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Congestion pricing strategies to investigate the potential of route diversion on toll facilities using en-route guidance

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ABSTRACT

The application of intelligent transportation systems (ITS) technologies to facilitate the traffic mobility requires dynamic routing decisions. This study examines the effectiveness of Paramics, a microscopic traffic simulation model that uses a link-to-link shortest path algorithm to consider both updated link travel times and incident conditions detected through different traffic assignment techniques. This paper describes modeling of an urban highway network's traffic conditions to investigate potential route diversion through congestion pricing strategies on toll facilities in Orlando, Florida using Paramics. The experimental design included a multi-level factorial design with three qualitative variables and four response quantitative variables. The experiment's objective was to investigate different scenarios for reducing tolls on less congested roads (SR528 and SR417) and increasing tolls on more congested roads (SR408) to determine the impact on travelers' route choices and overall congestion in the network. The simulation results demonstrate that the Dynamic Feedback Assignment (DFB) led to a reduction in the average queuing delay and average travel time when compared to results from the Stochastic Assignment (SA). DFB significantly affected the percentage of diversion in the network. Drivers saved 10%–16% of travel time when DFB information was provided. Results also show that percentages of route diversion vary from one route to another and depending on the travel cost between specific origin-destination pairs. While drivers incorporate real time guidance information to maximize their own utility, not all drivers gain the same benefit. This was attributed to the limited extra capacity of the alternative routes and the longer travel distance. Combining congestion pricing strategies with traffic information maximize travel time benefits.

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1. Introduction

Simulation modeling is an increasingly popular and effective tool for analyzing a wide variety of dynamic problems, which are challenging to study by other means. Furthermore, the economic impact of traffic management is growing every day. Well-designed and well-managed highway systems could reduce the cost of transporting goods, cut energy consumption, and save countless hours of driving time. To reduce congestion, many countries have been investing heavily in building roads and improving their traffic control systems. ITS technologies present a positive step towards reducing congestion. ITS is implemented to optimize traffic assignment on the network by delivering static and dynamic information to drivers, thus allowing the drivers to adjust their travel routes to the least congested streets. Comprehensive research tools for quantifying the expected benefits from ITS are ongoing and extensive nowadays. In order to quantify the potential benefits prior to any major investment in development and deployment, the use of traffic simulation is regarded essential.

Computer simulation models are very valuable tools in investigating the potential of route diversion through ITS applications, as well as quantifying those benefits in a cost-effective manner. Such models can be used to evaluate modifications not only under existing conditions, but also under hypothetical scenarios that are difficult to observe in the real world. Such models can be used to predict route diversion based on demographic forecasts. Simulation models are designed to mimic the behavior of such systems. Properly, calibrated and validated models could transform these separate parameters and interactions to produce a detailed, quantitative description of system performance.

In this paper, a detailed examination of a severely congested Orlando network is analyzed and modeled using a powerful and popular traffic simulation model, Paramics. The dynamic re-routing strategies embedded in Paramics were utilized to address the benefits of such diversion strategies in response to different assignment techniques.

1.1. *Literature review*

Mahmassani and Jayakrishnan (1991) studied applications such as users' route choice dynamics in the case of lane closures of in a simulation environment. The results show that providing real time, in vehicle information to users could lead the network to reach a steady state at a faster rate than under the no-information case. A weighted average approach was suggested by Ben-Akiva et al. (1991) to represent drivers' perceived travel times as a function of the historic perceptions and the information travel time. This information model assumes that travel times are deterministic variables and thus doesn't account for the drivers' stochastic perceptions of travel times.

Another study of modeling traffic flows in networks of advanced traffic control and route guidance systems by Yang and Koutsopoulos (1996) using the Microscopic Traffic Simulator (MITSIM) on the A10 network in California with non-recurrent congestion caused by a 20 min incident was investigated. The case study demonstrates that an average 2%–4% of travel time savings is achieved when real time traffic information is provided to 30% of drivers. For drivers with viable alternative routes, real time route guidance is very effective, creating travel time savings of up to 18%.

Analysis of equilibrium dynamic assignments by Mahmassani and Peeta (1993) presents a large-scale study using the DynaSmart simulation assignment model to perform both user equilibrium (UE) and system optimal (SO) equilibrium calculations for a specified network. These calculations were completed over a range of traffic loading conditions, from unsaturated to over-saturated. This is an example of using a traffic simulation as a component of a larger model to perform a complex analysis of ITS initiative.

Al-Deek et al. (1989) discussed a study on the I-10 corridor project using Freeway Queuing Simulation Model version 8 (FREQ8) to evaluate the benefits of In-vehicle Information Systems (IVIS). In this study the FREQ model was used to simulate a section of the Santa Monica I-10 freeway in California. The study estimated delays, queues and travel times on the freeway based on scenarios of recurring and incidental congestion. The study produced a simulated corridor representative of the study section, which helped in testing the benefits of IVIS.

Gardes et al. (2002) developed a calibration process for the Paramics microscopic traffic simulation model to assess the model's ability to serve as a tool for evaluating freeway improvement strategies. Paramics was applied to the Interstate 680 in the San Francisco Bay Area, CA, providing a case study for an in-depth calibration of the model, as well as an evaluation of potential freeway improvement alternatives. Ma and Abdulhai (2002) also developed a genetic algorithm-based optimization approach to serve as a generic tool for calibrating microscopic traffic simulation model parameters.

Shaw and Nam (2002) concluded that micro simulation is a relatively new type of computer modeling that performs a detailed stochastic analysis of traffic operations on a series of roadway segments by simulating the motion of cars, second by second. The team evaluated the Paramics and Vissim packages. Both offered significant advantages compared to CORSIM, and Paramics is recommended as the basis for further simulation work. Fujii et al. (2004) found that, in Sweden, public acceptance of road pricing decreases as it is perceived as unfair and an infringement on freedom. Schmöcker et al. (2012) reported a survey investigating whether the same effects are found in the Asian country and region of Japan and Taiwan. The results indicated that fairness plays the same role. However, income had a direct effect on acceptance to Taiwan but not in Japan or Sweden. Bhatt et al. (2008) reported that in 1999, 90% of residents thought there was too much traffic in the capital, and 41% of survey participants believed that the best way to fund public transport improvements in London was congestion charge. Kim et al. (2013) investigated determinants of acceptability of environmental (carbon) taxation, for which trust in government and environmental concern are additional determinants. Carbon taxation is an extension of fuel taxes and may be viewed as transport pricing. Zheng et al. (2014) investigated the public acceptance of pricing schemes in