A DYNAMIC FEEDBACK-CONTROL TOLL PRICING METHODOLOGY FOR MANAGED LANES

PRINCIPAL INVESTIGATOR

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TRB KEYWORD

Variable Toll Lanes, Managed Lanes, Congestion Pricing, Revenue Maximization, High Occupancy Toll.

FUNDS REQUESTED

The total project cost is $59,637. This includes a total of $29,178 from UTC and $30,459 matching funds from LSU.

PROJECT SUMMARY

With the fast increase in passenger and freight travel demand, traffic congestion has become a persistent problem to the surface transportation network in the United States. Congestion undermines people's quality of life through wasted time, energy, money, as well as associated environmental concerns and safety issues. Traditional solutions to mitigate traffic congestion through capacity expansion projects are not always feasible due to the exceedingly high cost or limited available land. Over the years, various operational policies have been adopted or proposed to relieve the traffic congestion at lower cost, for instance, reducing demand by imposing bans on commercial vehicles for particular hours, discouraging peak-hour traveling, re-timing of traffic lights, metering access to highway and so on.

PROJECT DESCRIPTION

Research Problem Statement

Recently, congestion pricing emerged as a cost-effective and efficient strategy to mitigate the congestion problem on freeways. The concept of congestion pricing was first introduced in "The Economics of Welfare" (Pigou, 1920) and was later greatly promoted both theoretically and practically (e.g. William Vickrey, 1968). Congestion pricing consists in imposing a fixed or variable toll on motorists for using a particular lane or roadway segment in an attempt to influence travel demand by encouraging motorists to either switch to alternative routes or changing their trip time (Kachroo, 2011). In the U.S., a common form of congestion pricing is used in the form of managed lanes or express toll lanes. The toll price on managed lane can be fixed or dynamic. In recent years, along with the advancement of technologies such as detectors, and electronic toll collection devices, a few states have deployed dynamic toll pricing systems such as the "San Diego I-15 Fas Trak" with a toll changing every 6 minutes, the Orange County, CA,SR-91 with a toll changing every hour, the Minnesota I-39 with a toll changing as frequently as every 3 minutes (Kachroo, 2011), and the I-95 express toll lanes in Florida updating toll rates every 15 minutes. Dynamic congestion pricing is a very complex topic which needs to be considered from different perspectives. An important concern is the objectives of the congestion pricing strategy. Previous researchers or road authorities have focused on many objectives of congestion pricing. For instance, the interstate 95 express toll lanes aims at providing the best traffic conditions possible on the managed lanes. Its toll rate only depends on the traffic conditions of express toll lanes. Other objectives include: maximizing the throughput of the freeway; minimizing the total travel time delay; maximizing the toll revenues; maximizing the travelers' utilities; maintaining a desirable traffic demand on freeway and others. Diverse objectives will lead to various toll pricing strategies. Another considerable issue is the heterogeneity of drivers' value of time. Due to the different socio-economic status, drivers have various values of time which result in distinct trip utilities and disparate route decisions. As a result, it is very important to incorporate the heterogeneity of drivers' value of time into the route decision model to reproduce realistic driver behaviors. Besides, questions such as "what's the appropriate frequency of change of toll rate?"; "how drivers will react to the change of toll rate and how road authorities can influence drivers' route decision through toll controlling?" should also be investigated when designing a dynamic toll pricing strategy. This study explored the dynamic congestion pricing in terms of three perspectives: the control mechanism of dynamic congestion pricing, the objectives of dynamic toll pricing and the impacts of heterogeneity of drivers' value of time on route decisions.

Goals and Objectives

The primary goal of this study is to develop a feedback-control based dynamic toll pricing strategy to formulate and solve optimal tolls with a focus on three distinct objectives of the road authority. The first objective of congestion pricing is to maximize toll revenues while maintaining a minimum desired level of service on managed lanes. The second one is to maximize total travel utility while keeping a minimum desired level of service on managed lanes. The third objective is to maximize total social surplus, which is the combination of revenue and travel utility maximization while meeting the constraint of desired level of service. According to Washington State Route SR-167 HOT Lane project, the minimum level of service requires the average speed on the managed lanes to be larger than 45 miles per hour at peak period. In addition the study will examine the interaction between toll exempt vehicles such as high occupancy vehicles with 3 or more passengers and buses. To accomplish the goal, specific objectives are: (1) Develop a feedback-control based dynamic toll strategy with a focus on two different objectives, (2) Build a freeway network of the study area in transportation simulation software, (3) Analyze the variation of value of time(VOT) among all drivers and the variation of VOT of each individual driver throughout of a day. Estimate drivers' value of time based on information of drivers' annual income and time-of-the day. (4) Analyze how drivers' value of time will influence route decisions and thus affect the optimal toll rates under the proposed toll methodologies with three different objectives, (5) Test the proposed dynamic toll strategies under traffic compositions with and without toll exempt vehicles. (6) Test the proposed dynamic toll strategies with a focus on three different objectives in microscopic simulation and compare their performances with that of the current toll strategy on Interstate 95.

Background

Congestion pricing has three important perspectives. The first considers congestion pricing in terms of static and dynamic toll pricing. In the early stage, researchers simplified the problem of congestion pricing to a state where the traffic demand or the network was static and only a fixed toll rate was explored. The second perspective involves research on the issue of heterogeneity of drivers' value of time (VOT) in the problem of congestion pricing. This heterogeneity influences the cost function in drivers' route decision model and thus influences subsequent traffic flows as well as toll rates on the toll lanes. The third perspective focuses on reviewing different objectives of toll pricing since diverse objectives result in distinct toll pricing schemes. Each of the three persepectives will be reviewed thoroughly in this project. A list of suggested publications to review is included at the end of this proposal.

SCOPE

The scope of this study will be limited to the study section that operates the managed lanes on Interstate 95 in Florida as a case study.

RESEARCH WORK PLAN

The following tasks will be completed in order to achieve the stated research objectives:

Task 1

In this task, the research team will search for studies with the purpose of gaining the state of the art knowledge on the subject matter. Published reports and journal manuscripts will be thoroughly reviewed to expand on the preliminary literature search presented in this proposal. Topics included in the literature review will cover: congestion pricing, dynamic toll strategies, drivers' value of time, drivers' route choice behavior. This task is expected to be completed within the first month of the project.

Task 2

Based on the literature search conducted in Task 1, the research team will develop a feedback control based dynamic toll strategy. The essential idea of the strategy is to divide the traffic conditions into two cases based on average speed on the managed lanes and formulate different control rules of toll determination of each case. Besides, a network of study area will be developed in VISSIM simulation. An external managed lane with proposed dynamic toll strategy will also be developed that can be integrated to VISSIM network through VISSIM_COM. This task is expected to be completed within the first three months of the project.

Task 3

Based on the literature search conducted in Task 1, the research team will also analyze the variation of individual driver's value of time throughout of a day. Then the driver's value of time will be estimated based on the results of time-of-day variation analysis and drivers' annual income information. With the estimated driver's value of time, drivers' route choice behavior will be analyzed under proposed toll strategies in the simulation network developed in Task 2. This task is expected to be completed at the end of the fourth month period.

Task 4

The performance of the proposed dynamic toll strategies will be tested in the simulated network with real traffic demand data. The testing period will include pre-peak hours and peak-hours in the morning including both high and low traffic demand. The interaction between toll-exempt vehicles and passenger cars will be tested under the proposed dynamic toll strategies. In addition, the performance of the proposed strategies will be compared to that of the I-95's current toll strategy in terms of resulting revenues, toll rate profiles, traffic conditions on both managed lanes and the general purpose lanes and others. This task will be completed at the end of the sixth month period or the end of the project.

WORK PLAN

The table below shows the anticipated timeline for each of the project tasks.

Task	Month					
	1	2	3	4	5	6
1	X					
2	X	X	X			
3	X	X	X	X		
4				X	X	X

DELIVERABLES

A final report will be submitted at the end of the 6-month period following the standard LSU UTC report format and documenting all research work completed and the findings. The research results will also be published in both peer-reviewed conference proceedings and journals.

PROJECT TEAM

The study team involves Dr. Ishak (PI) and one graduate student. Dr. Ishak will lead the execution of all project tasks. Dr. Ishak assumes the responsibility of timely submission of progress and final reports. A graduate student at the MS level will be hired on this project to assist in all research tasks.

Dr. Ishak has research experience in several and diversified topics in transportation engineering including traffic simulation, data collection technologies, traffic operations, traffic safety, Intelligent Transportation Systems applications, and artificial intelligence. Project management skills as a result of managing and directing as a PI and Co-PI several research projects. Some related previous and current research projects are:

- S. Ishak (PI), "A Driving Simulator to Study Human Behavior and Improve Traffic Operation and Safety in Louisiana," LA Board of Regents, $182,060 (2010-2011).
- S. Ishak (PI), "Resilient Transportation: An Integrated Corridor Management Approach," US Department of Transportation, $37,023 (2009-2010).
- S. Ishak (PI) and B. Wolshon, "Establishing an Intelligent Transportation Systems (ITS) Lab at LTRC," Louisiana Department of Transportation and Development / Louisiana Transportation Research Center, $49,994 (2007-2008).
- B. Wolshon (PI) and S. Ishak (Co-PI), "Safety and Operational Assessment of Unconventional Lane Merges in Freeway Work Zones", Louisiana Department of Transportation and Development / Louisiana Transportation Research Center, $140,000 (2007-2000).
- S.S. Ishak (PI), "The Urban Data Warehousing/Data Mining (Dw/Dm) Component For ITS: Statewide Planning Phase," Louisiana Transportation Research Center through Tulane University (2003-2005).
- S.S. Ishak (PI), "Exploring New Traffic Characteristics and Performance Measures Using Feature Extraction and Texture Characterization of Spatiotemporal Traffic Contour Maps," National Science Foundation (2003-2006).

Recent Refereed Journal Publications

1. Ishak, S., Y. Qi, and P. Rayaprolu. Crash Analysis and Safety Evaluation of Joint and Conventional Lane Merge Configurations for Freeway Work Zones, Journal of Traffic Injury Prevention, Vol. 12 (2), 2012.
2. Korkut, M.*, S. Ishak, and B. Wolshon. (2010) Freeway Truck Lane Restriction and Differential Speed Limits: Crash Analysis and Traffic Characteristics, Transportation Research Record, Journal of the Transportation Research Board, No. 2194, 11-20.
3. Ishak, S., H.C. Shin, B. Sridhar*, and D. Zhang. (2010) Characterization and development of truck axle load spectra for future implementation of new pavement design practices in Louisiana, Transportation Research Record, Journal of the Transportation Research Board, No. 2153, 121-129.
4. Ishak, S., C. Mamidala, and Y. Qi*. (2010) Stochastic Characteristics of Freeway Traffic Speed during Breakdown and Recovery Periods, Transportation Research Record, Journal of the Transportation Research Board, No. 2178, 79-89.
5. Sun, X., B. Huang, S. Ishak, and B. Wolshon. (2009) Estimating the Safety Impact of Differential Speed Limit and Truck Lane Restriction on Interstate-10 through Atchafalaya basin in Louisiana, Journal of Transportation Safety and Security, Vol. 1, 169-180.
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10. Katerina, S. and M.C.J., Bliemer. Dynamic road pricing with traffic-flow dependent tolling. Presented at 87th Annual Meeting of the Transportation Research Board, Washington, D.C., 2008.
11. Li, Y., S., Romesh and H., Hao. Distance-based dynamic pricing strategy for managed toll lanes. Presented at 91st Annual Meeting of the Transportation Research Board, Washington, D.C., 2012.
12. Dimitra, M., Y.Y., Lou and Y.F., Yin. Proactive and robust dynamic pricing strategies for High Occupancy/Toll (HOT) Lanes. Presented at 90th Annual Meeting of the Transportation Research Board, Washington, D.C., 2011.
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