

Feedback control-based dynamic toll pricing scheme to enhance traffic flow conditions on a suburban freeway

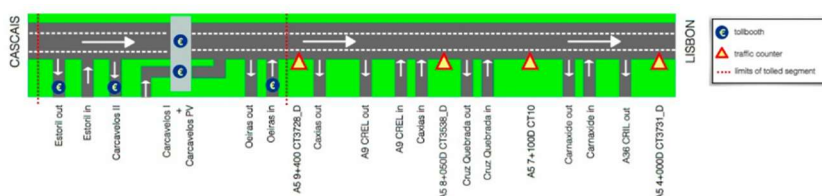
Summary

The environmental and inefficiency concerns generated by traffic congestion push research to investigate new solutions to tackle the problem. During the last two decades, the technique of dynamic pricing, which entails the variation of prices according to market conditions in response to the demand-supply imbalance, has gained great success in the transportation field for congestion relief purposes. While most of the dynamic toll pricing studies in the literature have been developed within the scope of managed lanes and networks, there are very few dedicated to the application of dynamic toll pricing to freeways giving access to attractive locations. In this thesis, a novel approach for alleviating traffic congestion in suburban freeways is proposed through dynamic toll pricing, adopting Portuguese freeway A5 as a case study. The first part of the thesis is constituted by an extensive review of the most recent research regarding design, simulation, implementation, and evaluation of dynamic tolling schemes aimed at defining the toll pricing mechanism to rely on to build a dynamic toll pricing for a suburban freeway. Analyzing the structure of the reviewed studies, the common elements and the differences in the approaches chosen by different authors were identified, presenting an overview of the methods for price definition and of the simulation techniques as well as a discussion on the newest technology applications in the field. Optimization revealed to be the dominant price definition method, while control-based algorithms are notably employed for managed lanes toll pricing schemes. Regarding traffic and driver behavior simulation, a great variety of solutions throughout the reviewed papers was observed, with a prevalence of macroscopic models for the former and logit models for the latter.

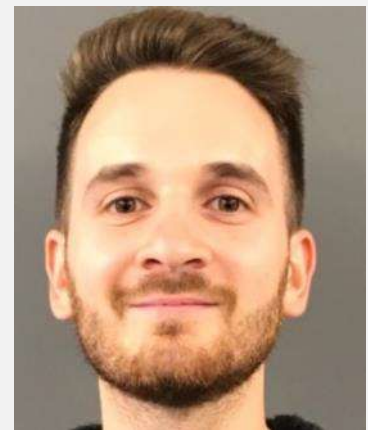
After the literature review, the reader will find the results of a survey conducted among the Portuguese national freeway network users, aiming to derive insights about their travel choice mechanism to test dynamic toll pricing schemes. Particular attention was dedicated to the value the drivers attribute to travel time by analyzing willingness-to-pay for avoiding congestion and saving travel time. The elaborated questionnaire survey was distributed through online survey campaigns between March and June 2021, reaching 180 complete responses. Even after a stratification process, results revealed that value of time (VOT) is generally lower than the original expectations; various statistical distributions were tested to fit the empirical data, the best performing ones were selected, and the results were compared with a previous survey-based VOT study. The elasticity of the freeway demand and of the whole demand for transportation were measured, confirming the generally low willingness to pay for less congested travel. Finally, the developed dynamic toll pricing strategy is detailedly described. The scheme is determined using model-based feedback control, with the underlying model derived using a combination of both traffic flow modeling and driver behavior. The case study is Portuguese freeway A5, a suburban freeway with multiple access locations. A model derived from the cell transmission method was utilized to develop the traffic flow model, with past traffic information from on-road sensors to determine the model parameters. The driver's behavior concerning whether or not to enter the freeway segment is modeled using utility theory and the VOT relative to the toll value. The proposed toll-pricing scheme is tested with traffic data from the Portuguese freeway and with different hypotheses on the driver's VOT distribution, derived from both the literature and the survey, showing a significant improvement in overall traffic conditions. Thus, the developed algorithm provides an opportunity to improve on the existing toll policy by guaranteeing more stable traffic conditions for the freeway users and optimizing the overall traffic throughput.

Keywords

Congestion management, suburban freeway, dynamic toll pricing, driver behavior model, traffic flow model.



The suburban freeway stretch adopted as case study.



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