Marginal Congestion Cost Pricing: Allocation of Spill-back Delay Costs to the *True* Causing Agents

Amit Agarwal*, Ihab Kaddoura†
Technische Universität Berlin

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Extended Abstract

Introduction The congestion externality is the leading contributor to the total external costs in the transport sector (Maibach et al., 2008). The exclusion of external cost from behavioral decision making processes lead to a demand level beyond the economic optimum which eventually yields losses in system welfare. In many past studies, authors tried to find optimal toll levels and discussed the economic interpretation of congestion pricing (see, e.g. Arnott et al., 1993, 1994; Lindsey and Verhoef, 2001; Lämmel and Flötteröd, 2009; Kaddoura et al., 2015).

Model In a recent report, the authors emphasized the use of congestion pricing where an efficient allocation can be achieved by forcing all agents to pay a congestion charge equivalent to the external costs they impose on others (Korzhenevych et al., 2014). Therefore, going further into this direction, the present study investigates and improves a marginal social costs pricing model which was introduced by Kaddoura et al. (2015) and further applied in various isolated and integrated pricing scenarios (Kaddoura, 2014; Agarwal and Kickhöfer, 2014). The innovative approach is based on a dynamic traffic simulation and computes delay effects on queuing network that are imposed on other travelers at a microscopic level.

Delay effects are classified based on the flow capacity (number of vehicles per hour) of a road segment (link) and the storage capacity (number of vehicles that can be placed on a link). On each link, an agent can cause a maximum delay equivalent to minimum time headway allowed on the link which is the inverse of the flow capacity (marginal flow delay). The present study keeps track of all entering and leaving agents for each link. If the actual travel time on a link exceeds the free speed travel time of the link, the agent is delayed by agents that have left the link before or by agents on a downstream link (spill-back). The spill-back delay occurs due to flow capacity somewhere downstream in the network. Thus, each delay effect can be allocated to the causing agent. In the initial approach, the allocation of spill-back related delays is approximated by assuming that the affected agent always passes through the bottleneck road segment from which the spill-back emerges. This, however, may not always be the case. The present study improves the existing approach by allocating the spill-back delays to the true causing agent, even if the affected agent does not move along the bottleneck road segment. In order to identify the methodological differences and understand the implementation of congestion cost pricing, several test examples are set up. The proposed approach (1) charges the *true* causing agent if the affected agent is not passing through bottleneck link and (2) charges agents for spill back

*Correspondence author: `amit.agarwal@campus.tu-berlin.de`
†`kaddoura@vsp.tu-berlin.de`

delays which in the initial approach were left *unaccounted*. Further simplified pricing approaches will be tested and compared with the above mentioned pricing approaches.

Results To test the applicability of the proposed approach for a large scale scenario, the approach is applied to a real-word scenario of Munich. Finally, the results of the two congestion pricing methods are compared and then interpreted by finding the system welfare and average tolls. The preliminary results show that for the proposed approach a higher system welfare is obtained and delay costs are lower with respect to the existing approach. As a side effect of the more complex allocation of spill-back related delays, the computational performance is marginally decreased in the proposed approach for the applied scenario. Clearly, the proposed approach is more sophisticated in terms of identifying the relevant links and causing agents and then allocating the delays. It can therefore be used to create benchmarks for the evaluation of real-world policies.

Keywords: Marginal congestion cost pricing, Road Pricing, Internalization, Agent-based Modeling, Spill-back delays, Queuing network

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