Optimal public transport pricing:

Flat pricing vs. user-specific marginal social cost charging

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1 Introduction

In the transport sector congestion, air pollution, noise and accidents are sources of inter- or intra-sectoral external costs leading to welfare losses and an inefficient market equilibrium [11]. External effects arise if marginal private user costs deviate from marginal social costs. Marginal social cost pricing means setting generalized prices equal to the sum of marginal producer costs, marginal private user costs and marginal external costs. Therefore, in the public transport market the optimal fare amounts to the difference between marginal private and marginal social costs. By charging the optimal fare, external effects are internalized and taken into account by users. Thus, the right incentives are given to achieve market efficiency and maximize social welfare.

Since theoretical first best conditions may not exist in reality (e.g. due to underpriced competing modes, difficult computation, unfeasible application), second best solutions are required. Insights from the first best solution may help to develop a second best pricing strategy [8].

2 Literature and problem statement

Most studies on transport externalities focus on the private transport sector. Congestion is usually the largest part of all external costs in peak periods, whereas in off-peak periods other externalities such as pollution and accidents have been found to be at comparable levels with congestion [2, 7]. In context of urban public transport modes, external effects among public transport users are investigated to a lesser extend [5, p. 128–142]. For the urban rail sector, delays are related to the traffic volume by regression, finding delay effects to be the most significant external effect [6]. In context of urban public transport several authors have incorporated external effects in analytical models. These models usually account for delays due to passenger transfers, the disutility of crowded vehicles and congestion effects among public vehicles at transit stops (e.g. [9, 10, 7, 4]). In [3] public transport fare and headway are optimized applying a simulation-based grid search approach, finding delay effects due to passenger transfers and capacity constraints to have a major impact on the social welfare and optimal pricing structure. The present study contributes to the setting of optimal public transport pricing by investigating the marginal cost imposed by public transport users on other users and the operator, at a microscopic level (user by user). We use an activity-based simulation with dynamic traffic assignment. Starting from a simple multi-modal corridor, the presented approach is going to be extended to a large scale scenario. Accounting for time-dependency and queue formation allows for simulating the interaction of activity scheduling decisions and public transport pricing.

3 Methodology

In this research, the open-source agent-based microsimulation MATSim[1] is used for the optimization of public transport fares by applying a marginal social cost pricing approach. On an agent-based level external effects, marginal delays and number of affected users, are traced back to their origin. The marginal cost of increasing dwell time imposed on passengers inside the vehicle (in-vehicle time delay effect), on users waiting for a delayed vehicle (waiting time delay effect) and on the operator are first considered, ignoring bus capacity restrictions. On a second stage, additional external effects such as the discomfort

[1] Multi-Agent Transport Simulation, see www.matsim.org

of crowding and increased waiting times due to binding capacity constraints are incorporated into our framework. These external effects are internalized by charging the equivalent monetary amount from the agent who is causing the delay effects. Users can adapt their transport mode (car or bus) and departure times following a multinomial logit model [3]. Finally, two pricing strategies are compared in terms of social welfare and external delay effects: user-specific pricing, in which each bus user is charged his/her external cost, and flat pricing, in which all users are charged the same (optimized) fare.

At this stage, marginal social cost pricing is applied to a multi-modal corridor (car and bus), with a total length of 20 km. On the demand side a total of 20,000 travelers are considered – split in two trip purposes: commuters and non-commuters – with randomly distributed activity locations along the corridor. Behavioral parameters for the users' utility function are borrowed from an Australian study by [10]. Operator cost functions are taken from [1].

4 Results

Our preliminary results show that the external delay costs and thus marginal cost fares increase as public transport demand rises. Different headways are simulated yielding an increase of delay costs for larger headways and higher load factors. For a headway of 5 min total internalized external delay costs amount to $31,930[2] . Marginal delay effects depend on the number of affected users and range from $0.00 to $3.04 per trip. During peak times more users are affected than off-peak. Hence, for trips starting between 2 p.m. and 4 p.m the average external delay cost is $1.05, whereas trips after 8 p.m. cause an average effect of only $0.36. For the whole day, the average is $0.89 per trip with a standard deviation of $0.36.

Furthermore, user-specific marginal social cost pricing is compared to the welfare maximum obtained with fares restricted to be constant for every passenger at any time. Increasing the fare in steps of $0.05 for a 5 min headway yields an optimal constant fare of $0.6 per trip. As expected, social welfare per day is found to be greater when charging marginal cost fares than charging a constant fare (+$1,652). User benefits are higher in the constant fare pricing scheme (+$7,952 per day), whereas operator revenues are larger

[2] Australian Dollar, $1.00 = 0.79 Euro (March 2013)

in the user-specific marginal cost pricing approach (+$9,603 per day). Computing the externalities for the flat pricing strategy shows that compared to the user-specific pricing strategy the average external delay costs are higher, in particular during peak times. The next stage is to extend our approach to a real-world transport network (Berlin) and include more effects associated with public transport users (e.g., crowding).

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