representation of the proposed model. Squares represent processes, trapezoids represent data and the sloping top quadrangles are input variables and data.

The *stakeholders model* considers the effects that emanate from a network situation and will deliver an (optimal) pricing scheme. To accomplish such scheme, information is required about stakeholders, their preferences, hierarchy and executive control is needed as input. For each stakeholder an objective function in terms of the effects is derived. Afterwards a game theoretical approach is considered to model the interactions between the stakeholders and to come up with a consensus and/or optimal pricing scheme.

This pricing scheme is used in the *transport & traffic model*, this model determines which displacements arise and how they load the network. There are two components of the model that have a specific synergy. The *demand model* collects all societal and user specific data and aims to generate travel demand origin-destination (O-D) matrices. For the trip, mode, destination and departure time choice a discrete choice model will be used. The route choice and network loading is performed in the traffic *assignment model*, the derived O-D matrices and a network representation are used as input. The assignment model is dynamic, multi modal and has to take multiple user classes (i.e., cars and trucks, different traveller types), spillback and shockwaves into account; the results of the assignment are traffic flows, times and costs.

The *effects model* derives the congestion levels, emissions (CO_2, NO_x, PM_{10}), safety levels, accessibility and user equity from the traffic flows, times and costs. It basically quantifies the externalities of the transport & traffic model. The resulting effects are input for the stakeholders models, this results in a feedback loop.

The interaction between the stakeholders model and the transport & traffic model results is described in a bilevel problem formulation. This kind of problems is not easy to solve, actually only heuristics can be applied. A major factor on the practicability of this approach will be the dimension of the design variables (i.e. the considered pricing measures).

EXPECTED CONTRIBUTIONS

This study aims to develop a practical tool to evaluate and optimise pricing measures for the Randstad area for all important stakeholders. The state-of-the-art of the different process blocks in Figure 1 is at a very high level, the challenge is to combine the contributions on individual models and thereby creating a high-quality tool. As the research has only just started, the paper will describe the aims, model framework, pricing measures, external effects, and stakeholders of the study in more detail.

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