



**Final Report**  
**to the**  
**CENTER FOR MULTIMODAL SOLUTIONS FOR CONGESTION MITIGATION**  
**(CMS)**

CMS Project Number: 2009-04

Title: Innovations in Pricing of Transportation Systems: Theory and Practice

February 1, 2009 to September 30, 2010

Siriphong Lawphongpanich  
Industrial and Systems Engineering  
University of Florida  
Gainesville, Florida 32611  
[Lawphong@ise.ufl.edu](mailto:Lawphong@ise.ufl.edu)

Yafeng Yin  
Civil and Coastal Engineering  
University of Florida  
Gainesville, Florida 32611  
[Yafeng@ce.ufl.edu](mailto:Yafeng@ce.ufl.edu)

Janet Degner  
Civil and Coastal Engineering  
University of Florida  
Gainesville, Florida 32611  
[JDegner@ce.ufl.edu](mailto:JDegner@ce.ufl.edu)

August 15, 2011

## TABLE OF CONTENTS

DISCLAIMER AND ACKNOWLEDGEMENT OF SPONSORSHIP .....	i
ABSTRACT.....	ii
EXECUTIVE SUMMARY .....	iii
CHAPTER 1: BACKGROUND.....	1
CHAPTER 2: CONFERENCE SUMMARY .....	2
APPENDIX: CONFERENCE PROGRAM.....	4

## **DISCLAIMER AND ACKNOWLEDGEMENT OF SPONSORSHIP**

### **Disclaimer:**

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

### **Acknowledgement of Sponsorship:**

This work was sponsored by a grant from the Center for Multimodal Solutions for Congestion Mitigation, a U.S. DOT Tier-1 grant-funded University Transportation Center.

## **ABSTRACT**

This report summarizes results from the conference titled “Innovations in Pricing of Transportation Systems” on May 12 – 14, 2010 at the Royal Plaza Hotel in Orlando, Florida. The primary objective of the conference is to bring together practitioners, experts, and researchers worldwide to discuss and share innovative ideas in using market-based approaches to encourage a more efficient use of and to better design a scheme for financing improvements to a multi-modal transportation system.

## **EXECUTIVE SUMMARY**

The conference titled “Innovations in Pricing of Transportation Systems” was held on May 12 – 14, 2010 at the Royal Plaza Hotel in Orlando, Florida. The conference organizing committee consisted of the Chair (Siriphong Lawphongpanich from Industrial and Systems Engineering), two Co-Chairs (Yafeng Yin, and Janet Degner, both from Civil and Coastal Engineering), and ten other members from industries and several universities in the U.S. and abroad.

The conference program was designed with assistance from an advisory board that included 36 distinguished individuals from federal, state, and local transportation agencies as well as those from industry and academia. The final program contained six plenary sessions by distinguished speakers and over 70 presentations by practitioners, experts, and researchers from various transportation agencies, non-profit organizations, and universities. Conference participants were from nine countries and had varied background such as economics, transportation, civil engineering, operations research, industrial engineering, urban planning, social science, etc.

The financial support from the Center of Multimodal Solutions for Congestion Mitigation at University of Florida, National Science Foundation, and University of Florida’s Office of Research enabled the conference to offer grants to nearly twenty graduate students to travel to Orlando and present their research. The conference was also sponsored by the Transportation Research Board.

## CHAPTER 1: BACKGROUND

Prior to 2010, the last international conference devoted to road pricing or congestion mitigation held in the U.S was the *International Perspective on Road Pricing: International Symposium on Road Pricing*, held at Key Biscayne in Florida on November 19 – 22, 2003. Considering the growing interests and advances in the theory and practice in pricing and congestion mitigation, an international conference on this and similar topics was both timely and appropriate. This led us to organize a conference titled “Innovations in Pricing of Transportation Systems” on May 12 – 14, 2010 at the Royal Plaza Hotel in Orlando, Florida.

The primary objective for our conference is to bring together practitioners, experts, and researchers worldwide to discuss and share innovative ideas in using market-based approaches to encourage a more efficient use of and to better design a scheme for financing improvements to a multi-modal transportation system. For example, common road or congestion pricing schemes such as High Occupancy Toll (HOT) lanes and cordon pricing use market-based approaches to manage travel demand and mitigate congestion. However, it is also possible to combine congestion pricing with other forms of revenue generating schemes to promote a more efficient use of a multi-modal transportation system as well as to finance its improvements such as adding additional bus or metro lines and building new roads or adding new lanes to existing ones.

Our plan for the conference is three-fold. First is to bring together those from various transportation agencies (e.g., the state DOTs, FHWA, private companies, etc.) who operate, finance, and support projects involving pricing of a transportation system for the purpose of mitigating congestion, improving its service to the traveling public, etc. Our plan is to have these professionals discuss and share their experience in operating, funding, and dealing with political and other issues associated with the pricing of transportation systems. Second is to host a conference where researchers from various backgrounds (e.g., economics, transportation, civil engineering, operations research, industrial engineering, urban planning, etc.) can present and share their works on pricing of transportation systems. Finally, the fact that this conference addresses both practice and theory of pricing should provide an environment conducive to encouraging discussion and the transfer of ideas between practitioners, experts, and researchers.

## CHAPTER 2: CONFERENCE SUMMARY

Below are statistics from the conference.

- There were 95 conference participants consisting of the following:
  - Faculty members and students: 63
  - Federal and state transportation agencies: 8
  - Consulting firms and companies: 16
  - Nonprofit organizations & research institutes: 8
- The participants were from nine countries. The distribution is as follow:
  - Australia and New Zealand: 3
  - Canada: 1
  - China: 5
  - India: 1
  - Japan: 6
  - Sweden: 1
  - The Netherlands: 1
  - USA: 79
- There were 87 presentations. Six of which were plenary presentations by distinguished speakers and the remaining 81 were contributed by participants.
  - Among the 81 contributed presentations, there were 33 presentations by graduate students.
- Eighteen travel grants were provided to students.
  - Seven students from foreign countries received \$1000 for travel per student.
  - The remaining were students at universities in the U.S. Each received \$700 for travel.

- Two individuals gave opening addresses.
  - Ms. Noranne Downs, District 5 Secretary, Florida Department of Transportation
  - Ms. Jennifer Olson, Deputy Executive Director and COO for Florida’s Turnpike Enterprise.
- The Journal of Transport Policy and European Journal of Transportation and Logistics will publish special issues on transportation pricing. Selected presentations from the conference will appear in the journal.
- In its Fall of 2010 issues, the newsletter for the Center for Multimodal Solutions to Congestion Mitigation at the University of Florida contains six articles written by conference participants.
- The conference program is in the Appendix.

## **APPENDIX: CONFERENCE PROGRAM**

The conference program is attached.

# Table of Contents

Welcome from Chair & Co-Chairs.....	2
Conference Organizers .....	3
Advisory Board.....	4
General Information .....	5
Area Information.....	6
Schedule .....	7
Abstracts.....	13
Plenary Presentation ~ Patrick DeCorla-Souza .....	21
Plenary Presentation ~ Terry Friesz .....	22
Plenary Presentation ~ Timothy Hau .....	25
Plenary Presentation ~ Donald Hearn .....	26
Plenary Presentation ~ Robert Poole, Jr. ....	42
Plenary Presentation ~ Brian Taylor .....	51
Conference Map .....	58
Notes .....	59

# Welcome from the Chair & Co-Chairs



College of Engineering

On behalf of the entire organizing committee, we would like to welcome you to Orlando and the conference and workshops on Innovations in Pricing of Transportation Systems. We have two dynamic days planned for you. We hope you find this meeting interesting, informative and useful.

The program consists of six plenary sessions by distinguished speakers and over 70 presentations by practitioners, experts, and researchers from various transportation agencies, non-profit organizations, and universities. Conference participants include citizens from twelve countries and individuals with varied background such as economics, transportation, civil engineering, operations research, industrial engineering, urban planning, social science, etc.

In addition to assistance and advice from members of our advisory board, this conference and workshops received generous support, financial and otherwise, from several sponsors and individuals. The Center of Multimodal Solutions for Congestion Mitigation at University of Florida and National Science Foundation are our leadership sponsors. Among others, their financial support enables us to offer grants to nearly twenty graduate students to travel to Orlando and present their research. University of Florida's Office of Research and College of Engineering, particularly its Departments of Civil and Coastal Engineering and Industrial and Systems Engineering also provided us with financial and other forms of support. Mr. Patrick DeCorla-Souza, co-chair of the Transportation Research Board's Congestion Pricing Committee, was instrumental in helping us obtain sponsorship from the Board. Ms. Catherine Gentilman from University of Florida's Department of Conferences helped us organize and plan this meeting. She made our tasks much easier and we are truly grateful for her assistance.

Finally, we hope that you can take some time during your stay to enjoy Orlando. With its world-class theme parks, diverse culinary offerings, and a wealth of fashion-forward stores, boutiques, and outlets, Orlando is one of the world's leading vacation destinations. Downtown Orlando and its trendy Thornton Park historic district provide a look inside the city of Orlando beyond the theme parks. Nearby communities such as Winter Park, Central Florida's oldest community dating back to the 1880s, offer European-style tree-shaded avenues, magnificent homes and a window into the world of Florida's past.

We wish you a successful and productive meeting. Thank you for joining us!

Best Wishes,

Siriphong (Toi) Lawphongpanich  
Chair

Yafeng Yin  
Co-Chair

Janet Degner  
Co-Chair

# Conference Organizers

## **Organizing Committee:**

### **Chair:**

*Siriphong (Toi) Lawphongpanich*, University of Florida

### **Co-Chair:**

*Janet Degner*, University of Florida

*Yafeng Yin*, University of Florida

### **Members:**

*John Doan*, SRF Consulting Group

*Lily Elefteriadou*, University of Florida

*Younes Hamdouch*, U.A.E. University

*Yingyan Lou*, University of Alabama

*Dimitra Michalaka*, University of Florida

*Siva Srinivasan*, University of Florida

*Ruth Steiner*, University of Florida

*Chris Swenson*, Wilbur Smith Associates

*David Ungemah*, Parsons Brinckerhoff

*Scott Washburn*, University of Florida

### **Meeting Coordinator:**

*Cathy Gentilman*, University of Florida

### **CMS Liaison:**

*Ines Aviles-Spadoni*, University of Florida

# Advisory Board

*Shi An*, Harbin Institute of Technology  
*Richard Arnott*, University of California at Riverside  
*David Boyce*, Northwestern University  
*Kenneth Button*, George Mason University  
*Patrick DeCorla-Souza*, Federal Highway Administration  
*Michael Florian*, University of Montreal  
*Terry Friesz*, Pennsylvania State University  
*Ziyou Gao*, Beijing Jiaotong University  
*Timothy D. Hau*, University of Hong Kong  
*Donald W. Hearn*, University of Florida  
*Jose Holguin-Veras*, Rensselaer Polytechnic Institute  
*Hai-Jun Huang*, Beijing University of Aeronautics and Astronautics  
*William H.K. Lam*, Hong Kong Polytechnic University  
*David Levinson*, University of Minnesota  
*Robin Lindsey*, University of Alberta  
*Hong K. Lo*, Hong Kong University of Science and Technology  
*Richard Long*, Florida Department of Transportation  
*Huapu Lu*, Tsinghua University  
*Hani Mahmassani*, Northwestern University  
*Patrice Marcotte*, University of Montreal  
*Anthony May*, University of Leeds  
*Pitu Michandani*, Arizona State University  
*Lee Munnich*, University of Minnesota  
*Robert Poole*, Reason Foundation  
*Debora Rivera*, Florida Department of Transportation, District Six  
*Don Shoup*, University of California at Los Angeles  
*Kenneth Small*, University of California at Irvine  
*Brian Taylor*, University of California at Los Angeles  
*Trey Tillander*, Florida Department of Transportation  
*Yinhai Wang*, University of Washington  
*S. C. Wong*, University of Hong Kong  
*Hai Yang*, Hong Kong University of Science and Technology

# General Information

**Date:**

Wednesday, May 12 - Friday, May 14, 2010

**Meeting Venue:**

Royal Plaza  
1905 Hotel Plaza Blvd.  
Lake Buena Vista, FL 32830  
Tel: (407) 828-2828

**Notice to Speakers:**

LCD (computer) projectors are available in every room. Please note that you must bring your laptop (or share with another presenter) and AC power adaptor.

**Meal Functions:**

All registered participants are invited.

Wednesday, May 12, 2010 at 6:30 p.m. ~ Opening reception

Thursday, May 13, 2010 at 12:00 p.m. ~ Lunch

Friday, May 14, 2010 at 11:30 p.m. ~ Lunch

Breakfast is on your own.

**Registration Classifications:**

Registration for the following classifications include admission to conference sessions, meal functions, abstract book and a list of registered participants.

Early Registration - \$325.00 (US)

Late Registration - \$425.00 (US)

Student Registration - \$150.00 (US)

**Official Language:**

All presentations are in English, no simultaneous translation is available.

# Area Information

## Area Dining:

Chevy's (Tex Mex)  
407-827-1052

TGIFriday's (American)  
407-827-1020

Sweet Tomatoes (Fresh Salads & Soups)  
407-938-9461

Red Lobster (Seafood)  
407-827-1045

Joe's Crab Shack (Seafood)  
407-465-1895

Black Angus (Steakhouse)  
407-239-4414

Bahama Breeze (Caribbean)  
407-938-9010

Golden Corral (Buffet)  
407-938-95000

Starbucks (Coffee & Pastries)  
407-387-8700

Portobello Yacht Club (Italian)  
407-934-8888

Rainforest Café (American)  
407-827-8500

Wolfgang Puck (Californian)  
407-938-9653

House of Blues (Cajun/ Creole)  
407-934-2583

Bongos (Cuban)  
407-828-0999

Benihana (Japanese)  
407-827-4000

Raglan Road (Irish)  
407-938-0300

## Local Attractions

Walt Disney World  
407-939-4636

Universal Studios  
407-363-8000

SeaWorld  
888-800-5447

Discovery Cove  
877-557-7404

Disney Quest  
407-828-3800

La Nouba  
407-939-7600

Premium Outlets  
407-238-7787

## Local Information:

For more information about the Orlando, FL area please visit the official travel site for the area at <http://www.orlandoinfo.com/>

# Schedule

Wednesday, May 12, 2010

Begin Time	End Time	Event	Location
6:30 p.m.	7:30 p.m.	<b>Opening Reception</b>	<i>Courtyard</i>

Thursday, May 13, 2010

Begin Time	End Time	Event	Location
7:30 a.m.	6:00 p.m.	<b>Registration &amp; Information Desk Open</b>	<i>Harrington Foyer</i>
8:30 a.m.	9:00 a.m.	<b>Welcoming and Opening Remarks</b> Welcoming Remarks, Ms. Jennifer Olson, Deputy Executive Director and COO for Florida's Turnpike Enterprise  Opening Address: "Congestion Issues in Central Florida," Ms. Noranne Downs, District Five Secretary, Florida Department of Transportation.	<i>Harrington 1</i>
9:00 a.m.	10:40 a.m.	<b>Session 1A      Session Chair: Yingyan Lou</b> <b>Mode Choice due to HOV to HOT Conversions</b> <i>Mark Burris, Texas A &amp; M University</i> <b>HOT Lane System Performance Optimization with Consideration of Revenue Enhancement</b> <i>Xiaojin Ji, Wilbur Smith Associates</i> <b>Tool for Estimating Managed Lanes Traffic and Variable Toll Rates</b> <i>Jack Klodzinski, Florida's Turnpike Enterprise</i> <b>A Unified Framework of Proactive Self-Learning Dynamic Pricing for High-Occupancy/Toll Lanes</b> <i>Yingyan Lou, University of Alabama</i>	<i>Harrington 1</i>
		<b>Session 1B      Session Chair: David Ungemah</b> <b>Innovations in Pricing from Around the World - Reducing Congestion and Funding Transportation Using Road Pricing (Part 1)</b> <i>John Doan, SRF Consulting Group</i> <b>Innovations in Pricing from Around the World - Reducing Congestion and Funding Transportation Using Road Pricing (Part 2)</b> <i>Patrick DeCorla-Souza, Federal Highway Administration</i> <b>Congestion Pricing and Greenhouse Gas Reduction: Possibilities</b> <i>David Ungemah, Parsons Brinckerhoff</i> <b>95 Express: Project Overview and Performance Update</b> <i>Debora Rivera, Florida Department of Transportation, District Six</i>	<i>Harrington 2</i>
		<b>Session 1C      Session Chair: Lei Zhang</b> <b>Optimal Mileage Fee Charges – A Network Perspective</b> <i>Jeff Ban, Rensselaer Polytechnic Institute</i> <b>Efficient Vehicle Assessment: Combining Non-Transportation Functions with Variable Fuel Tax Criteria to Make Alternative Gas Tax a Reality</b> <i>Kevin Condon, Core Computer Group</i> <b>A National System of Variable Distance-Based User Charge for Revenue Generation, Congestion Mitigation, and Sustainable Transportation</b> <i>Lei Zhang, University of Maryland</i>	<i>Jasmine Room</i>

## Thursday, May 13, 2010 (Continued)

Begin Time	End Time	Event	Location
10:40 a.m.	11:00 a.m.	<b>Coffee Break</b>	Harrington Foyer
11:00 a.m.	12:00 p.m.	<b>Plenary Session 1A</b> <b>Session Chair: Patrick DeCorla-Souza</b> <b>The Politics of Freeway Congestion Pricing</b> <i>Robert Poole, Reason Foundation</i>	<i>Harrington 1</i>
		<b>Plenary Session 1B</b> <b>Session Chair: Karla Hoffman</b> <b>The Toll Set Approach to Congestion Pricing: A Tutorial</b> <i>Donald Hearn, University of Florida</i>	<i>Harrington 2</i>
12:00 p.m.	1:00 p.m.	<b>Lunch Break (provided)</b>	<i>Giraffe Lounge</i>
1:00 p.m.	2:40 p.m.	<b>Session 2A</b> <b>Session Chair: Robert Abrams</b> <b>Loops and the Existence of Equilibrium-Inducing Tolls</b> <i>Robert Abrams, University of Illinois at Chicago</i> <b>On the Role of the Link Performance Function on Multi-Class Optimal Tolls</b> <i>Jose Holguin-Veras, Rensselaer Polytechnic Institute</i> <b>Optimal Deployment of High-Occupancy-Vehicle/Toll Lanes in General Networks</b> <i>Ziqi Song, University of Florida</i> <b>Time-Dependent Tolling Strategies</b> <i>Wai Yuen Szeto, University of Hong Kong</i>	<i>Harrington 1</i>
		<b>Session 2B</b> <b>Session Chair: Chris Swenson</b> <b>Congestion Pricing Triggers on Toll Roads</b> <i>Phani Jammalamadaka, Wilbur Smith Associates</i> <b>Paying for Transportation: What Would George Washington Do?</b> <i>David B McBrayer, Parsons Brinckerhoff</i> <b>Enabling a Flexible Ridesharing Response to Congestion Pricing</b> <i>Paul Minett, Trip Convergence Ltd</i> <b>Federal Programs and Public Transportation Financing and Pricing</b> <i>Robena Reid, Federal Transit Administration</i>	<i>Harrington 2</i>
		<b>Session 2C</b> <b>Session Chair: Scott Washburn</b> <b>Propitious Selection in the Vehicle Insurance Market</b> <i>Sara Arvidsson, Swedish National Road and Transport Research Institute (VTI)</i> <b>Applying Behavioral Economics Concepts in Designing Usage-Based Car Insurance Products</b> <i>Allen Greenberg, U.S. Dept of Transportation/FHWA</i> <b>A Heuristic Congestion Pricing Scheme for Capacitated Traffic Networks</b> <i>Amir Shahpar, University of Delaware</i> <b>Determinants of Customer Loyalty in Automobile Insurance: The Role of Private Information on Traffic Safety Violations</b> <i>Sara Arvidsson, Swedish National Road and Transport Research Institute (VTI)</i>	<i>Jasmine Room</i>
2:40 p.m.	3:00 p.m.	<b>Coffee Break</b>	Harrington Foyer

## Thursday, May 13, 2010 (Continued)

Begin Time	End Time	Event	Location
3:00 p.m.	4:00 p.m.	<b>Plenary Session 2A</b> <b>Session Chair: José Holguin-Veras</b> <b>Road Pricing: An Economic Approach</b> <i>Timothy Hau, University of Hong Kong</i>	<i>Harrington 1</i>
		<b>Plenary Session 2B</b> <b>Session Chair: David Boyce</b> <b>The Theory and Art of Dynamic Congestion Pricing</b> <i>Terry Friesz, Pennsylvania State University</i>	<i>Harrington 2</i>
4:00 p.m.	4:20 p.m.	<b>Coffee Break</b>	Harrington Foyer
4:20 p.m.	6:00 p.m.	<b>Session 3A</b> <b>Session Chair: Wai Yuen Szeto</b> <b>Quantitative Method for Analyzing Road Network Ownership</b> <i>Mingxin Li, University of Utah</i> <b>Comparison of Optimal Area and Cordon Road Pricing Scheme: Methodology and Policy Implications</b> <i>Takuya Maruyama, Kumamoto University</i> <b>Urban Network Privatization: A Small Network Example</b> <i>Omid Rouhani, University of California at Davis</i> <b>Road Pricing Strategies to Resolve Both Emission and Braess' Paradoxes</b> <i>Wai Yuen Szeto, University of Hong Kong</i>	<i>Harrington 1</i>
		<b>Session 3B</b> <b>Session Chair: Ruth Steiner</b> <b>Evaluation of Parking Deposit System (PDS) with Integrated Travel Demand Forecasting Model</b> <i>Ryo Kanamori, University of Tokyo</i> <b>\$2 Daily Workplace Parking Charge + \$4 Cashout: Cut U.S. Commute VMT 23</b> <i>Steve Raney, Cities21</i> <b>Congestion Pricing for On-Street Parking</b> <i>Katsunobu Sasanuma, Carnegie Mellon University</i> <b>Controlling Congestion through Better Land Use Planning</b> <i>Sterren Latsky, University of Bath</i>	<i>Harrington 2</i>
		<b>Session 3C</b> <b>Session Chair: Siriphong Lawphongpanich</b> <b>Social Welfare Justification for Market-Based Approaches for Airport Congestion Management</b> <i>Michael Ball, University of Maryland</i> <b>Congestion Pricing Applications to Manage High Temporal Demand for Public Services and Their Relevance to Air Space Management</b> <i>Karla Hoffman, George Mason University</i> <b>A la Carte Pricing to Generate Ancillary Revenue: The Case of European LCCs</b> <i>Richard Klophaus, Worms University of Applied Sciences</i> <b>Cargo Revenue Management with Allotments and Spot Market Demand</b> <i>Yuri Levin, Queen's School of Business</i>	<i>Jasmine Room</i>

# Friday, May 14, 2010

<b>Begin Time</b>	<b>End Time</b>	<b>Event</b>	<b>Location</b>
8:00 a.m.	4:00 p.m.	<b>Registration &amp; Information Desk Open</b>	<i>Harrington Foyer</i>
8:30 a.m.	10:10 a.m.	<b>Session 4A      Session Chair: Mark Burris</b> <b>Managed Lane Choice by Carpools Comprised of Family Members Compared to Non-Family Members</b> Mark Burris, Texas A & M University <b>Value of Reliability: High Occupancy Toll Lanes, General Purpose Lanes, and Arterials</b> Carlos Carrion-Madera, University of Minnesota <b>Quantifying Dynamic Tolling Impacts on Single Occupancy Vehicles' Usage of High Occupancy Toll Lanes: An Empirical Approach Based on Field Observations</b> Xiaoyue Liu, University of Washington <b>A Behavior-Based Simulation Tool for HOT Lane Operations</b> Di Wu, University of Florida	<i>Harrington 1</i>
		<b>Session 4B      Session Chair: Jeff Ban</b> <b>Theoretical Behavior of Mobility-Sharing Auction Mechanism Under Uncertainty</b> Yusuke Hara, University of Tokyo <b>Urban Delivery Industry Response to Cordon Pricing, Time-Distance Pricing, and Carrier-Receiver Policies</b> Jose Holguin-Veras, Rensselaer Polytechnic Institute <b>Cross-fertilisation Between Road Pricing and Pricing in Electricity Infrastructure Networks</b> Sterren Latsky, University of Bath <b>Why Congestion Tolling Could Be Good for the Consumer</b> Vincent van den Berg, VU University	<i>Harrington 2</i>
		<b>Session 4C      Session Chair: Siva Srinivasan</b> <b>How Transit and HOV Reduces Traffic Congestion</b> Rajashekar Reddy Dudipala, Osmania University <b>Not Only Seeing, But Also Knowing Who Is in the HOV</b> Paul Minett, Trip Convergence Ltd. <b>New York City's Dysfunctional Tolling Scheme</b> Sam Schwartz, Sam Schwartz Engineering <b>Effect of Off-Peak Toll Reduction</b> Toshinori Nemoto, Hitotsubashi University	<i>Jasmine Room</i>
10:10 a.m.	10:30 a.m.	<b>Coffee Break</b>	<i>Harrington Foyer</i>
10:30 a.m.	11:30 a.m.	<b>Plenary Session 3A      Session Chair: Robert Poole, Jr.</b> <b>Thinking about Equity in Transportation Pricing and Finance</b> Brian Taylor, UCLA Institute of Transportation Studies	<i>Harrington 1</i>
		<b>Plenary Session 3B      Session Chair: David Boyce</b> <b>Creating an Environmentally Sustainable, Financially Feasible, High Performance Metropolitan Transportation System</b> Patrick DeCorla-Souza, Federal Highway Administration	<i>Harrington 2</i>
11:30 a.m.	12:30 p.m.	<b>Lunch Break (provided)</b>	<i>Giraffe Lounge</i>

## Friday, May 14, 2010 (Continued)

Begin Time	End Time	Event	Location
12:30 p.m.	2:10 p.m.	<b>Session 5A</b> <b>Session Chair: Tao Yao</b> <b>Robust Optimization for Congestion Pricing Under User Equilibrium</b> <i>Byung Do Chung, Pennsylvania State University</i> <b>A Study on Expressway Toll Pricing under Travel Demand Uncertainty</b> <i>Sho-ichiro Nakayama, Kanazawa University</i> <b>Congestion Pricing under Travel Time Uncertainty: A Game Theory Perspective</b> <i>Peng Zhang, State University of New York at Buffalo</i>	<i>Harrington 1</i>
		<b>Session 5B</b> <b>Session Chair: Qian Wang</b> <b>Integrative Freight Demand Management in the New York City Metropolitan Area</b> <i>Matthew Brom, Rensselaer Polytechnic Institute</i> <b>Road Pricing and Freight Transportation Modeling: A Critical Review of Freight Modeling Approaches</b> <i>Kaveh Shabani, Portland State University</i> <b>Modeling the Behavior Responses of Freight Carriers Towards Time of Day Pricing in a Competitive Urban Freight Market</b> <i>Qian Wang, State University of New York at Buffalo</i>	<i>Harrington 2</i>
		<b>Session 5C</b> <b>Session Chair: Yingyan Lou</b> <b>Pareto-Efficient Build-Operate-Transfer Contracts and Regulations in Presence of User Heterogeneity</b> <i>Zhijia Tan, Hong Kong University of Science &amp; Technology</i> <b>Price and Investment Competition in an Oligopoly Market</b> <i>Feng Xiao, University of California at Davis</i> <b>Private Toll Road Financing and Regulation on a General Network</b> <i>Lei Zhang, University of Maryland</i> <b>Lessons Learned in Establishing Concession Level Public-Private-Partnerships on Brownfield U.S. Toll Roads</b> <i>Eric Magazu, University of Massachusetts at Amherst</i>	<i>Jasmine Room</i>
2:10 p.m.	2:30 p.m.	<b>Coffee Break</b>	Harrington Foyer
2:30 p.m.	4:10 p.m.	<b>Session 6A</b> <b>Session Chair: Yafeng Yin</b> <b>Dynamic Price Bidding Mechanism for Time Slots Allocation in Attended Home</b> <i>ChengChieh Chen, University of Maryland</i> <b>Pareto-Improving Congestion Pricing and Revenue Refunding with Elastic Demand</b> <i>Xiaolei Guo, University of Minnesota</i> <b>Proactive and Robust Dynamic Pricing Strategies for High-Occupancy/ Toll Lanes</b> <i>Dimitra Michalaka, University of Florida</i> <b>Variable Rate Structure for Efficient, Equitable, and Stable Mileage-Based User Fees</b> <i>Tra Vu, Polytechnic Institute of NYU</i>	<i>Harrington 1</i>
		<b>Session 6B</b> <b>Session Chair: Siva Srinivasan</b> <b>An Exploratory Analysis of the Value of Travel Time for Work Trips</b> <i>Ashish Kulshrestha, University of Florida</i> <b>The Evaluation of the Network Travel Time Reliability Benefits from the Road Charging Systems</b> <i>Fayyaz Qadir, University of Leeds</i> <b>Implications of Vehicle-Miles-of-Travel Methodologies for Traffic Impact and Calculation of Vehicle Mileage Systems</b> <i>Ruth Steiner, University of Florida</i>	<i>Harrington 2</i>

## Friday, May 14, 2010 (Continued)

Begin Time	End Time	Event	Location
		<b>Session 6C</b>	
		<b>Session Chair: Siriphong Lawphongpanich</b>	<i>Jasmine Room</i>
		<b>Effect of Congestion Pricing on Environment due to Traffic Congestion in Urban Area (A Case study)</b>	
		<i>Rajashekar Reddy Dudipala, Osmania University</i>	
		<b>It Pays to Do the Right Thing: Incentivizing Responsible Commuting</b>	
		<i>Deepak Merugu, Stanford University</i>	
		<b>User Fees for the Invisible User</b>	
		<i>Rick Rybeck, Just Economics, LLC</i>	

# Abstracts

## **Loops and the Existence of Equilibrium-Inducing Tolls**

R. A. Abrams; J. N. Hagstrom

*rabrams@uic.edu*

*University of Illinois at Chicago*

We investigate when tolls of various classes can be used to establish a given pattern of traffic flow. When considering congestion pricing methods to obtain a desired flow, a first question is whether there exist tolls such that the flow can be achieved as a Wardrop equilibrium. In this paper we establish necessary and sufficient conditions for a given feasible flow to be realizable as Wardrop equilibrium with tolls of various classes. We consider commodity-independent (standard) tolls, commodity-dependent tolls, and incentives (negative tolls). Our characterizations are in terms of the existence of loops in the desired flow. Our primary results are, assuming nonnegative link traversal costs, i) A given feasible flow can be realized as a Wardrop equilibrium flow using nonnegative commodity-independent tolls if and only if the flow is “loop-free” in the sense of (Gallager 1977). ii) Nonnegative commodity-specific tolls enlarge the set of flows which can be achieved as Wardrop equilibrium to include all those without a single-commodity loop. iii) If negative tolls (incentives) are allowed, any feasible flow may be realized as Wardrop equilibrium, even those containing loops, but in this case the cost of traveling around the loop must be zero in equilibrium and the given flow will not be a unique equilibrium flow. We also show how a set of tolls making a given flow an equilibrium can be adjusted to change the total revenue while maintaining the equilibrium.

## **A Study on the Public Acceptability of a Parking Deposit System (PDS)**

Akira Ando

*andoua@nikken.co.jp*

*Nikken Sekkei Researche Institute, Inc*

Road pricing (RP) is considered to be the most effective of the many TDM options available for reducing road traffic. This is corroborated by the experience of London, which actually introduced road pricing in February 2003. As RP’s introduction by very few cities (such as London and Stockholm) reflects, however, its poor social acceptability is a serious problem. In Edinburgh, Scotland, for example, which made an aborted attempt to introduce RP, a referendum on the introduction of congestion charges in February 2005 resulted in a vote against the scheme of 74.4%. While this is primarily due to RP’s strong association with penalization of car use, another important reason is concern about the decline of commercial activity in the charging zone. Similar concerns have been noted in many other cities. In London, for example, it is reported that many business owners are considering closing or moving outside the charging area. In their study of the impact of the introduction of RP in London on shoppers, Schmöcker et al. found from questionnaire data that there has been a clear decline in the frequency of shopping visits, indicating the need for new measures to reverse this trend.

The authors therefore propose a “parking deposit system”(PDS) as a road pricing scheme that is capable of reducing the decline of city centers and is also highly socially acceptable. PDS is based on the full or partial refund of the zone entry charge to drivers entering the charging area who shop or use parking facilities in the area, and is capable of reducing road traffic entering city centers while limiting the decline in city center visitors and fall in social acceptability.

The purpose of this study is to demonstrate empirically the effectiveness of PDS by forecasting attitudes to policy and changes in transport behavior using questionnaire data obtained from the general public and businesses premised on the introduction of PDS in the center of Nagoya, which experiences significant road traffic congestion.

The results of this study show the followings;

- a) The refund of PDS improves the acceptability of road user charging so that we can gain the higher acceptability than conventional road pricing.
- b) The amounts of changes on visitors to charged area according to PDS are less than conventional road pricing scheme.
- c) Financial balance of PDS governing body may be affected by refund of PDS to an extent.
- d) This study shows that applying PDS revenues to the discounts of public transportation fee is useful manner. But the revenues should be applied not only to the discount but also to developing the public transportation network.

Totally, we can safely say that PDS can be radically new and effective road pricing scheme.

### **Propitious Selection in the Vehicle Insurance Market**

Sara Arvidsson

*sara.arvidsson@vti.se*

*VTI (Swedish National Road and Transport Research Institute)*

By combining Contract Theory and vehicle positioning techniques, insurance companies can replace some of the proxies for risk by actual traffic behavior when pricing the premium. A mechanism design model is used to illustrate that Usage Based Insurance (UBI) can separate risks in terms of driving behavior. This makes it possible to reward safe driving habits since the pricing scheme better reflects the accident risk. The conclusion is that UBI provides an actuarially fair premium for the policyholder. It is further an efficient instrument to separate risks for the insurer since it reduces the information asymmetries highlighted in this paper.

### **Determinants of Customer Loyalty in Automobile Insurance: The Role of Private Information on Traffic Safety Violations**

Sara Arvidsson

*sara.arvidsson@vti.se*

*VTI (Swedish National Road and Transport Research Institute)*

In this paper we empirically investigate the effect of the policyholders' private information about traffic safety violations on the choice to leave the insurer after one period respective being a loyal customer. To test this we estimate two probit models of loyalty and departure respectively. We use data of approximately 1.5 million policyholders combined with information of on-the-spot-fines and convictions for traffic safety violations. The majority of contracts are repeated and when including those we have about 9.3 million contracts. Private information and previous claims where the policyholder was to blame increase the probability of leaving the insurer after one period. Similarly, private information and at fault claims decreases the probability of being a loyal customer. These results indicate that switching policyholders are disproportionately high risks that constitute an adverse selection, while loyal customers constitute a propitious (favorable) selection. Our conclusion is that the insurer would benefit from accessing information of traffic safety violations since it provide a strong signal of risky behavior. With access to this information the premium pricing could improve.

## **Evaluating Technology and Administrative Tradeoffs in Vehicle Mileage Fee System Development**

Richard Baker

*r-baker@ttimail.tamu.edu*

*Texas Transportation Institute*

There is a growing concern in the transportation industry that the fuel tax is an unsustainable source of revenue in the long term for the funding of state and national roadway programs. The fact that these taxes are mostly assessed on the gallon purchased, as opposed to the purchase price, means that they lose significant purchasing power over time, and in many cases these taxes have not been raised in over 15 years. The ever increasing fuel efficiency of the US auto fleet has resulted in a general trend of highway use outpacing fuel consumption, exacerbating gaps between highway enhancement needs and highway investment. Furthermore, the continued development of vehicles that operate independent of fossil fuels could result in a significant portion of the future US auto fleet falling wholly outside of the traditional fuel tax collection system. One of the leading alternatives to the fuel tax that is currently being studied is the vehicle mileage (VM) fee; also called vehicle miles travelled (VMT) fees, mileage fees, and road user charges. Levied on a vehicle by vehicle basis be per-mile fee of travel, these fees could theoretically vary based on a wide array of factors such as vehicle type, road type and time of day. They have been tested in Oregon, the Puget Sound Region of Washington State, and a national evaluation is currently underway by the University of Iowa. One of the issues that these tests have had to address is the various tradeoffs inherent in a system that is as technologically dependent as VM fees require. For example, reducing the amount of travel information collected by the system increases driver privacy but reduces the ability of the driver to audit their travel and contest any errors in assessment. And while phasing in such a system slowly and on a voluntary basis while offering incentives to participate may be more acceptable to the public and face less resistance than an immediate and mandatory phase in, it also reduces the ability to apply various differential pricing elements such as congestion pricing. Most elements of a VM fee system will require the assessment of various tradeoffs in terms of what technology is used and how the system is administered. This presentation will present a logical framework that allows the user to prioritize the various policies that can be pursued through VM fee implementation and then evaluate tradeoffs in terms of technology and administration that would be required to meet those goals.

## **Social Welfare Justification for Market-Based Approaches for Airport Congestion Management**

Michael O. Ball; Prem Swaroop; Mark Hansen

*mball@rhsmith.umd.edu*

*Robert H Smith School of Business & Institute for Systems Research, University of Maryland; University of California, Berkeley*

Over the past four years there have been several airport congestion management initiatives undertaken by the Federal Government in the US. These have principally been aimed at the large airports in the New York region: LaGuardia Airport (LGA), Kennedy Airport (JFK) and Newark Liberty International Airport (EWR). These initiatives sought to control congestion and, at the same time, free up capacity so as to allow access to new and emerging air carriers. Among other features, these initiatives included the provision to auction a portion of the airport slots. While rulemakings were instituted, their implementation was eventually blocked by legal actions of various constituencies. Over the past few years, we have provided research to support government decision-making regarding the various rulemakings. Using these activities to provide background and motivation, we examine fundamental questions underlying the need for airport congestion management. Specifically, we model a fundamental tradeoff arising when setting the level of operations at an airport. As airport operations increase and approach airport capacity, the ex-post delays against schedule passengers experience increase. On the other hand, as operations are restricted, airlines reduce their service frequency in city-pair markets leaving passengers with fewer options and an increase in the ex-ante schedule delay. Using historical data and models we estimate the

marginal cost of these two effects and argue that many US airports today have operational levels set at much larger operational levels than the social optimal. We further investigate other implications of airport congestions management and the alternative mechanisms that might be used to achieve restrictions on the level of operations at an airport. These lead to an analysis of the tradeoffs between administrative and market mechanisms, including auctions.

### **Optimal Mileage Fee Charges – A Network Perspective**

Jeff Ban; Rui Ma

*banx@rpi.edu*

*Rensselaer Polytechnic Institute*

To address transportation financing issues, the concept of mileage fee - charges based on the distance and locations a vehicle has traveled - has been emerged and tested in several states of the US as an alternative way for gas taxes. This is particularly proposed in response to the recent rapid development of hybrid electric vehicles (HEV): the wide deployment of HEV may diminish the basic transportation revenue sources based on gas taxes developed more than half century ago.

In this research, we will study the problem of determining optimal mileage fees in a traffic network. The focus is how driver's responses to the charges, modeled as user equilibrium, may impact the optimal charging scheme under various scenarios. While drivers focus more on their travel costs and the total fees they need to pay, the system manager (like DOTs) may need to consider different objectives when designing the optimal fee scheme. Several objectives will be modeled in this study including the total system travel time (i.e. to minimize the congestion), the total system emissions, the total revenue, and a combination of them. Correspondingly, how to properly set the model constraints will also be discussed. The results will show the tradeoffs among different objectives and the resulting optimal fee schemes.

The proposed model will be formulated as a bilevel problem to capture the decision makings of both the drivers and the system manger. The model will be tested in small yet illustrative networks to show the main research findings. The purpose of this talk is to show the challenge of determining optimal mileage fee charges in a traffic network, which can hopefully motivate more discussions in this topic among transportation researchers, practitioners, and decision makers.

### **Integrative Freight Demand Management in the New York City Metropolitan Area**

Matthew A. Brom; José Holguín-Veras

*bromm@rpi.edu*

*Rensselaer Polytechnic Institute*

This paper describes a USDOT funded project investigating policies intended to encourage an increase in off-hour deliveries (7PM to 6AM) in New York City. The method investigated provides receivers and/or carriers an incentive(s) in exchange for changing delivery times. This is a shift from the previous approach of charging carriers higher tolls during the regular hours (6AM to 7PM). Using data from stated preference surveys and ZIP code business pattern data obtained from the U.S. Census Bureau, the authors found that the most effective policy would be to provide the receivers with a financial incentive (e.g. tax deduction). The results indicate that receivers in the food and retail sectors would be good targets of such policies due to the large number of deliveries in each of the sectors and their willingness to shift deliveries to the off-hours in exchange for a financial incentive. Results of the pilot test evaluating the feasibility and benefits of such a policy are presented.

## **Mode Choice due to HOV to HOT Conversions**

Mark Burriss

*mburriss@tamu.edu*

*Texas A & M University*

This paper examines the nine high-occupancy/toll (HOT) lanes around the country for a variety of issues relating to their usage. This research focuses on how travelers reacted to the new option of paid access to the HOT lanes. Factors examined for potential impact of HOT lane usage were grouped into three categories: (a) HOT lane characteristics (such as travel time savings, travel time reliability, and geometric design), (b) traveler characteristics (such as income, gender, age), and (c) alternative characteristics (such as transit, parallel facilities). One of the key issues examined was mode shift due to the HOT lanes. It was found that, in general, the vast majority of low-occupancy vehicles (LOVs)—paying customers—on HOT lanes were former single-occupant vehicles (SOVs) from the general purpose lanes (GPLs). There are similarities in the demographic characteristics of more likely/ frequent users of HOT lanes. They were most often well educated, between 35 and 54 years old, with high incomes. However, many surveys of paying HOT lane customers show that people of all ages, income levels, and educational backgrounds use the lanes. Little is known about the impact of geometric design on the use of the HOT lanes—although many travelers did feel the design was adequate and felt safe in the lane. Overall, no safety concerns in the use of HOT lanes were found; in fact, safety of these lanes was a positive influence on the use of the lanes.

## **Managed Lane Choices by Carpools Comprised of Family Members Compared to Non-Family Members**

Mark Burriss

*mburriss@tamu.edu*

*Texas A & M University*

Carpools can be comprised of family members (fam-pools), non-family members (non-fam-pools) or a combination of both. Overall, carpool mode share has decreased during the 1980's and 1990's, even as the policies were in place to encourage carpooling, but at the same time the share of fam-pools increased quite significantly. By analyzing the characteristics of fam-pools and non-fam-pools, we can better understand how policies may impact each group. One area of particular interest is the impact of managed lanes on the mode choice of fam-pools and non-fam-pools.

For this research, survey data collected from both Houston and Dallas, Texas was used to investigate the mode choice of fam-pools and non-fam-pools on managed lanes. Non-fam-pools were formed more frequently in a week than fam-pools. The average carpool formation time was similar for both fam-pools and non-fam-pools at 6.4 minutes and 6.2 minutes, respectively. Fam-pools rated “drop off kids at school or day care” higher than non-fam-pools and non-fam-pools rated “sharing vehicle expenses” higher than fam-pools as the most important reason for the formation of their current carpool. A majority of travelers from both groups showed an interest in using managed lanes and “travel time reliability” was rated most important factor for this interest.

Random parameter logit models were developed for both fam-pools and non-fam-pools. For the fam-pools, the value of travel time savings was estimated to be \$ 22.80 per hour. Non-fam-pools were not sensitive to the travel time. Different travel scenarios were simulated for both fam-pools and non-fam-pools. The results showed that with increased tolls on the managed lanes the decrease in carpool mode share on managed lanes was compensated by an increase in carpool mode share on the GPLs for both fam-pools and non-fam-pools.

## **Value of Reliability: High Occupancy Toll Lanes, General Purpose Lanes, and Arterials**

Carlos Carrion-Madera; David Levinson

*carri149@umn.edu*

*University of Minnesota*

In the Twin Cities, the Minnesota Department of Transportation (MnDOT) converted the Interstate 394 High Occupancy Vehicle (HOV) lanes to High Occupancy Toll (HOT) lanes (or MnPASS Express Lanes). These lanes allow single occupancy vehicles (SOV) to access the HOV lanes by paying a fee. This fee is adjusted according to a dynamic pricing system that varies with the current demand. In this paper, the authors study the value placed by the travelers on the HOT lanes because of improvements in travel time reliability. This value depends on how the travelers regard a route with predictable travel times (or small travel time variability) in comparison to another with unpredictable travel times (or high travel time variability). For this purpose, commuters are recruited and equipped with Global Positioning System (GPS) devices and instructed to travel on each of three plausible alternatives for their particular commute (from the western suburbs of Minneapolis eastbound to downtown or the University of Minnesota): I-394 High-Occupancy Toll lanes (HOT), I-394 General Purpose lanes (untolled), and signalized arterials close to the I-394 corridor, for two weeks of commuting. They are then given the opportunity to travel on their preferred route after experiencing each alternative. This revealed preference data is then analyzed using route choice models (econometrics models) based on Random Utility Theory. These models are operationalized by two-level nested logit methods. In addition, three measures of reliability are explored and incorporated in the estimation of the models. These travel time measures are: standard deviation (a classical measure in the research literature); shortened right range (typically found in departure time choice models); and interquartile range (75th - 25th percentile). Each of these measures represents distinct ways about how travelers deal with different sections of reliability. In all the models, it was found that reliability was valued highly, but differently according to how it was defined. The estimated value of reliability in each of the models indicates that commuters are willing to pay a fee for a reliable route depending on how they value their reliability savings (earliness vs. lateness).

Keywords: time reliability, GPS, route choice, random utility, I-394 HOT, MnPass.

## **Dynamic Price Bidding Mechanism for Time Slots Allocation in Attended Home Delivery Service**

ChengChieh Chen

*frank542@umd.edu*

*University of Maryland*

Offering customers the choice of delivery time slots is an emerging business strategy in attended home delivery service. It is intended to provide higher service level and reduce the risk of delivery failure. The study proposes a dynamic price bidding mechanism (DPBM) which accommodates a flexible and behaviorally-realistic decision rule so that certain customers' desirable delivery requests can be transferred to the suppliers' preferable time slots. A bi-level optimization model is developed, where a vehicle routing problem with time window constraint is solved at the lower level while the time slots allowed for bidding and corresponding bidding prices are determined to maximize the total revenue at the upper level. Numerical tests are performed to evaluate the potential benefit of the DPBM.

## **Robust Optimization for Congestion Pricing Under User Equilibrium**

Byung Do Chung; Tao Yao; Terry L. Friesz

*buc139@psu.edu*

*Pennsylvania State University*

Congestion pricing has been regarded as an efficient method to manage travel demand by affecting travel behavior to minimize social cost or maximize a private firm's revenue. Typically, congestion pricing models assume that demand is known in advance and deterministic values of demand are used in solving for optimal tolls. However, system performance can be negatively impacted when deterministic demands are employed, especially when demands depart significantly from their expected nominal values (Waller et al. (2001) and Gardner et al. (2008)). Also, precise travel demands are virtually impossible to obtain, due to specification errors and imperfect data that plague real-world forecasting. Accordingly, in this paper, we consider robust congestion pricing problems in the presence of transportation demand uncertainty.

The main focus of this research is the formulation and solution of robust congestion pricing problems in which only a subset of the links in a transportation network can be tolled. We propose to apply a robust optimization (RO) approach to user equilibrium optimal toll problems under demand uncertainty. Differently from traditional stochastic programming (Gardner et al. (2008) and Nagae and Akamatsu (2006)), we will not assume the availability of a probability distribution for the underlying uncertain data. Moreover, the RO approach guarantees feasibility through the use of prescribed uncertainty sets and can be made computationally tractable through an appropriate reformulation (Ben-Tal and Nemirovski (1999) and Ben-Tal et al. (2004)). Recently, Lou et al. (2010) applied the notion of RO and studied robust congestion pricing to minimize total system travel time among all possible boundedly rational user equilibrium distribution.

In this research, we begin with a robust static user equilibrium optimal toll problem. Next, we will explore the robust optimization of a dynamic optimal toll problem with equilibrium constraints (DOTPEC) (Friesz et al. 2007). Finally, we will conduct numerical experiments and qualitative analysis to investigate tractability of robust counterpart problems and to evaluate the robust solutions obtained from them.

## **Efficient Vehicle Assessment: Combining Non-Transportation Functions with Variable Fuel Tax Criteria to Make Alternative Gas Tax a Reality**

Kevin J. Condon

*kcondon@corecomputergroup.com*

*Core Computer Group*

This presentation explores using a variable-agnostic variable tax platform beyond the capture of a mileage taxes to create political and public support for VMT and other variable gas taxes. As the crisis in transportation funding accelerates, the case for an alternative fuel tax system is urgent but the path to political adoption is by no means certain. It is crucial to make the case as compelling as possible to overcome the strong political hesitation to tackle large matters involving taxes.

One approach to creating the most attractive case for moving to the necessary alternative tax system, called Efficient Vehicle Assessment (EVA), provides a wide variety of features that move well beyond traditional transportation funding and therefore generating new and proactive allies to make adoption much more likely. The presentation comprises two main areas:

- **Practical Principles to Building Support:** (Approximately 25% of session) While the subject of alternative gas tax approaches is relatively recent, the general rules of the political arena are not. In today's highly charged partisan atmosphere, however, one rule is more important than ever – get it right the first time. Today, the internet is a tool for instant partisan mobilization at the grass roots level. The presentation will look at some of the basic elements of strategy for building sufficient support and momentum for an alternative gas tax approach

- Beyond the Mileage Tax: (Approximately 75% of session) An EVA approach to a new tax system leverages functions to achieve policy goals that go well beyond the fundamental function of VMT. These can be grouped into a few categories that include
  - o More choices of criteria for a variable gas tax
  - o Methods to play a more central role in achieving national goals in addition to transportation revenues, therefore enlisting strong allies from outside the traditional transportation constituencies.

Achieving the goal of a new transportation funding mechanism is necessary. This session presents how to make achieving that goal more likely and less contentious.

### **Congestion Pricing Triggers on Toll Roads**

Michael Copeland

*mcopeland@wilbursmith.com*

*Wilbur Smith Associates*

Increasing congestion is one of the most important challenges facing transportation professionals across the nation. According to a recent Texas Transportation Institute (TTI) report 63 percent of peak-period vehicle miles traveled (VMT) in 2007 were undertaken during congested hours compared to 29 percent of peak-period VMT in 1982(1). According to the same report, congested time increased from 4.2 hours in 1982 to 7.0 hours in 2007. Congestion is expected to worsen. Chicago's travel time index, which is a ratio of peak and off-peak travel times, is expected to increase to 1.88 in 2030 from 1.56 in 2006 while Dallas Fort/Worth's travel time index is expected to increase to 1.73 in 2030 from 1.36 in 2006(2).

Increasing road capacity by adding lanes is one of the solutions to the challenge of meeting increasing road demand. However, it suffers from the problem of "triple convergence"(3). Relatively low price related to the usage of expensive new capacity encourages more users to drive the expanded roadway. Congestion pricing is one of the tools available to address triple convergence. Congestion pricing works by eliminating low-valued trips or shifting some peak hour travel to off-peak periods, alternative routes or other transportation modes. In addition, a region designated as non-attainment area for ozone must ensure any proposed single occupancy vehicle capacity additions are compatible with the region's air quality goals. Congestion pricing is one of the strategies that can also help with meeting air quality goals. However, timing of the implementation of congestion pricing needs to be carefully analyzed. Triggers need to be established for congestion pricing during early stages of operation of the roadway to gain the full benefits of congestion pricing (e.g. public acceptance, maintenance of desired level of service, opportunities for pilot studies and scenario testing). The triggers can be set based on the selected performance measures such as average speed, traffic throughput, etc.

Wilbur Smith Associates' (WSA) toll diversion models are useful for deriving appropriate triggers for consideration of variable pricing implementation on traditional toll roads based on selected performance measures. For example, by using level of service (LOS) as a performance measure, a preliminary congestion pricing regime (PCPR) can be triggered at LOS D and an aggressive congestion pricing regime (ACPR) can be triggered at LOS E on a given length of the roadway for selected periods of time during a typical day. For the selected performance measure, various pricing schemes under PCPR and ACPR will be tested to determine the impacts on traffic and the performance measure. In addition, triggers for lane expansion will also be determined under a selected pricing and performance measure combination.

This analysis can help toll agencies develop plans to better manage congestion on their existing facilities and to plan for future lane expansions.

## **PLENARY PRESENTATION**

### **Creating an Environmentally Sustainable, Financially Feasible, High Performance Metropolitan Transportation System**

Patrick DeCorla-Souza, AICP

*patrick.decorla-souza@dot.gov*

*Federal Highway Administration*

Metropolitan areas are facing increasing congestion but financial resources to provide new or expanded transportation infrastructure will be limited in the future. Also, environmental constraints will inhibit widening of the highway footprint. This paper presents a new approach to address metropolitan mobility and access issues in a way that provides an environmentally sustainable and financially feasible solution to congestion.

The concept presented seeks to reduce costs for expanding transportation capacity and provide a new revenue source to pay for that capacity expansion, while at the same time ensuring that the highway system maintains a high level of performance throughout the day.

The strategy seeks to eliminate recurring congestion on metropolitan highway systems by adding “dynamic” capacity using shoulders as travel lanes along with variable peak-period user charges. The concept, termed “Flexible, Efficient, Express” or FEE highways, builds on emerging strategies now being explored by the transportation community as possible options for providing new highway capacity without the need for new rights-of-way or major reconstruction. The idea is being proposed to engender discussion and further exploration through collaboration among the transportation planning, finance, safety, and operations communities to find workable strategies to advance sustainable mobility and access strategies in the United States.

The paper presents an analysis of the impacts on traffic, delay, fuel consumption, CO2 emissions, revenue, social benefits and costs. It compares the impacts of “full” pricing of all highway lanes (FEE highways) with “partial” pricing involving pricing only some lanes (FEE lanes). It then responds to various technical and public acceptance issues with regard to the concept, showing how these issues might be addressed.

### **Innovations in Pricing from Around the World - Reducing Congestion and Funding Transportation Using Road Pricing**

John Q. Doan; Patrick DeCorla-Souza

*jdoan@sriconsulting.com; patrick.decorla-souza@dot.gov*

*SRF Consulting Group, Inc.; Federal Highway Administration*

Broad application of road pricing in the U.S. has been limited due to political, technical, and institutional issues. However, variable charges have been used successfully by many U.S. industries, including hospitality, air travel, utilities, and telecommunications. In addition, road pricing has been instituted on a broader basis in other countries, notably Singapore, Germany, the UK, and Sweden, and to a limited degree in the U.S. through the implementation of High Occupancy Toll (HOT) lanes. The application of road pricing has been employed to reduce congestion, which has positive environmental effects, and to generate new revenues for transportation.

Both the U.S. Department of Transportation (USDOT) and the American Association of State Highway Transportation Officials (AASHTO) have made the issue of economic and environmental sustainability and community livability top priorities. Road pricing can help achieve these goals as well as play a vital role in creating a sustainable funding source for transportation and as a strategy for reducing congestion and emissions.

Over a period of 16 days in December 2009, a team comprised of representatives from the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA); the Georgia, Minnesota, Virginia, and Washington State Departments of Transportation; the Port Authority of New York and New Jersey; and SRF Consulting visited with representatives from Sweden, the UK, Singapore, Germany, the Czech Republic, and the Netherlands. The purpose of the scan was to identify new ideas and practical, workable models for integrating road pricing approaches into state, local, and regional policies, programs, and practices. The findings are intended to inform the U.S. road pricing research agenda and identify best practices from international experience that will assist U.S. practitioners.

Based on information collected and observations made during the scan, the scan team arrived at the following 11 preliminary major findings:

1. Many European Union (EU) countries and Singapore are far ahead of the U.S. in broad-scale road pricing implementation, business practices, and technology deployment.
2. Countries and regions with clearly defined and well understood policy goals had the most effective road pricing programs and comprehensive program plans.
3. Political and executive champions are essential for initial implementation. Consistency of leadership provides for a more sustainable and effective road pricing program.
4. Clear, salient, and timely messages about the purpose and benefits of pricing help to educate key stakeholders and garner public acceptance; thus thorough planning and public involvement are essential.
5. Linking the price-setting mechanism to the benefits received provides a clear connection to why road pricing is being pursued.
6. Coupling transit with road pricing provides a more balanced, comprehensive, and multi-modal approach.
7. Equity and privacy concerns are addressed through exemptions, revenue use, technology, and business rules.
8. Interoperability amongst states and countries needs to be addressed at a higher level.
9. Open-source technologies have long-term advantages.
10. Intergovernmental coordination and sharing of vehicle registry information between public agencies is key for operations and enforcement.
11. A demonstration project is a powerful tool for public acceptance and enables the public to experience the benefits of road pricing.

## **PLENARY PRESENTATION**

### **The Theory and Art of Dynamic Congestion Pricing**

Terry L. Friesz

*tlf13@psu.edu*

*The Pennsylvania State University*

In this talk we review notions of first best and second best dynamic congestion pricing in an informal way, including a discussion of why both problems are important to present and future efforts to control road traffic congestion. This review will include a discussion of the dynamic traffic assignment problem that is intrinsic to dynamic congestion pricing. Following our informal review, we discuss how mathematical models of first and second best dynamic congestion pricing problems may be formulated and the challenges posed by their numerical solution. We present a list of algorithms that have been or could be employed to determine dynamic congestion prices. We close by outlining the R&D activities necessary to create and implement software for dynamic congestion pricing

## **A Kilometre-Based Rewards System to Encourage Safer Driving Practices**

Stephen Greaves

*s.greaves@itls.usyd.edu.au*

*University of Sydney*

There is growing interest in using kilometre-based financial mechanisms to encourage safer driving practices and reduce accident claims (Litman, 2008; Zantema et al. 2008). The rationale is that in addition to driver characteristics such as age and gender, risk is intrinsically a function of both the kilometres driven and the circumstances under which those kilometres are driven (time-of-day, day-of-week, road type, speeding etc). Within this context, the current paper details the development of a kilometre-based rewards system designed to encourage safer driving practices and reduce the risk of crash involvement. The emphasis on rewarding desirable behaviour versus the traditional approach of punishing undesirable behaviour is deliberate and rooted in psychological theory showing this to be generally a more effective means of influencing behaviour (Mazureck and Van Hatten, 2006). Responses to the scheme are evaluated through a 12-week field study of 140 motorists in Sydney, which is currently in the field and due for completion by the end of 2009. Motorists are monitored using Global Positioning System (GPS) technology for a six week period to build up a detailed profile of their regular driving routines and patterns. This information is used to set a 'budget' for each motorist based on their kilometres driven, night-time driving and speeding. Motorists are then informed they can make money based on the reduction in these measures relative to the before period and monitored for a further six weeks. At the end of the 12 weeks, they receive a financial reward based on the observed changes. The paper will present details of the study and preliminary results, specifically on the extent to which such pricing mechanisms are found to impact the key measures of VKT, night-time driving and speeding.

## **Applying Behavioral Economics Concepts in Designing Usage-Based Car Insurance Products**

Allen Greenberg

*Allen.Greenberg@dot.gov*

*U.S. Department of Transportation/FHWA*

Behavioral economics, a discipline combining economics and psychology to explain consumer decision making, offers insights on how best to institute transportation pricing in a manner that is acceptable to drivers and also meets public policy objectives. As an example of how to use this relatively new discipline to enhance the acceptance and benefits of transportation pricing, its application to designing usage-based or pay-as-you-drive-and-you-save (PAYDAYS) insurance products is explored.

Specifically, this research would apply lessons from behavioral economics to the marketing and designing of PAYDAYS insurance products to maximize profitability, consumer acceptance, and public benefits. By converting fixed insurance costs to per-mile or per-minute-of-driving charges, PAYDAYS insurance encourages voluntary reductions in driving and related decreases in congestion, air pollution, and crashes, and for these reasons has garnered substantial interest among government entities, environmental and other non-profit organizations, insurance companies, and consumers. General behavioral economics research findings strongly suggest substantial but rarely acknowledged differences in vehicle-miles traveled would result depending upon which PAYDAYS insurance product features, from a large variety of possibilities, are chosen.

Behavioral economics demonstrates that how economic choices are framed for consumers affects the choices they make. The pricing levels and structure of different usage-based pricing plans affect initial purchasing decisions, customer retention, and usage. After summarizing the PAYDAYS insurance pricing schemes being tested in the U.S. marketplace, this paper examines the broadest array of existing and potential PAYDAYS insurance pricing attributes and their effects, at least directionally, on attracting and retaining customers and discouraging driving. Summary tables at the end identify target markets, product structure, and pricing and related attributes that would maximize participation and mileage reduc-

tions among participants. A pilot experiment design is proposed to increase understanding about the application of behavioral economics to PAYDAYS insurance. Public policy options to encourage PAYDAYS insurance generally, and the product attributes that lead to the best outcomes specifically (e.g., the greatest congestion and crash reductions), are discussed.

### **The Option of Pricing Road with C-means Clustering Algorithm Based on Interval Fuzzy Numbers**

Sun Guanglin; WANG Jian

*mumulinhit@126.com*

*Harbin Institute of Technology*

The option of pricing road is observably influential on the results of road-based congestion charging. This paper takes c-means clustering algorithm based on interval fuzzy numbers to classify pathes on transport network, and gain the optimum number of categories as the results of classification. Calculating the social welfare of each category of toll road respectively to identify a set of pricing roads, and comparing the welfare of congestion charging to determin charging road set. Finally, we take a numerical example to show the validity of this method.

Keywords: pricing road option; interval fuzzy numbers; c-means clustering algorithm

### **Pareto-Improving Congestion Pricing and Revenue Refunding with Elastic Demand**

Xiaolei Guo; Hai Yang

*guoxl@umn.edu*

*The Hong Kong University of Science and Technology; University of Minnesota, Twin Cities*

This study investigates Pareto-improving congestion pricing and revenue refunding schemes in a general network with elastic trip demand. We propose a Pareto-improving refunding scheme under certain ideal conditions by rebating toll revenue to all travelers in proportion to their pre-toll trip consumptions. Specifically, the amount of refund to each traveler per pre-toll trip should be equal to the equilibrium travel disutility increase due to congestion charge. We also establish an average-improving refunding scheme under realistic conditions by rebating toll revenue as an equal lump-sum payment to all registered drivers or qualifying travelers. In addition to trying to make every traveler better off, the proposed refunding scheme preserves the trip demand level realized under pricing as if there is no refund and thus keeps the original role of pricing intact for congestion relief. Under certain technical conditions, it is proved that the proposed Pareto-improving refunding scheme does not use up the total toll revenue. The resulting revenue reserve after refunding consists of two parts that accrue from two different effects of congestion pricing: depression of auto trip consumption to optimize demand level, and driver rerouting to rationalize route usage.

### **Theoretical Behavior of Mobility-Sharing Auction Mechanism Under Uncertainty**

Yusuke Hara; Eiji Hato

*hara@bin.t.u-tokyo.ac.jp*

*University of Tokyo, Japan*

Recently, by the development of information technology such as IC smart cards and mobile phones, there is the combination of price system and new technology. Until now, the fee of transportation system is static and it can't correspond to the sequential changes of the demand and supply. However, information technology can make personal identification, vehicle management and demand management connected. And we can implement a new transport price system by the development of technology. The prime example is auction system as a dynamic price mechanism. The auction is an older method of price determination, but it has been popular at the individual level such as consumers and users since internet auction like e-bay was born. Internet auctions enabled individual to participate in the market more easily as well as enabled the market price to be reflected by the willing to pay of a diversity of people.

On the other hand, the fee of transportation system is still much to be a fixed rate. As a particular case, there is a peak road pricing but it is reflected by not the relation of demand and supply but empirical peak time. However, new transport price policy has been proposed in these days. Tradable bottleneck permit system by Akamatsu (2007) is the trade system of access right of traffic bottleneck and its double auction system achieves the efficiency and fairness of the market in the capacity constrained situation. Vehicle quota system in Singapore (see Chu, 2002, Koh, 2003, Chu et al., 2004) is part of a series of measures to optimize traffic flow by managing the growth of vehicle ownership to acceptable levels. In order to register a new vehicle, the would-be-buyer must bid for and obtain a license, referred to officially as a Certificate of Entitlement (COE). The COEs can be obtained through an auction, the COE electronic Open Bidding System, which is held twice a month.

Mobility sharing exists as to encourage this trend. New IT technologies are beginning to implement new car-sharing system and bike sharing system globally. You remind that sharing system has supply constraints necessarily. As we all know, sharing systems which have explicit supply constraints have good chemistry with auction system. Hara and Hato (2010) implemented the joint of bicycle sharing system and auction system as a pilot program in Japan.

The purpose of this paper is to conduct a theoretical study about the effects of schedule in future decision making under uncertainty and bias of transaction cost itself on participating auction and price determination.

## **PLENARY PRESENTATION**

### **Road Pricing: An Economic Approach**

Timothy D. Hau

*timhau@hku.hk*

*University of Hong Kong*

If economists agree that road pricing would benefit society by reducing congestion, why is it that road pricing inevitably fails on political grounds? An economic justification based on efficiency analysis is offered here using first principles. The aim is to demonstrate that road pricing makes travelers worse off on average except the government. The lesson is that road users must be compensated or else they will rationally vote against road pricing. A policy implication is that unless road price is viewed (and sold) as a road user fee - as opposed to a tax - road pricing is doomed to political failure.

In order to get road pricing to fly so as to curtail congestion and pollution, a policy to compensate road users in an indirect manner so as not to distort incentives should be pursued, for instance, by: i) lowering fuel taxes, first registration taxes, annual license fees, etc. - if they are already high; ii) constructing and improving the road system for the tolled, and/or iii) improving the public transport system for those who are tolled off and the tolled on. In this way, travelers would perceive that they would not be made worse off and would be more inclined to support road pricing.

Lessons from Hong Kong's electronic road pricing experiment in 1983-85, the feasibility study on electronic road pricing in 2001 and the Council for Sustainable Development's Report on the Better Air Quality Engagement Process, 2008, support the hypothesis put forth here.

## **PLENARY PRESENTATION**

### **The Toll Set Approach to Congestion Pricing: A Tutorial**

Donald W. Hearn

*hearn@ise.ufl.edu*

*University of Florida*

In this tutorial we will review the toll set approach to congestion pricing which extends the concept of marginal social cost pricing to identifying the set of all tolls that will cause user-equilibrium flows to utilize the system resources most effectively. Included are first and second best congestion pricing models for both fixed and elastic demand traffic assignment models and the combined distribution-assignment model. Secondary objectives include minimizing system toll revenue (MINREV), minimizing maximum tolls (MINMAX) and minimizing the number of required toll booths (MINTB), all of which are modeled as optimization problems. Theoretical and computational results from the literature will be summarized and numerical issues addressed.

### **Congestion Pricing Applications to Manage High Temporal Demand for Public Services and Their Relevance to Air Space Management**

Karla Hoffman; Frank Berardino; George Hunter

*khoffman@gmu.edu*

*George Mason University; GRA, Inc.; Sensis Corporation*

This paper surveys pricing mechanisms used by government agencies to manage congestion, as well as highlight the many political and social issues that had to be addressed in order to implement the pricing mechanism. This survey was undertaken in order to be able to understand how congestion pricing could be used to help manage airspace capacity. This is an important question since a 2008 analysis by the Joint Economic Committee of the U.S. Congress suggested that domestic air traffic delays in 2007 cost the economy as much as \$41 billion, including \$19 billion in increased operational costs for the airlines and \$12 billion worth of lost time for passengers.

The paper begins by surveying roadway congestion approaches throughout the world. We survey the successes of peak pricing charges have had on reducing such congestion delays and report the other benefits that such practices have had: improving the public transportation network, improving the economy of the region, reducing carbon emission and creating new urban living spaces. We next examine other applications of congestion pricing including managing demand for canal and bridges passage, port usage, access to city centers, and peak use of energy resources.

The paper ends with a proposal for a two-staged approach to the management of air space and runway congestion. The first stage imposes a service standard on runway access that is consistent with an airport's capacity during good weather days. Then, when weather reduces capacity either in the airspace or on runways, we propose a congestion pricing mechanism that charges flights based on the amount of congestion the flight imposes on the entire system.

### **Urban Delivery Industry Response to Cordon Pricing, Time-distance Pricing, and Carrier-Receiver Policies**

José Holguín-Veras

*jhv@rpi.edu*

*Rensselaer Polytechnic Institute*

The presentation discusses the economic foundations of congestion pricing, its potential use for freight demand management, and the associated limitations. The paper on which the presentation is based develops a set of analytical formulations to study the behavior of the urban delivery industry in response to

cordon time-of-day pricing, time-distance pricing, and comprehensive financial policies targeting carriers and receivers. This is accomplished by modeling the behavior of receivers in response to financial incentives, and the ensuing behavior of the carrier in response to both pricing and the receiver decisions concerning off-hour deliveries. The analytical formulations consider both the base case condition, and a mixed operation with both regular hour and off-hour deliveries; two pricing schemes: cordon time of day, and time-distance pricing; two types of operations: single tour, and multi-tour carriers; and three different scenarios in terms of profitability of the carrier operation, which include an approximation to the best case, the expected value, and the worst case. The analyses, both theoretical and numerical, highlight the limitations of pricing-only approaches. In the case of cordon time of day pricing, the chief conclusion is that it is of limited use as a freight demand management tool because: (1) in a competitive market the cordon toll cannot be transferred to the receivers as it is part of the fixed costs; and (2) the structure of the cost function, that does not provide any incentive to the carrier to switch to the off-hours. The analyses of time-distance pricing clearly indicate that, though its tolls could be transferred to the receivers and provide an incentive for behavior change, the magnitude of the expected toll transfers under real life conditions are too small to have any meaningful impact on receivers choice of delivery times. In essence, the key policy implication is that in order to change the joint behavior of carrier and receivers, financial incentives should be provided to receivers in exchange for their commitment to do off-hour deliveries. As the paper proves, if a meaningful number of receivers switch to the off-hours, the carriers are likely to follow suit.

This paper was selected for presentation at the plenary session of International Transportation Economics Conference in Minneapolis, Minnesota 2009

### **On the Role of the Link Performance Function on Multi-Class Optimal Tolls**

José Holguín-Veras

*jhv@rpi.edu*

*Rensselaer Polytechnic Institute*

The author's previous research on optimal tolls for multi-class traffic (Holguín-Veras et al., 2006; Holguín-Veras and Cetin, 2008) has highlighted what seems to be a pattern of overcharging trucks, and undercharging passenger car traffic, when setting tolls. The evidence on this regard is rather strong as it includes an empirical analysis of toll policy (Holguín-Veras et al., 2006) and the computation of optimal tolls in an idealized setting (Holguín-Veras and Cetin, 2008). One of the most intriguing aspect of the work done is that the optimal tolls for truck traffic are, in some cases, equal and even smaller than those for passenger cars. This result stands in sharp contrast with the long held assumption that optimal truck tolls must be equal or larger than the optimal passenger car tolls multiplied by a suitable passenger car equivalency (PCE) factor. This is what has been termed the proportionality assumption.

The paper examines this intriguing result and concludes that the assumption of proportionality between optimal tolls is not correct. At the root of the explanation, one finds the mathematical nature of the underlying link performance functions. Functions such as the Bureau of Public Roads, which is in essence a, a univariate function in which the contributions to congestion of truck traffic is a direct function of the PCEs, leads unavoidably to proportional optimal tolls. In contrast, more realistic multivariate functions, e.g., those empirically estimated from micro-simulations, lead to marginal contributions to congestion that are not constant (and proportional to the PCEs).

The paper discusses the implications of these findings for congestion pricing policy.

## **Public Acceptance of Urban Road Congestion Pricing Analysis**

Xiaowei Hu; Jian Wang; Chong Wei

*xiaowei\_hu@yahoo.com*

*Harbin Institute of Technology*

Urban road congestion pricing as an efficient measurement to relief road congestion, reduce environment pollutants' emission and improve road transportation efficiency has been successful implemented in many cities. Public as key stakeholders, the acceptance of public is the premise in the congestion pricing policy's successful implementation. The current study on congestion pricing ignored the public's acceptance and support issues. This article starts with the congestion pricing revenue distribution, perceived equity, personal choice's expression and the changing public benefits, analyzing the different benefit stakeholders' acceptance in the congestion pricing process, combining with small-world network model to establish the formation and propagation model of public acceptance of urban road congestion pricing. Through the completely explanation of the network simulation testing, data, and the results to show the formation and propagation law in the public acceptance during the implementation process of the congestion pricing, which provides the theoretical support to search kinds of measures to increase public acceptance of urban road congestion pricing.

Key words: road congestion pricing, public acceptance, revenue distribution, small-world network

## **Traveler's Mode Choice Behavior Responses After the Implementation of Road Charging Policy**

Xiaowei Hu; Jian Wang; Chong Wei

*xiaowei\_hu@yahoo.com*

*Harbin Institute of Technology*

Traveler's mode choice behavior is a complex decision-making process, which is affected by travel purpose, travel utility costs, income level and many other factors. In the implementation of road congestion charging policy, traveler's mode choice behavior will change due to the travel utility costs' changing. This paper from the behavioral science perspective to analyze traveler behavior, including explain level, prediction level and control level. After comparing the four kinds of different modes travel utility costs, which cover private car, bus, subway and taxi, establishes the traveler mode choice behavior model after the implementation of road congestion charging policy, and adopts case study to compare the traveler mode choice change before and after the pricing policy. This model explains the traveler model choice behavior changes after the implementation of road charging policy.

Key words: road congestion charging; mode choice behavior; travel utility cost; decision-making

## **HOT Lane System Performance Optimization with the Consideration of Revenue Enhancement**

Xiaojin (Jerry) Ji

*xji@wilbursmith.com*

*Wilbur Smith Associates*

The HOT concept that began with SR 91 (Orange County, California) in 1995 has gained growing interest in the U.S. Several projects are now currently implementing HOT lane operations in the nation and many more are under study or will be operational in the near future. The evolution of the high-occupancy-toll (HOT) lane concept originated from the need to address multiple objectives related to congestion management, throughput optimization, revenue optimization, transit and carpool encouragement, or user convenience and safety. The operational measures taken to ensure meeting the multiple objectives of the HOT lanes have been diverse in nature and take into consideration eligibility strategies (vehicle occupancy or vehicle types), pricing strategies (fixed, variable, or dynamic, HOV2+ or HOV3+ pricing), and accessibility controls (access configuration, access types).

There are no standard HOT lane system performance measures accepted nationwide and various measures have been applied to evaluate the currently operating HOT facilities. The main objective of most existing HOT lanes that was converted from HOV lanes has been to fully utilize the excess capacity especially during peak periods. Some newly constructed HOT lanes often bear more comprehensive objectives that include vehicle throughput maximization, person throughput maximization, reliable travel alternative, congestion management, and revenue optimization. The pilot nature of most existing HOT lanes ensures the emphasis of mobility objective with revenue generation a lower-priority objective.

The continuing worsening of infrastructure funding shortfall and higher capital investment requirement of many recent and future HOT projects will put more expectation on the revenue generation potential of the project to make it financially feasible. This paper discusses and analyzes various HOT lane policy design and operational strategies on how revenue generation could be enhanced while still fulfilling the operation and mobility requirement of the HOT lanes. A HOT lane system performance optimization framework with the consideration of revenue enhancement will be provided as the end result of this research.

### **Evaluation of Parking Deposit System (PDS) with Integrated Travel Demand Forecasting Model**

Ryo Kanamori

*kanamori@bin.t.u-tokyo.ac.jp*

*University of Tokyo*

Road Pricing (RP) is one of the most efficient policies to reduce a car traffic volume and to ensure a revenue source for an enhancement of mass transit's service level. However, RP might bring a decrease of the number of visitors to the object area because of its additional charge. Prof. Morikawa proposed "Parking Deposit System (PDS)" as a new congestion management policy which is capable of reducing a decline of downtown and is also highly acceptable. Unlike a conventional RP, PDS does not levy a charge on all vehicles entering the charging area. Under PDS, if drivers park in parking lot and buy something in the charged area, they receive a credit equivalent to the full or partial of the entry charge. PDS is able to eliminate a street parking and through traffic, reduce a cost burden on drivers, prevent a decline of central shopping area, and thus improve the acceptability of concerned parties.

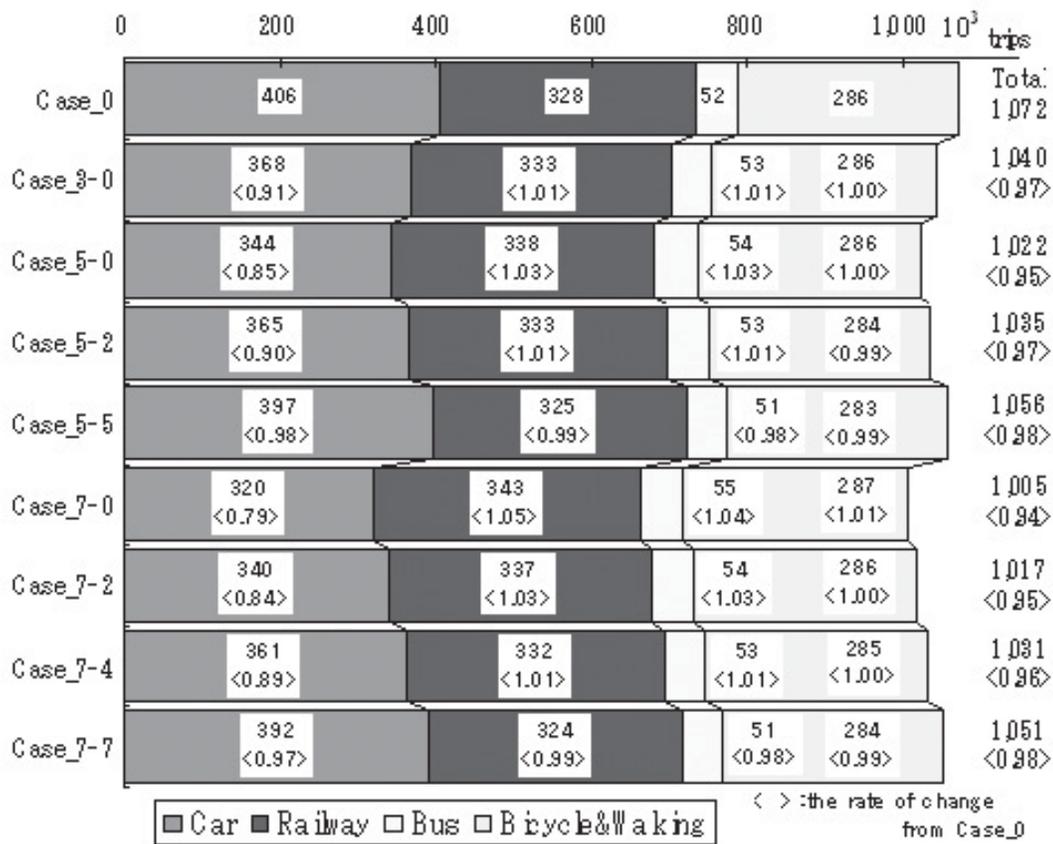
In this paper, we evaluate the effects of PDS in an actual situation, in this case the Nagoya Metropolitan Area in Japan. The travel demand forecasting model in this study improved our semi-dynamic combined stochastic user equilibrium model which has the following characteristics: 1) integration of trip generation (i.e. activity choice), destination choice, mode choice and route choice; 2) expression of traveler's choice behavior as a nested logit structure; 3) consideration of hourly traffic condition variations including queue evolution; and 4) approximate reproduction of trip chain along the time axis. In addition, the parameters of mode choice are estimated from the SP survey data and the multi-class equilibrium assignment model is applied for a consideration of different charge and credit levels in PDS.

In order to compare the effect of various charging pattern in PDS, the some cases are introduced, with charging from 7:00 a.m. to 7:00 p.m. The evaluation indices are the reduction of car trips and through traffic, the improvement of travel time and CO2 emissions, the change of the number of visitors to the charge area, activity duration and stop-points in downtown and the user benefit calculated from the log-sum term of nested logit model.

Below figure shows the number of trips to the city center of Nagoya City where the railway network is sufficiently developed. Although the total number of trips attracted to the city center is reduced in all cases, it turns out that the number of visitors recovered due to the credit of PDS. On the other hand, the reduction effects of car trips become small as the refund increases. However, through traffic is reduced regardless of the level of refund (for example, in case\_5-0: -78%; in case\_5-2: -79%; in case\_5-5: -80%), thus PDS is one of the desirable policy from an environmental viewpoint of CO2 emissions

reduction.

Finally, judging from the results in this study and in another that the acceptability of PDS is higher than the conventional RP by the SP survey, it can be said that PDS is a new powerful policy.



For example, case\_0 is no pricing case, case\_5-0 is normal pricing in case of price level 500JPY/enter. Case\_5-2 is PDS in case of price level 500JPY and refund 200JPY.

### Tool for Estimating Managed Lanes Traffic and Variable Toll Rates

Jack Klodzinski; Tom Adler; William T. Olsen

jack.klodzinski@dot.state.fl.us

Florida's Turnpike Enterprise; Resource Systems Group Inc.; Florida's Turnpike Enterprise

Regional models provide reliable estimates of overall corridor volumes and the distribution of traffic on a network. However, current regional traffic forecasting models do not efficiently forecast hour-by-hour traffic volumes and most forecast only total daily traffic. Since toll rates and apportionment of traffic between express lanes and general use lanes can depend heavily on hour-by-hour traffic conditions, detailed analysis is necessary to properly represent these conditions. In addition, express lane toll rates vary based on traffic levels and thus the supply-demand equilibration process needs to include supply functions that allow both time and cost to vary dynamically. While hourly traffic forecasting with dynamic tolling could be done with a regional network model, the required computing time would be substantial and makes production of multiple scenarios cumbersome. The post-demand model application described in this paper provides the user with a tool to quickly produce multiple hourly toll and traffic forecasts for a managed lanes project with a short turnaround time. The Express Lane Time-of-Day ("ELTOD") procedure's primary inputs are total daily corridor traffic from a regional travel forecasting

model, geometric configuration of the facility, and tolling policy. ELTOD estimates the traffic on both general use and toll lanes in the corridor by solving for supply/demand equilibrium for each hour and a suggested hourly toll rate. Changing ELTOD parameters can test variable pricing strategies for demand management to preserve a desired level of service in the express lanes when there is an adjacent non-tolled facility as an alternative. This ELTOD application was used on a managed lanes project in south-west Florida on Interstate 75.

### **A La Carte Pricing to Generate Ancillary Revenue: The Case of European LCCs**

Richard Klophaus

*klophaus@fh-worms.de*

*Worms University of Applied Sciences*

More and more airlines adopt a strategy to unbundle their services in order to create additional revenue from non-ticket sources. This ancillary revenue has become a key revenue component for low-cost carriers (LCCs) in Europe but carriers throughout the world are following the ancillary revenue movement. Three categories of optional services leading to ancillary revenue can be distinguished: A la carte features, commission-based products and frequent flyer programs. A la carte features are onboard sales of food and beverages, checked baggage, seat selection, etc. Commission-based products refer to commissions earned by the sale of hotel accommodation, car rentals, travel insurance, etc. The frequent flyer category refers to the sale of miles or points to program partners.

The present paper focuses on ancillary revenue generated by à la carte pricing. It provides an overview on the practice of à la carte pricing among European airlines broadly categorized as LCCs with an emphasis on Ryanair as the largest LCC in Europe. Ryanair is often considered as pioneering airline of the à la carte business model unbundling its services into core air travel from A to B, charging very low base fares while offering an increasing list of optional services at a fee. Data is provided on relative frequencies of different categories of à la carte items among European LCCs and price ranges for these optional services.

The economic justification of à la carte pricing to date is rather vague. Hardly any economic literature exists on the optimality of unbundling air travel services. In contrast, a plethora of normative guidelines can be found for bundling services as reviewed by Venkatesh and Mahajan (2009). Unbundling air travel services into core product and à la carte items turns bundling into its opposite. Hence, by reviewing normative guidelines on bundling the present paper develops hindsight for practitioners, when and how airlines benefit from à la carte pricing. It also provides researchers with promising directions for further research.

### **An Exploratory Analysis of the Value of Travel Time for Work Trips**

Ashish Kulshrestha; Sivaramakrishnan Srinivasan

*ashishkul@ufl.edu*

*University of Florida*

Evaluation of the behavioral responses to changes in the pricing of transportation systems requires an understanding of how travelers trade-off additional costs incurred against the travel-time savings. This trade-off is measured as the value of travel time (VOTT) and is often obtained from multinomial-logit (MNL) models for the choice of the mode of travel to work. The state-of-the-practice approach predominantly involves the determination of a single VOTT measure (for any trip purpose) across all modes and all travel distances. However, individuals may have differential sensitivities to times spent in different modes (for example, car and transit) because of issues such as comfort, and hence, resulting in differences in values of travel times across modes. Similarly, individuals may not be willing to pay as much for saving a minute of travel time from a longer-distance trip compared to a saving a minute from a shorter-

distance trip.

In the light of the above discussion, the objective of this paper is to empirically evaluate the reasonableness of a single (“average” / “representative”) measure of VOTT for home-based work trips across all modes and all travel distances. Data from the Bay Area Travel Survey (BATS) from 2001 are used to estimate several MNL models for the mode choice for work trips. These models differ in their specifications of the utility functions leading to differences in the implied VOTT measures across modes and trip distances. Preliminary results indicate that the VOTT is higher for transit compared to auto-modes (perhaps reflecting a greater comfort associated with time spent in the car relative to time spent in buses) and that the VOTT value for the auto mode is lower than the estimate of the VOTT obtained from models that “force” this measure to be the same across all modes. In addition, the models also provide evidence for the variation of VOTT values with trip lengths. Further empirical estimations will be undertaken and a detailed comparative analysis of the different specifications and the implied VOTT measures will be presented in the paper.

### **Controlling Congestion Through Better Land Use Planning**

Sterren Latsky

*S.C.Latsky@bath.ac.uk*

*University of Bath*

Congestion on heavily utilised roads is now at a critical point and the level of the congestion is set to rise still. This congestion causes excessive delay in travel time, which is a huge burden on the economy. The situation has arisen because infrastructure expansion requirement is outstripped by demand (Pagano 2008). There are only two acceptable solutions; spend more on infrastructure or better distribute the demand. The former is very difficult due to the lack of available finances, so most efforts have been spent on the latter.

For a particular origin and destination, the route that drivers take and the time they choose to depart will have an effect on congestion, but the actual location of the point of interest has a much greater effect. A new development (referred hereafter as scheme), such as new housing estate or supermarket, will have direct consequences for the level of traffic on roads in the surrounding area. A scheme could either increase travel down heavily used routes, or divert traffic away by offering an alternative destination. The degree of penalty or credit should be related to the level of impact it has on the road traffic.

Section 106 of the Town and Country Planning Act 1990 (S106) states that developers must pay for the negative consequences of a scheme. However, it is not stated what an adequate contribution is. Many boroughs calculate contributions on a basis of type and floor space of a scheme. The charge therefore is not cost-reflective, as it is not based on the actual negative effects caused by the scheme. To make the charge cost-reflective, the negative effects need to be evaluated and accounted for.

The paper proposes a Long-Run Incremental Cost (LRIC) pricing methodology that can directly relate the degree of impact to the road traffic from a scheme. The effect of this induced traffic is to either advance or defer the time that various roads are expected to be expanded. LRIC pricing thus calculates the change in present value of future investment for all roads in the network as a result of a scheme at a given location. For a scheme that increases traffic on a road, its future investment will be brought forward and this results in a positive LRIC for the road, and vice versa. Aggregating this LRIC cost across all roads in the network, the total effect that a scheme has on road infrastructure cost is the locational LRIC charge against the developer.

The charging methodology is tested on a small example city network. Cost-reflective LRIC charges are calculated for different locations available to a developer. When compared to the static figures quoted in S106, these locational differentiated charges weigh up the complex effects that a scheme has on the future of the transportation network much better. Charging the developer in relation to this LRIC will incentivise them to locate at a place that can delay or defer the anticipated future investment, therefore minimise the infrastructure development cost.

## **Cross-fertilisation between Road Pricing and Pricing in Electricity Infrastructure Networks**

Sterren Latsky

*S.C.Latsky@bath.ac.uk*

*University of Bath*

Electrical network pricing used to be quite simplistic. Charges were based on the voltage level of connection; all downstream customers have to pay for the use of all upstream assets, thus prices decrease per unit as voltage increases. This is known as postage stamp pricing, based on the Distribution Reinforcement Model (DRM) (Li, and Tolley, 2007) and it has several problems. The most significant is that it only gives a loose message about the extent of the costs involved in transferring that energy, as the cost of energy transportation at different locations could vastly differ for different locations.

In the last 20 years, there have been major advances in electrical network pricing. First came distance-based pricing. This meant that customers pay more for electricity that has to travel further, giving a stronger message about the costs involved in transmitting the power. Most recently, the amount of spare capacity, linked to the future expected cost of expanding the network, has been taken into account.

These advances were designed to better utilize the existing infrastructure. This would defer the otherwise necessary network expansion. Study suggests that the move from postage stamp pricing to an economic long-run incremental cost pricing saves the UK industry £200m in the network development (Li et al, 2006). The question is whether the successes in electrical network pricing can be transferred to road pricing. To answer this question, it is necessary to look at the similarities and differences between the network structure, investment, operation and political influences.

The majority of the road pricing in use is similar to the rudimentary electrical network pricing; they are the same to all network users no matter how far your travel and where you travel. Some recent road pricing schemes (Steen 2009) also acknowledge the distance the road users have to travel; they do not go as far as the electrical infrastructure network pricing that relates to network investment cost by considering both the distance and the degree of utilization (Li and Tolley, 2007).

There are, however, fundamental differences between the two networks. Drivers, unlike electricity, can choose which routes to take through the network and only broadly do so at equilibrium that makes best use of the network. Recent road pricing schemes aim to better distribute the traffic by making the users accountable for the congestion they cause. These similarities and differences need to be explored to know what can be learned from pricing between the two networks.

The paper explores the commonality between the networks, especially in terms economic investment and service pricing. It is investigated if advanced pricing principles in electrical energy network and road network are cross-compatible and where there are limitations in the comparisons. This helps the cost-effective development of both electrical and road networks into the future.

## **Cargo Revenue Management with Allotments and Spot Market Demand**

Yuri Levin; Mikhail Nediak; Huseyin Topaloglu

*ylevin@business.queensu.ca*

*Queen's School of Business*

We consider a problem faced by an airline that operates a number of parallel flights to transport cargo between a particular origin destination pair. The airline can sell its cargo capacity either through allotment contracts or on the spot market where customers exhibit choice behavior between different flights. The goal is to simultaneously select allotment contracts among available bids and find a booking control policy for the spot market so as to maximize the sum of the profit from the allotments and the total expected profit from the spot market. We formulate the booking control problem on the spot market as a dynamic program and construct approximations to its value functions, which can be used to estimate the total expected profit from the spot market. We show that our value function approximations provide

upper bounds on the optimal total expected profit from the spot market and they allow us to solve the allotment selection problem through a sequence of linear mixed integer programs with a special structure. Furthermore, the value function approximations are useful for constructing a booking control policy for the spot market with desirable monotonic properties. Computational experiments show that the proposed approach can be scaled to realistic problems and provides high quality allotment allocation and booking control decisions.

### **Quantitative Method for Analyzing Road Network Ownership**

Mingxin Li; Li Su

*m.li@utah.edu*

*University of Utah*

The present highway funding system, especially fuel taxes, may become less reliable revenue sources in the future, while the transportation public agencies do not have sufficient financial resources to meet the increasing traffic demand. Regarding the economic impact of road privatization, a wide range of approaches and models have been proposed, but few studies have been devoted to the detailed analysis of the ownership structure and the corresponding socio-economic outcomes. This paper aims to develop a framework to measure the system performance of network flow evolution and estimate the relative socio-economic performance under different Public-private partnership (PPP) ownership structure, which is incorporated into a simulation-based network loading for a multiple years planning horizon. The mathematical models are based on the economic impact of specific composition between centralized and decentralized ownership structures. Specifically, in a centralized ownership model, the government agencies are responsible for all the ownership activities. In a decentralized ownership structure, the ownership is shared by a variety of interest groups. This paper examines the efficiency of the application of the proposed transportation model to highway planning with cost-benefit analysis approaches. Based on a quantitative analytical method, we examine the impacts of ownership structures on the socio-economic performance in transportation systems. A case study on a regional network is presented to demonstrate how the proposed approaches can be employed to make relative comparisons among possible alternatives in road concession. The simulation results indicate that the economic performance of PPPs projects can be quantified according to different ownership structures at the network level and the proposed model and approaches can be used in long-run prediction of economic performance. Under certain constraint conditions, these approaches can be adopted for evaluating, comparing and ranking investment decisions.

### **Quantifying Dynamic Tolling Impacts on Single Occupancy Vehicles' Usage of High Occupancy Toll Lanes: An Empirical Approach Based on Field Observations**

Xiaoyue Liu; Guohui Zhang; Yin Hai Wang

*liuxy@u.washington.edu*

*University of Washington*

High Occupancy Toll (HOT) lane systems have been widely accepted as a cost-effective countermeasure against freeway congestion and means to enhance travel reliability. Under HOT lane operations, a Single Occupancy Vehicle (SOV) can pay a fee to access the HOT lane in exchange of a travel time saving or a reliable trip. For existing HOT lane systems, toll rate is dynamically adjusted based on the real-time traffic condition on both HOT and General Purpose (GP) lanes. A dynamic tolling strategy is typically set to sufficiently utilize the HOT lane capacity while ensuring that HOT lane vehicles operate at a reasonably high speed.

Different states have been using different tolling strategies on their HOT lane facilities and the performance of an HOT lane system ties directly to the tolling strategy. However, comparing tolling strategies have been a difficult problem due to the lack of field data as well as the missing pieces of information

critical to HOT lane operations. For example, how SOVs choose the types of lane to use under the effect of tolling and the flow friction between HOT and GP lanes remains unclear.

Therefore, this research aims at analyzing the attractiveness of HOT lanes for SOV drivers using the field data collected by point traffic sensors and transponder toll tags on Washington State Route 167 (SR167). A model is developed to quantify the relationship between SOVs' choice and HOT utilization. The SOV users on HOT lane are further classified into regular users and infrequent users by matching their transponder ID through a period of one month. Preferences of regular users and infrequent users for using HOT lane are modeled separately because regular users are most likely commuters who have the incentive to choose the HOT lane to ensure a reliable trip even when there is no significant travel time saving while infrequent users' choices are more sensitive to real-time traffic conditions and perceived travel time savings. It is noteworthy that two of the most important parameters for HOT lane operations, the Value of Time (VOT) and Value of Reliability (VOR), can be calculated for heterogeneous motorists under various traffic conditions using this method. The analysis results show that with motorists' willingness of paying HOT lane tolls formatted and considered, travel patterns on HOT and GP lanes can be better interpreted and modeled for performance enhancement.

### **A Unified Framework of Proactive Self-Learning Dynamic Pricing for High-Occupancy/Toll Lanes**

Yingyan Lou

*ylou@eng.ua.edu*

*The University of Alabama*

This paper presents a unified framework to determine dynamic pricing strategies for high-occupancy/toll (HOT) lanes. By allowing lower-occupancy vehicles to pay a toll to gain access, HOT lanes provide additional travel option to road users and are expected to increase the utilization level of high-occupancy vehicle facilities. In order to better achieve the HOT design objectives of providing a superior free-flow traffic service on the toll lanes while maximizing the throughput of the freeway (FHWA 2003), the ideal toll rates should be adjusted in response to the current traffic condition in a real-time manner. Recently, Yin and Lou (2009) and Lou et al. (2007) delivered a proof of concept of a self-learning dynamic pricing approach that, in a sequential fashion, learns motorists' willingness-to-pay (WTP) and explicitly optimizes the toll rate for the next rolling horizon. This paper further advances the self-learning approach to a unified framework that addresses several additional critical issues, including integrated traffic state estimation and WTP learning, and proactive robust toll optimization in coupled with demand prediction. The framework is built upon an advanced simulation model, and consists of two critical steps: system inference and toll optimization. Based on the multi-lane hybrid cell transmission model proposed by Laval and Daganzo (2006), the simulation model is able to describe traffic dynamics for merging and diverging respectively, where lane-changing vehicles are treated as moving bottlenecks. The simulation is also equipped with a built-in lane choice model that replicates users' actual responses to the toll rates and calculates endogenously the inflow rate for both HOT and general purpose lanes according to the current traffic condition. The first step of the framework is to reveal both supply and demand information of the system through mining the real time traffic sensor data. This step employs advanced Kalman filtering (e.g., Kalman, 1960 and Julier et al., 1995) and Bayesian inference techniques to learn travelers' WTP, estimate traffic condition for the entire freeway based on sensor data from limited locations, and predict short-term traffic demand. The attained knowledge is then used in the second step to explicitly optimize the dynamic toll rates to maximize the freeway throughput while ensuring a free-flow travel speed on HOT lanes. The simulation evaluates the objective values for a given toll rate within a rolling horizon and simulation-based optimization is used to search for the near optimal toll scheme. Given the future traffic demand is likely uncertain, robust toll optimization is proposed to address this issue by taking into account possible future demand scenarios to seek for a toll rate that performs well under most of the circumstances. The paper discusses the model and the solution of each step in detail and validates the framework in a simulation experiment. To demonstrate the effectiveness and efficiency of

the proposed framework, this paper further compares the approach with the HOT pricing scheme that is currently in practice in Florida. It is demonstrated that the framework is efficient, effective and flexible, and has the potential to be readily implemented in practice.

### **Urban Network Privatization: A Small Network Example**

Omid M. Rouhani; Debbie Niemeier

*omrouhani@ucdavis.edu*

*University of California, Davis*

The private sector has made significant investments in both existing and new highways through public-private partnerships (PPPs) in the recent years. The majority of the recently introduced private facilities are rural highways but privatization of other types of roads could be more beneficial to the society. From a social welfare view, the ever increasing congestion problems and the existence of alternative modes to private cars may encourage urban roads' privatization. This research examines the effects of different privatization strategies on a simple network, with two modes of transportation. By refining the general costs of travel, the choice of the links to be privatized and the enabling policies, a more efficient roadway usage can be achieved. The results from the small network will be used to develop a framework for larger network's privatization.

### **Comparison of Optimal Area and Cordon Road Pricing Scheme: Methodology and Policy Implications**

Takuya Maruyama; Ryota Takaki; Agachai Sumalee; Shoshi Mizokami

*takumaru@kumamoto-u.ac.jp;*

*Kumamoto University; The Hong Kong Polytechnic University*

The design of a congestion pricing policy clearly determines its performance. Therefore, many studies have attempted to determine the optimal design of various pricing schemes. Cordon-based and area-based congestion pricing are two well-known pricing policies that are designed to alleviate city-center congestion. In cordon-based pricing, drivers are charged when they cross the cordon boundary, while in area-based pricing, the drivers pay a daily charge to enter or drive within a charged area. For these schemes, the toll level and charging boundary must be determined.

Cordon-based pricing has been extensively examined (Zhang and Yang, 2004; Sumalee 2004, 2007; and others), but area-based pricing has received little attention. This study proposes a modeling framework for designing an optimal area-based pricing policy and investigates the properties of optimal area-based pricing. The travel costs for area-based tolls are expressed using a trip-chain-based network equilibrium model proposed by some of the authors (Maruyama and Sumalee 2007).

The aim of this study is to answer the following research questions.

1. How do the optimal-area and judgmental-area pricing schemes differ?
2. How do the optimal area and optimal cordon pricing schemes differ in terms of the charging boundary and toll level?
3. Does an optimal area-pricing scheme have a wider or smaller area than an optimal cordon pricing scheme?
4. When applying congestion pricing for the first time, which pricing scheme should be introduced first: cordon tolls or area tolls?

The pricing design model is formulated as a bi-level programming problem and solved using a genetic algorithm. Sumalee (2004, 2007) adopted a branch-tree concept to represent the cordon-toll boundary. This concept can be used for analyzing area tolls. Roughly speaking, the leaves in the branch tree represent the cordon and all of the components of the tree correspond to the area boundary.

This model was applied to a real-world network in Utsunomiya, Japan. This case study produced several interesting findings. The shapes of the optimal boundaries for area toll and cordon toll pricing schemes differ significantly. Optimizing the area toll increases the social surplus by 50% over that generated by a judgmental area toll, while optimizing the cordon toll increases the social surplus by 100%. An optimal area toll has a wider area than an optimal cordon toll.

Results of several calculations imply that a carefully designed cordon toll could produce a higher social surplus, but an area toll would be safer and more stable and would produce a moderate but reliable increase in the social surplus. Therefore, careful consideration of the charging boundary for the cordon toll is important, perhaps more important than the charging boundary of an area toll. In other words, a cordon toll has a more sensible boundary shape than an area toll. Then, an area toll may be a better first option because we don't know the demand information accurately in the city before introducing some toll policy.

### **Lessons Learned in Establishing Concession Level Public-Private Partnerships on Brownfield U.S. Toll Roads**

Eric Magazu; Christopher J. Ahmadjian; John Collura; Raju P. Khanta  
*emagazu@gmail.com*

*University of Massachusetts Amherst; Wilbur Smith Associates*

Over the last several years, public-private partnerships (P3) have been negotiated on major highway toll facilities in the U.S. including the Chicago Skyway, Indiana Toll Road, and Pennsylvania Turnpike. These three P3 initiatives potentially represent a new management paradigm in transportation. Each P3 agreement involves long-term concessions to private companies and in return the government entity owning the toll facility received or will receive a multi-billion dollar lump sum payment. After each of the agreements was signed, questions were raised regarding both the wisdom of the decisions and the size of the onetime payment. Arguments were made on both sides as to whether too much or too little was paid by the concessionaire and whether each decision was a bold initiative or simply a short-term folly that will be regretted.

This paper does not attempt to enter into that argument. The objective is instead to draw conclusions with regard to both the short-term lessons learned and how these lessons might be used during the negotiation of future agreements. Major lessons learned were that more can be done to hedge the risk associated with all stakeholders; forms of financial compensation other than lump sum should be considered; sensitivity analysis should be used to identify key variables, such as toll schedule; demand models other than those based on the traditional four step process are needed; the motives of all stakeholders need to be carefully considered.

The results of this research should be of interest to government officials involved in establishing public private partnerships associated with the management and operations of existing public infrastructure facilities and services.

### **Paying for Transportation: What Would George Washington Do?**

David B. McBrayer  
*mcbayer@pbworld.com*  
*Parsons Brinckerhoff Americas*

Discussions of transportation policy and finance tend to devolve all too quickly into debates between liberal and conservative views, although there are notable exceptions. Toll roads and heavily pro-transit policies are most often assigned to the liberal side, while freeways and minimal transit are generally seen as conservative views. That being said, where would George Washington and his colleagues, who declared independence and established the constitution of the United States, stand within this spectrum? What would they do about transportation policy and pricing today?

It is instructive – perhaps even surprising – to consider our current policies and attitudes about transportation within the context of 18th Century circumstances, to see what light this might shed on the choices before us during our current early-21st Century period.

When George Washington led the creation of our nation, the main intercity roads, both on this continent and in his original native land, England, were turnpikes. These were private commercial enterprises responding to the need for movement of people and goods. In England, the primary force that led to the abandonment of turnpikes late in the 19th Century in favor of the fee-to-the-user “King’s Highway” network was the competition brought by another transportation private enterprise, the steam-engine-powered railway networks. Their success destroyed the financial viability of turnpikes, or toll roads, as we generally designate them today.

Moving ahead to the early and mid-20th Century, the post-turnpike scenario remained dominant in the United States. Intercity passenger rail was a major mode, and freight rail was the main carrier for goods movement. Within cities, transit systems were still privately owned, financially viable, and paying franchise fees for the privilege of profiting from their passengers. Post-World-War-II prosperity and the Interstate System of Defense Highways brought in the current status quo, in which intercity passenger rail is at a low point, freight rail focuses on long-haul goods movement, and the direct revenues earned by urban and metropolitan transit systems pay only a third or less of operating costs and contribute nothing to the required capital investment.

Bringing President Washington back into the picture, would he now (a) do nothing, (b) augment public funding of the road system, (c) commission a policy study, or (d) sell the road system to private enterprise as turnpike projects, and withdraw government funding of transit systems?

This paper provides a brief exploration of those options, with emphasis primarily on person trips, not goods movement, and considering several viewpoints that influence the provision and use of modal transportation in the United States:

- Transportation user perceptions regarding the cost of individual trips,
- Public perceptions as to how the costs of transportation are paid, and
- Actual transportation expenditures, by source of funds.

### **It Pays to Do the Right Thing: Incentivizing Responsible Commuting**

Deepak Merugu; Balaji Prabhakar; Naini Gomes

*deepakm@stanford.edu*

*Stanford University*

Frustrating traffic jams are well known to commuters. Quite surprising is just how expensive road congestion can be: A study by the Texas Transportation Institute estimates that \$87.2 billion was incurred in delay and fuel costs in the U.S. in 2007. Increased vehicular traffic also means more pollution and parking problems. To combat these staggering costs and undesirable effects of congestion, cities like London, Singapore and Stockholm have introduced congestion charging.

We describe a fundamentally different approach to combat road congestion. Rather than just charging congestors, we advocate paying monetary incentives to decongestors. The goal is to wean commuters away from congestion causing behavior by incentivizing them to commute at less congested times. Our incentive mechanism has an interesting random payoff component.

Our approach was validated in a 6-month pilot deployment at Infosys Technologies Ltd. Bangalore, from October 6, 2008 through Apr 10, 2009. Over 14,000 commuters were part of the pilot and over 9,000 of them commuted to work at off-peak hours, up from about 4,200 before the pilot’s launch.

We plan to use a similar approach to address the traffic congestion at Stanford University. Stanford has a peak-hour congestion problem with increasing number of vehicles entering or exiting the campus in

peak hours. Thus, there is a strong need to incentivize off-peak commuting. We plan to use RFID systems to monitor commute times; an incentive mechanism will use this information to reward off-peak commuting.

Stanford University's transportation problems are representative of that faced by a typical autonomous entity such as a city or a neighborhood. Thus, Stanford can be viewed as a test bed for developing and testing innovative schemes which can be applied elsewhere in other wider contexts; for example, to encourage off-peak commuting in public transport and private vehicles.

### **Proactive and Robust Dynamic Pricing Strategies for High-Occupancy/ Toll Lanes**

Dimitra Michalaka; Yingyan Lou; Yafeng Yin

*dimichalaka@ufl.edu*

*University of Florida; University of Alabama; University of Florida*

Congestion pricing has been promoted by economists and transportation researchers as one of the most efficient means to mitigate traffic congestion. When tolls implemented on highway lanes vary by the time of day, with higher values charged during peak traffic periods, it is called as dynamic tolling. The tolled lanes are high occupancy/ toll lanes (HOT) if the high-occupancy vehicles are allowed to use the lanes for free. In the literature, many studies have been conducted to determine optimal dynamic pricing strategies. However, most of these studies take into consideration idealized and hypothetical situations in order to derive solutions. For instance, the travel demand is assumed to be known as well as motorists' willingness to pay, i.e., how much they would like to pay for using the managed facility. In addition, none considers the uncertainty associated with travel demand in the determination of toll rates. This study develops a more robust and proactive approach to determine time-varying tolls for HOT lanes in response to real-time traffic conditions. The toll rates are optimized to provide free-flow conditions to managed lanes while maximizing freeway's throughput. The approach consists of several key components, including demand learning and scenario-based robust toll optimization. Simulation experiments using field data from I-95 Express in Miami are conducted to validate and demonstrate the proposed approach. The proposed tolling scheme is compared with the one implemented for I-95 Express.

### **Enabling a Flexible Ridesharing Response to Congestion Pricing**

Paul Minett

*paulminett@tripconvergence.co.nz*

*Trip Convergence Ltd*

The objective of congestion pricing is to change the distribution of use of the facility. In its purest form economists suggest that the funds received should be passed back to the community such that there is no economic distortion, except in the use of the congested facility. This is distinguished from distance based pricing, which should be used to recover the costs of providing the public facility. The gas tax is observed to be a quasi distance-based pricing system, where the rate of payment per mile is determined by the distance the vehicle is able to travel on a given amount of fuel. A vehicle that achieves 18.5 miles per gallon of gas is paying \$0.01 per mile in gas tax.

If the objective of congestion pricing is to distort the usage of the facility, then mechanisms which make it easy for users to switch between transport modes in response to the congestion price, and therefore increase people-throughput with fewer vehicles, should come to the fore. In most cases people make their modal decision before they leave home in the morning such that by the time they reach the congested facility, and certainly for their return in the evening, they do not have many options for switching. The congestion charge then becomes a tax that they cannot avoid, once they are on the journey.

Flexible carpooling is a system by which qualified members meet and form fuller cars to predetermined destinations. Ride credits are transferred between riders and drivers to enable sharing of benefits. Ride credits have economic value. Membership is required to ensure safety (members are pre-screened) and

accounting of ride credit transactions. Technology used for the system enables communication with the toll collection system such that if there are discounts for high occupancy vehicles these can be accounted for directly to the occupants.

Placing of a flexible carpooling meeting place upstream from the congested facility would enable drivers who are members to switch, in response to the price, from being SOV to being HOV, therefore reducing demand on the facility. Those who become riders use the same system to return to their vehicles in the evening. An alternative mode is provided at much lower cost and with greater flexibility than the usual public transport alternative.

This paper describes how flexible carpooling works and can be provided as a low cost alternative to enable mode-shift in response to (or in anticipation of) congestion pricing on a facility. It calculates the likely impact on traffic volumes on a theoretical facility, and reports on flexible carpooling initiatives implemented to date.

### **Not Only Seeing, But Also Knowing Who Is in The HOV**

Paul Minett

*paulminett@tripconvergence.co.nz*

*Trip Convergence Ltd*

From a distance, a car with one person in it, an SOV, looks pretty much the same as a car with four people in it, an HOV.

Many priced facilities give free or discounted access to high occupancy vehicles. Current tools for managing this access are very costly and unreliable. Even the best managed systems believe that some percentage of users are successfully avoiding tolls by using the HOV access points when they should not. The cost of enforcement is high. Technologies are being developed to detect warm bodies or skin, but these require enforcement officers to intercept those that the 'camera' thinks are frauds, and the technologies are expensive. On-road enforcement can also create safety issues as officers chase down potential infringers. Bona fide users resent the system as much for the fraudsters as for the tolls themselves.

New and inexpensive technologies are making it possible to change the regime. A biometric 'ridesharer ID card' is envisaged that provides positive proof of presence, including the account number of each of the people in the car. The HOV occupants can use these technologies to claim an 'HOV credit' to offset the toll. By tolling all vehicles, and processing HOV credits for qualifying ones, the cost and challenges of enforcement would become a thing of the past. Different levels of HOV credit could be offered depending on the time of day and the number of people in the vehicle. The HOV credit could be paid back to the toll account for the vehicle, or paid to individual accounts of the people in the car.

The same technologies and the same process could create a 'virtual HOV lane' at key (un-tolled) congestion points by rewarding high occupancy with incentives, at much lower cost than providing permanent HOV facilities. Similarly these incentives could vary with the time of day and the number of occupants, or even the conditions of the traffic at the time. Raising the incentives for short periods of time (in campaigns) could lead to greater levels of permanent ridesharing, or encourage dynamic ridesharing during times of heavy traffic.

This paper will explore the issues associated with the introduction of these technologies and report progress by the author's company in bringing about trials.

## Congestion, Road Capacity, and Tolling

Adrian Moore

*Adrian.moore@reason.org*

*Reason Foundation*

Congestion is already severe and projected to worsen in US metro areas. Few current long range transportation plans call for reducing congestion, even though recent research findings are revealing that congestion imposes higher costs than are usually considered. Capacity additions are a key part of reducing congestion, in the context of other congestion management policies, including pricing. I provide estimates of nationwide capacity needs to keep volume/capacity below 1.0 and thus avoid severe congestion over the next 25 years, and the costs of building the new capacity. I then identify a set of specific tolled capacity additions in several US metro areas and then examine how those additions would affect metro area congestion, how much of the new capacity costs could be covered by the tolls, and possible effects on the regional economy.

### A Study on Expressway Toll Pricing Under Travel Demand Uncertainty

Sho-ichiro Nakayama

*snakayama@t.kanazawa-u.ac.jp*

*Kanazawa University*

The high-quality expressway network has been established all over Japan. Also, urban expressways are in service in Tokyo metropolitan area and Hanshin area covering Osaka and Kobe. The expressway public corporations including urban expressways were privatized, and they have to repay construction expenses within 45 years.

The expressway companies obtain revenues mainly from collecting tolls. The repayment schedule depends on future travel demands, but they are uncertain. In addition, the travel demand is also affected by the tolls. When pricing the toll, uncertain demands and feedback relationship between the demand and the toll should be taken into account.

In this study, pricing the toll under travel demand uncertainty is examined within the framework of transportation network equilibrium.

For simplicity, a simple network, which connects a pair of origin-destination by a toll expressway and a highway, is adopted. Assume that flows on both links follow the binomial logit model. The flow on the expressway,  $x$ , is given by:

$$x = q \frac{\exp(-\theta[c_1(x) + \tau \lambda])}{\exp(-\theta[c_1(x) + \tau \lambda]) + \exp(-\theta c_2(q - x))} = g(x, q)$$

where  $c_1$  is the travel time on the expressway,  $c_2$  is the travel time on the highway,  $q$  is the total demand,  $\lambda$  is the toll, and  $\tau$  is value of time.

Assume the travel demand is normal distributed. Then, the flow is also random. Let  $Q$  and  $X$  denote the random variables of the demand and the expressway flow, respectively. The probability of the expressway flow can approximately be obtained using the Taylor expansion.

$$X = x(Q) \approx x(\bar{q}) + \frac{dx(\bar{q})}{dq} (Q - \bar{q})$$

where  $x(q)$  is a function of the demand for the expressway flow,  $\bar{q}$  is the mean demand.  $Q$  is normal distributed, and  $X$  also follows a normal distribution. Using the sensitivity analysis,  $\frac{dx}{dq}$  is given as:

$$\frac{dx}{dq} = - \frac{dh/dq}{dh/dx}$$

where  $h(x, q) = x - g(x, q) (= 0)$ . The function,  $h$ , is an implicit function.

Imagine that the expressway toll is £1.00 and the demand distribution is  $N[2.0, 0.4]$  (normal distribution, mean is 2.0, S.D. is 0.2). The expressway distribution is:

$$x(Q) = 1.063 + 0.745 (\bar{Q} - 2).$$

Therefore, the toll revenue,  $R (= 1.0 * X)$ , follows the normal distribution, in which the mean is 1.063 and the standard deviation is 0.745. The expressway company is able to repay £0.818 ( $\square 103$  per hour) with a probability of 0.95.

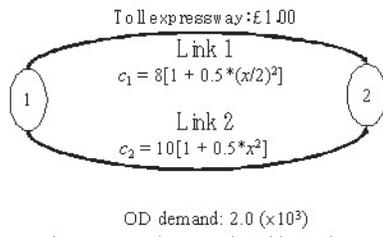


Fig. 1. Example network and its setting

### Effect of Off-peak Toll Reduction

Toshinori Nemoto; Yoshikazu Imanishi; Kumio Kono

cc00330@srv.cc.hit-u.ac.jp

Hitotsubashi University, Graduate School of Commerce and Management; Public Planning & Policy Studies, Inc.

A transport economic model was developed to evaluate changes in total travel costs on congested toll roads by dispersing peak-hour traffic to the pre-peak hours with a toll discount. To empirically analyze the effectiveness of the early-morning toll discount, traffic data of Metropolitan Expressway Route 3 was assigned. The result shows that the pre-peak hour's toll discount, shifting the peak-hour traffic to the pre-peak hours, produces a long-lasting effect of congestion mitigation starting from the peak-hours and thus makes significant contribution to cutting travel costs. In short, it is empirically presented that an early-morning toll discount is effective in cutting travel costs.

## **PLENARY PRESENTATION**

### **The Politics of Freeway Congestion Pricing**

Robert W. Poole, Jr.

bob.poole@reason.org

Reason Foundation

A growing community of transport economists and urban planners believes that the best solution to U.S. freeway congestion is to impose congestion pricing on all such freeways. Simultaneously, however, most political scientists and other political observers consider that idea politically impossible, for a variety of reasons primarily based on strong opposition from taxpayers/voters and highway user groups. This paper suggests that even if the political difficulties could be overcome, the conventional model of freeway congestion pricing would not be optimal, since it would likely create more losers than winners. In analyzing this conundrum, the author looks more closely at two assumptions implicit in the standard congestion pricing model: uniform (variable) pricing and general-purpose lanes. Revisiting both assumptions leads to a proposal for multi-tier pricing and specialized lanes, which the author argues would be more politically feasible and likely to produce greater economic benefits.

## **The Evaluation of the Network Travel Time Reliability Benefits from the Road Charging Systems**

Fayyaz M Qadir

*trafmq@leeds.ac.uk*

*University of Leeds Institute for Transport Studies*

An obvious advantage of any charging system is to retard the expected future traffic growth in a network. In addition, the benefits of any charging system can be seen in various forms such as economic, environment, revenue, social inclusion, accessibility and equity. Nonetheless, the role of a road charging system has never been examined to alleviate the adverse effect of travel time variability (TTV) in daily commuting. The objective of the paper is to test various road charging systems in order to compute the level of improvement to the network travel time reliability (TTR).

A traffic assignment model is developed which replicates the effect of TTV on the route choice decision in the form of risk-related preferences and schedule delay. The developed model differs from existing models since it consists of both risk-related and schedule-related elements. Another vital aspect of the paper, which has not been investigated yet, comes from the investigation of the effect of various road charging systems on route choice behaviour of the risk-averse, risk-neutral and risk-seeking travellers for a given arrival time flexibility.

The consequence of including the risk-related and schedule-related elements in a model violates the assumption of an additive traffic assignment problem. Therefore, a path-based solution algorithm is devised to solve a non-additive stochastic traffic assignment model.

The paper analyses the application of various charging systems, such as cordon-based, area-based, distance-based, travel time-based and delay-based charging systems, from three different aspects: i)- demand reduction level, ii)- improvement to the network's general performances; and iii)- benefits to the network's TTR performances. Numerical results for a small transport network represent that for a particular level of the demand reduction a lower charge is required for the risk-seeking travellers than others. It is also observed that the TTR benefits vary between 16% and 19% of the travel time savings. The paper also finds that the delay-based, area-based and time-based charging systems can be considered as the appropriate charging systems for improving travel time and TTR conditions in a network.

## **\$2 Daily Workplace Parking Charge + \$4 Cashout: Cut U.S. Commute VMT 23%**

Steve Raney

*steve\_raney@cities21.org*

*Cities21*

This congestion pricing policy offers large driving/CO<sub>2</sub> reduction similar to a \$5 per gallon gas tax increase, in a more politically palatable manner. Past efforts to convert free workplace parking to charged or cashout have not flourished. A "cashout" is where the employer pays employees not to park at the office. This new scheme begins with \$0.25/day charge and \$0.50/day cashout. Charges/cashout increase over time to \$2/\$4 as more companies adopt the scheme, addressing the previous recruiting/retention objection. Trust-based, self-reporting enables very low-cost implementation, addressing the previous cost objection. The scheme is marketed to workers as a climate-protecting measure. Potential U.S. commute VMT savings is 23%, reducing 51.7M tons CO<sub>2</sub>/year. Compared to past efforts, this scheme uses a) collective, phased action to overcome the Tragedy of the Commons, b) simultaneous charge and cashout, c) trust-based reporting, and d) monetization of saved parking spaces. A company that voluntarily implements this scheme risks productivity-reducing internal employee strife between climate protectors and climate skeptics. To address this objection, a "least- worse alternative" state-level meta-strategy is proposed.

A California state legislative proposal is provided, highlighting: State Employment Development Department monthly commute mode change data collection from employers, payroll software changes

to processors (Oracle, SAP, Paychex), enforcement, policy phasing conditioned on adoption by other states, environmental streamlining for virtuous employers, and exceptions “case law” development via an implementation commission. Particular scrutiny is given to implementation costs. Public resistance to other driving reduction policies is analyzed. The legislative proposal includes Sierra Club and tech business lobby endorsements.

This policy research is informed by behavioral psychologists, listserv communities of practice, and advocacy to nine large Silicon Valley employers. A web-based employee survey was developed to understand qualitative issues associated with the scheme. The survey presented the scheme as a policy debate, with pros and cons. Responses identified special cases in need of clarification and provided colorful and useful comments from the extreme ends of the response spectrum.

Especially for suburban commutes, the projected large shift in commuting patterns will accelerate further high tech ridesharing / carpooling innovation using smartphones and social networking.

### **Effect of Congestion Pricing on Environment due to Traffic Congestion in Urban Area (A Case study )**

D.Rajashekar Reddy

*dudipalars@yahoo.com*

*Osmania University*

Traffic congestion in urban areas, particularly in developing countries is posing a serious threat to the healthy economic development of the area. Due to rapid industrialization and urbanization, most of the cities in developing countries are witnessing mass migration of people from rural areas. Public transport facilities in most of the cities are inadequate in terms of frequency, punctuality, comfort and convenience which force commuters to prefer personalized vehicles which in turn is causing traffic congestion. Air pollution has been aggravated by developments that typically occur. Currently in India air pollution is wide in urban areas where vehicles are major contributors because of increase in urban population, increase in number of vehicles, increase in industrial activity etc.

The paper discusses the environmental impact of transport, particularly that of road transport. It reviews current conditions in Andhra Pradesh specifically Hyderabad, standards prevalent elsewhere and discusses measures that could be taken to reduce environmental damage by road transport in this paper we have also considered the effect of Congestion pricing on environment due to traffic congestion in Hyderabad city and to draw conclusions from study to ease the traffic congestion at different locations of the congested areas.

### **How Transit and HOV Reduce Traffic Congestion**

D.Rajashekar Reddy

*dudipalars@yahoo.com*

*Osmania University*

Urban traffic congestion tends to maintain equilibrium. If congestion increases, people change destinations, routes, travel time and modes to avoid delays, and if it declines they take additional peak-period trips. Reducing this point of equilibrium is the only way to reduce congestion over the long run. The quality of travel alternatives has a significant effect on the point of congestion equilibrium: If alternatives are inferior, few motorists will shift mode and the level of equilibrium will be relatively high. If travel alternatives are relatively attractive, motorists are more likely to shift modes, resulting in a lower equilibrium.

The actual number of motorists who shift from driving to transit may be relatively small, just a few percent of total travelers on the corridor, but that is enough to reduce roadway congestion delays. Congestion does not disappear, but it never gets as bad as would occur if quality transit service did not exist.

To attract discretionary riders (travelers who have the option of driving), public transit must be fast, comfortable, convenient and affordable. Grade-separated transit (such as rail on its own right-of-way or

buses with (HOV priority features) provides a travel time advantage that tends to attract discretionary riders. When transit is faster than driving, a portion of travelers shift mode until the highway reaches a new congestion equilibrium (that is, until congestion declines to the point that transit is no longer faster). As a result, the faster the transit service, the faster the traffic speeds on parallel highways. Other types of Transit improvements can also encourage motorists to shift to transit.

Shifting traffic from automobile to transit on a particular highway not only reduces congestion on that facility, it also reduces the amount of vehicle traffic discharged onto surface streets, providing “down-stream” congestion reduction benefits. For example, when comparing the congestion reduction benefits of a highway widening project with some sort of transit service improvement, the analysis should not be limited to just the highway that is expanded. It is important to also account for the additional congestion on surface streets where highway traffic discharges resulting from increased traffic volumes, and the reduction in surface street traffic congestion that would result if the transit improvement attracts highway drivers out of their cars.

Improving travel options can therefore benefit all travelers on a corridor, both those who shift modes and those who continue to drive.

In this paper we are going to consider the various alternatives to discourage the private vehicles for different routes of Hyderabad city and to attract the people to public transport.

## **Federal Programs and Public Transportation Financing and Pricing**

Robena Reid

*robena.reid@dot.gov*

*Federal Transit Administration*

This presentation will examine the role of Federal programs that assist public transportation projects, including TIFIA, the State Infrastructure Bank program and Build America Bonds. The presentation will examine trends in revenue streams that have been used to repay capital investment loans such as tax increment financing, assessment districts, and the monetization of toll road revenues. The presentation may also examine the recent changes in the Community Reinvestment Act and how these changes may promote additional public transportation investment.

## **User Fees for the Invisible User**

Rick Rybeck

*RickRybeck.JE@gmail.com*

*Just Economics, LLC*

There has been an explosion of interest in user fees for transportation infrastructure – both roadways and transit. This arises from the failure of the Highway Trust Fund to provide sufficient funds to maintain existing transportation infrastructure as well as to create new projects. It also arises from an understanding that user fees provide behavioral incentives that can encourage better transportation decision making. In other words, when properly designed and implemented, user fees can reduce excess demand, shift demand from peak to off peak, and, in some cases, encourage land use decisions that enhance the efficiency of the entire transportation system.

Yet practitioners too often ignore the concept of user fees for a group that benefits substantially from transportation investment. This “invisible” user group receives tremendous windfalls from transportation facility and service investments. Furthermore, their behavior often induces sprawl which hinders transportation efficiency, wastes scarce resources, and contributes to congestion, pollution and climate change. Fortunately, the application of user fees to this group can harness market forces and incentives that will encourage more affordable and more compact development – that can boost the efficiency of the existing transportation system and reduce the need for infrastructure expansion.

The invisible users of transportation investments are the individuals and corporations that own land that is best-served by transportation investments. It is well understood that the benefits of transportation investments are “lumpy.” In other words, they do not provide equal benefits to all areas. Some areas (near interchanges, transit stations, etc.) are better served and these areas command higher land rents and prices as a result.

Underassessment of land combined with relatively low rates of taxation make the cost of holding undeveloped (or underdeveloped) land relatively low. This allows landowners to seek land rents or prices in excess of what space users are willing to pay – often driving space users to more remote, less productive locations. Even when land is made available to space users, premium land values, generated by transportation investments, end up as windfalls to these landowners and are therefore largely unavailable to public agencies to fund debt service, operations or maintenance.

A higher tax rate on land values can serve as a “user fee” to landowners who benefit from transportation infrastructure investments. Not only does this practice help make transportation investments self-financing to a greater degree, but it can also induce landowners to develop land more intensely. More intense development of land near transportation facilities can reduce average trip lengths, enhance opportunities for shared transportation, and reduce the need to prematurely extend or expand transportation and related infrastructure.

Land taxes internalize significant externalities associated with transportation investments. Like other user fees, they can result in more equitable distribution of costs among beneficiaries and create more efficient land use patterns that conserve fiscal and physical resources while reducing unnecessary congestion, energy use and pollution.

This paper will focus on practical techniques, political considerations and examples of implementation.

### **Congestion Pricing for On-Street Parking**

Katsunobu Sasanuma; Robert C. Hampshire; Richard C. Larson

*ksasanum@andrew.cmu.edu*

*Heinz College, Carnegie Mellon University; MIT*

Drivers in urban neighborhoods who cruise streets, seeking inexpensive on-street parking create a significant fraction of measured traffic congestion. The solution to this problem is to reduce the total traffic volume including cruising traffic by implementing a congestion pricing scheme: the imposition of a usage fee on a limited-capacity resource during times of high demand. A parking pricing system is needed in many environments where a significant fraction of drivers are simply cruising, looking for inexpensive on-street parking.

In this presentation, we analyze the optimal level of parking pricing quantitatively by establishing a queueing model for parking behavior. We view that the pool of drivers cruising at any time can be modeled as a queue, where ‘queue service’ is the act of parking in a recently vacated parking space and queue discipline is SIRO – Service In Random Order. We develop a queueing model of such driver behavior, allowing impatient drivers to abandon the queue and to settle for expensive off-street parking. We then relate the model to the economic theory of congestion pricing, arguing that price differentials between on-street and off-street parking should be reduced in order to reduce traffic congestion.

Using the “Parking Queue” model and collected data, we can estimate the number of cruising drivers and the optimal parking price. Our survey in Boston shows that the number of cruising vehicles reaches 10-20% of the total number of parking spaces during peak hours and the required congestion price for

on-street parking is at least about \$1/ hour. The optimal congestion price could be much higher if we take into account environmental and health concerns when evaluating the cost of congestion. We further extend the model to include non-parking drivers and argue its impact on the necessary congestion price and the expected reduction of vehicle miles travelled (VMT).

### **New York City's Dysfunctional Tolling Scheme**

Sam Schwartz

*jknoller@samschwartz.com*

*Sam Schwartz Engineering*

New York City's tolling scheme is dysfunctional in the sense that over 500,000 people drive across the city's four East River Bridges every day, and they pay nothing. With last June's recent toll hikes by the Metropolitan Transportation Authority (MTA), neighborhoods like Bay Ridge, Brooklyn and Throgs Neck, Queens get sucker punched with higher tolls even though many of these residents never set tire in Manhattan, the root of most congestion.

While toll increases are necessary to maintain the city's vast transportation network, let's fix Mayor William Gaynor's 1911 blunder and toll the East River Bridges with all funds going towards New York City's transportation network.

### **Road Pricing and Freight Transportation Modeling: A Critical Review of Freight Modeling Approaches**

Kaveh Shabani; Miguel Figliozzi

*kaveh@pdx.edu*

*Portland State University*

Freight transportation is a critical component of modern production and service economies. In the last decades, freight growth surpassed the growth of passenger transportation. Ubiquitous, efficient, and less expensive transportation, communication, and information technologies have stimulated the extension of supply chains and the globalization of the world economy. In addition, companies have become increasingly responsive to customer demands, which include shippers' preference for fast and more reliable modes of transportation, smaller consignments, and the adoption of JIT (just-in-time), lean, and time based systems by service or manufacturing systems.

Public policies and freight transportation models have not kept pace with the fast evolution of supply chain and logistics. In large part, this is due to the growing gap between traditional four-step modeling approaches and the complex behavior of customer-driven supply chains. The workings of most customer-driven or international multi-echelon supply chains cannot be accurately captured by existing freight transport models at the international, national or regional level. As a result, most freight models have no behavioral link between private companies' operations and goals, public policy decisions, and freight transportation performance. The need to improve freight modeling is timely due to the emergence of new freight and policy issues such as tolling, the rapid fluctuations in energy prices and freight rate prices, and the growing need to support greenhouse gas and carbon emissions analysis as requested by state and federal agencies.

This research presents: (a) a critical review of existing freight models, developed inside and outside the US, in relation to their ability to model road pricing impacts on supply chains and freight flows, (b) an analysis of the unique and distinct characteristics of Oregon's supply chains and key commodities and their sensitivity to road pricing, and (c) the identification of freight modeling gaps, opportunities, and challenges.

## **A Heuristic Congestion Pricing Scheme for Capacitated Traffic Networks**

Amir Shahpar; Ardeshir Faghri

*ashahpar@udel.edu*

*University of Delaware*

Traditional congestion pricing schemes may not necessarily reduce traffic congestion to the level that does not violate maximum capacity of streets. This paper proposes a heuristic congestion pricing scheme that provides a financing pattern encouraging drivers avoid entering over-capacity streets. The proposed scheme is implemented by adding a continuously differentiable penalty function to the capacitated link travel time. The problem is formulated as an optimization model with generalized link travel time and is solved iteratively using GAMS. The value of the penalty function is updated dynamically while the solution method iterates. Numerical examples are presented to demonstrate the performance of the suggested pricing scheme. The results show that the proposed pricing scheme can successfully reduce traffic congestion by taking into account link capacities, whereas the conventional link-based Marginal-Cost (MC) pricing scheme does not. For the nine-node network, the MC pricing scheme achieves 1.937 for the maximum flow to capacity ratio, however, this ratio for the proposed pricing scheme can be as low as 1.0.

## **Optimal Deployment of High-Occupancy-Vehicle/Toll Lanes in General Networks**

Ziqi Song; Yafeng Yin; Siriphong Lawphongpanich

*ziqu@ufl.edu*

*University of Florida*

This paper considers the problem of how to deploy high-occupancy-vehicle/toll (HOV/HOT) lanes in general networks in order to maximize the social benefits. Key decisions in the problem consist of deciding roads in the network whose lanes to convert to HOV and HOT lanes. For the latter, the associated toll rates for single-occupancy vehicles must be determined as well. The problem is formulated as a mathematical program with complementarity constraints and solved using an active set algorithm. To illustrate decisions generated from the model and the effectiveness of the algorithm, numerical results using data from a network in the literature are presented.

## **Implications of Vehicle-Miles-of Travel Methodologies for Traffic Impact and Calculation of Vehicle Mileage Systems**

Ruth L. Steiner; Siva Srinivasan; Russell Provost

*rsteiner@dcp.ufl.edu*

*University of Florida*

In recent years increasing attention has been given to the use of vehicle miles of travel as a means of identifying the impacts of new development, closing the gap in the federal Highway Trust Fund, and in mitigating for the greenhouse gas emissions from the transportation sector. This presentation reports on the results of a study, funded by the Center for Multimodal Solutions to Congestion Mitigation, that develops a methodology for estimating trip lengths based upon land use characteristics and socioeconomic and demographic characteristics of the population in Southeast Florida (Miami-Dade, Broward and Palm Beach Counties). This methodology was developed using a mixture of methods, including analysis of trip diaries, outputs from regional transportation models, geographic information systems (GIS) data at the parcel, neighborhood and regional scale, and regression analyses. In the presentation, the methodology will be described, future areas for enhancement of the methodology and the implications for policy will be discussed.

## **Road Pricing Model with Multiple User Classes under Stochastic Capacity**

Li Su; Mingxin Li

*li.su@utah.edu*

*University of Utah*

Conventional static traffic assignment approaches are generally developed based on users' perfect knowledge of network and deterministic capacity assumptions. Recent empirical researches reveal that highway capacity is characterized by all natures of random variables. This is not surprising given that highway capacity is the result of driver behavioral interaction, and also depends on many external factors such as incidents, work zones, weather etc. The introduction of stochastic capacity at the critical points of networks which suffer from queue and congestion more frequently, i.e. freeway bottlenecks and signalized intersections, enables realistic modeling the impact of dynamic road tolls on travel time variability. Therefore, the mathematical model pertaining to traffic assignment can be more tenable under stochastic capacity framework with an ability to capture more network dynamics. To this end, this paper considers a road pricing model based on user equilibrium under stochastic capacity, which captures route choice behavior with multiple user classes (MUC). A new analytical framework is proposed by including the uncertainty of travel time and ATIS information strategies. An analytical approach is developed to quantify the network-wide impact of possible tolling strategies. Based on the analytical method, a number of insights are provided about impacts of road pricing on the measures of effectiveness (MOE) in transportation systems as well as the corresponding user cost savings and benefits. A numerical example is presented to illustrate the proposed methodology, explore how heterogeneous users respond to dynamic road tolls under stochastic capacity and indicate how the proposed model can be used to quantify the value of information (VOT).

## **Road Pricing Strategies To Resolve Both Emission and Braess' Paradoxes**

Wai Yuen Szeto

*ceszeto@hku.hk*

*The University of Hong Kong*

Braess (1968) presented a remarkable example and demonstrated a phenomenon that adding a new link can increase total system travel time. This phenomenon is known as Braess' paradox, which has been drawn great attention in the transportation area. In particular, Pas and Principio (1997) shows that the traditional marginal cost pricing can prevent the occurrence of Braess' paradox in the classical network. However, whether this pricing strategy can resolve Braesses' network and emission paradox discussed in Nagurney (2000) in general traffic networks is questionable, where emission paradox is said to occur when total emissions increase after adding new links to the traffic network. Moreover, whether both paradoxes always occur at the same time has not been studied yet.

In this paper, we analytically examine the occurrence of the emission paradox and the simultaneous occurrence of congestion and emission paradoxes in the classical Braess' network. We ascertain that the occurrence of emission paradox depends on the demand for travel, the parameters of link performance functions as well as link emission factors. We find that congestion and emission paradoxes do not always occur at the same time. We also discover that under some conditions of parameters in link performance functions, emission and congestion paradoxes must not occur, as new link is not used. More importantly, we show that the marginal cost pricing strategy cannot always prevent the occurrence of the emission paradox.

Ultimately, we propose new pricing strategies to prevent the occurrence of both paradoxes simultaneously in a general transportation network. The new strategies are compared with the existing and well known pricing strategies in some test examples. Results are provided to highlight the benefit of different pricing schemes.

## **Time-Dependent Tolling Strategies**

Wai Yuen Szeto

*ceszeto@hku.hk*

*The University of Hong Kong*

This paper develops a single-level optimization model to determine time-dependent optimal tolls while considering the dynamic relationships between land use, transport, and environment. To illustrate the importance of incorporating land use, transport, and environment considerations in determining time-dependent tolls, and the effect of tightening vehicular emission standards on link tolls, numerical studies are set up. The results show that the tighter the vehicular emission standards, the higher the toll charges are required, and that the vehicular emission standards have direct impacts on the overall vehicular emissions, the operational strategies and profit of public transit, the mode and route choices of travelers, the residential and employment distributions, the profits of land owners, and rents. The government should consider these impacts when determining the vehicular emission standard of each road.

## **Pareto-Efficient Build-Operate-Transfer Contracts and Regulations in Presence of User Heterogeneity**

Zhijia Tan; Hai Yang

*cezjatan@ust.hk*

*The Hong Kong University of Science & Technology*

Build-operate-transfer (BOT) road concessions are long-term contracts between governments and private firms. These contracts are designed to promote private participation in the building and operation of roads, and they seek to achieve several simultaneous objectives: construction and operation of the project at minimum cost; provision of quality services to drivers; efficient use of capacity by appropriate pricing; expansion of capacity according to social needs; and the financial equilibrium of the concessionaire (Nombela and de Rus, 2004). With the growing private participation in road projects around the world, there has been substantial intellectual and practical development in this area in recent years. A comprehensive treatment of road pricing, including private roads, can be found in recent monographs and reviews (Small and Verhoef, 2007; Lindsey, 2006; Yang and Huang, 2005).

Recently, Guo and Yang (2009) conducted a preliminary study on the selection of the concession period with deterministic demand and homogeneous users. They incorporated all three essential variables (concession period, road capacity and toll charge) and explicitly considered traffic congestion and demand elasticity for an optimal BOT contract. Tan et al. (2009) went further to examine the properties of the Pareto-efficient BOT contracts via bi-objective programming and discussed a variety of economic regulation mechanisms to achieve a predetermined Pareto efficient contract. Their analysis is restricted to a single highway with homogeneous users.

Small and Yan (2001) investigated the effects of heterogeneous degree on the efficiency of the toll policy by enlarging the VOT difference of two user classes and keeping the average VOT as a constant. They suggested that ignoring user heterogeneity may lead to serious underestimation of the efficiency of a value pricing highway policy. Verhoef and Small (2004) examined the extent of the effects of user heterogeneity on pricing policy by varying the type of the VOT distribution using in their numerical examples. They claimed that VOT distribution as “imperfect information” should be considered when applying a road pricing policy. Surely, in reality, since the VOT distribution is not exactly known, especially before a toll road project is conducted.

This consideration motivates us to reconsider the BOT problem built up on the study of Tan et al. (2009) and analyze the Pareto efficiency of BOT contracts for road franchising with heterogeneous users. A continuous approach for VOT distribution proposed by Dial (1999) is adopted in this study. Distinguished from various studies, the distribution family is assumed to have the property of increasing

failure rate (IFR), not a given VOT distribution. And thus, the analysis suits for the commonly used distributions, such as, uniform, normal, exponential, truncated normal distributions and other distribution families. Under some widely used assumptions, the level of service, represented by the volume-capacity ratio, is dependent on the curvature (convex, affine or concave) of the mean residual VOT function of the VOT distribution. This paper also investigates the behavior of the profit-maximizing private firm under various economic regulations including the price-cap and rate-of-return (ROR), demand and markup regulatory mechanisms.

## **PLENARY PRESENTATION**

### **Thinking about Equity in Transportation Pricing and Finance**

Brian D. Taylor

*btaylor@ucla.edu*

*University of California*

Concern with the sustainability of auto-dependence, chronic metropolitan traffic congestion, and decades-long erosion in the buying power of motor fuel taxes has left many public officials looking for ways to increase the efficiency, equity, and financial stability of transportation systems. One approach to both increase transportation efficiency and secure new revenues is to meter road use with electronic tolls. While technological advances make such tolling easier, cheaper, and more reliable than ever, many worry that charging people for driving on public roads is unfair, even un-American. Such concerns reflect the complex, and sometimes confusing, nature of road pricing and its outcomes. This presentation first examines road pricing equity from a variety of perspectives to shed light on the often competing views of equity in political debates over pricing. Second, I propose an evaluation framework that defines three distinct bases for evaluating equity. Given this framework, I then review some of my empirical work comparing the equity of road pricing with other common methods of transportation finance. Fourth, I examine how equity concerns have been raised and addressed in practice, through an examination of several cases studies. And finally I identify strategies that have proven most effective in mitigating equity concerns and overcoming opposition to road pricing on equity grounds.

### **Congestion Pricing and Greenhouse Gas Reduction: Possibilities**

David Ungemah

*ungemah@pbworld.com*

*Parsons Brinckerhoff*

The transportation sector's contribution to global greenhouse gas (GHG) emissions is neither trivial nor unruly. However, stabilizing total sector emissions at current levels involves onerous policy options: doubling fuel economy, conversion to carbon-neutral fuel sources, or dramatic reduction in annual vehicle miles traveled. Furthermore, total success with energy-based options does not address growing traffic congestion and public health. Congestion pricing, though, provides for stabilization of flow conditions, reduction in vehicular hours of travel, and minimization of GHG emissions at stop-and-go conditions. The use of price signals and structural options in congestion pricing are identified, including the collaboration between congestion pricing and carbon credits. When examined holistically, congestion pricing provides a key pillar in the provision of a sustainable transportation system, with a focus on operations and management strategies, providing for an internal balance in demand and capacity, and appropriately leveraging spatial and temporal awareness technologies.

## Why Congestion Tolling Could Be Good for the Consumer: The Effects of Heterogeneity in the Values of Schedule Delay and Time on the Effects of Tolling

Vincent van den Berg; Erik T. Verhoef

*vberg@feweb.vu.nl*

*VU University*

In studying congestion tolling, it is important to account for heterogeneity in preferences of drivers, as ignoring it can bias the welfare gains. We analyse the effects of tolling, in the bottleneck model, with continuous heterogeneity in the value of time and schedule delay. The welfare gain of a time-variant toll increases with heterogeneity in the value of schedule delay. With heterogeneity, tolling makes the arrival ordering more efficient, and this lowers scheduling costs. If there is not much more heterogeneity in the value of time than in the value of schedule delay, then first-best tolling decreases the generalised price for most users. In our model, first-best tolling is not most detrimental for the lowest values of time and schedule delay: it raises prices more for users with an average value of schedule delay and a slightly larger value of time. Further, the lowest values of time are among those who gain most from a public pay-lane.

## Variable Rate Structure for Efficient, Equitable, and Stable Mileage-based User Fees

Tra T. Vu

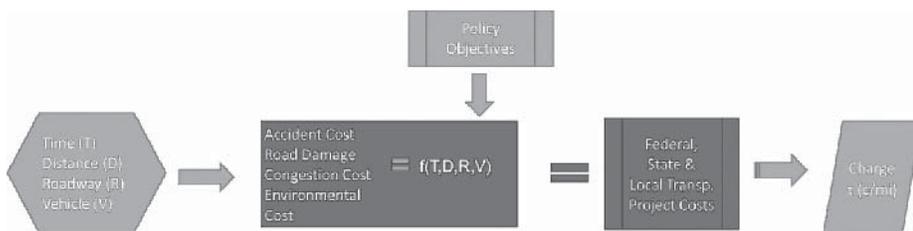
*bachdiep85@gmail.com*

*Polytechnic Institute of NYU*

In recent decades, there have been considerable effort by different authorities to influence the way people drive. This is partly fueled by limited capacity, increased congestion, rising accident rates, and motor vehicle related pollution costs. One of the tools that are often employed by policy makers is road pricing. Unfortunately, road pricing in the United States has been limited in scope, such as in the case of tolling and congestion pricing schemes.

A new movement toward national scheme for road pricing has been implemented in some European countries, and is being pilot studied in the United States. It is clear from the amount of research funding and the results of past pilot studies that there would be a transition from fuel tax to distance-based charge as the main source of transportation revenue. The potentials are limitless and thus its rate structure should reflect such expectations.

Variable Rate Structure is a framework for determining the appropriate charge per mile of distance traveled by motorway users. The structure utilizes social cost equity as the fundamental principle to calculate rates that are tailored to each user's specific vehicle characteristics and road network usage. An illustration of the variable rate structure is below.



Variable rate structure considers specific vehicle, infrastructure, spatial, and temporal attributes. Firstly, adjustments for vehicles include fuel efficiency, weight, and emission levels are made. Secondly, infrastructure, such as roadways, bridges, and tunnels are adjusted based on construction and maintenance needs. Thirdly, local jurisdiction has different financial obligation and demographic. Finally, time adjustments for peak hour and inflation are applied.

The charge obtained from the model would be an average charge for a region over a period of three months. This amount is the target for that quarter, to which all vehicle charges are adjusted weekly to reflect such target.

For end user, the charge is tailored to their specific vehicle, roadway, time and distance of travel. Success of the model is clarity of charges that will, in turn, influence users' travel patterns.

It is suggested that the revenue obtained go directly to the region's transportation fund, as the charge was calculated based on its needs. Furthermore, public acceptance of a national-scale road pricing scheme depends heavily on transparency in revenue usage, which is more manageable at the local level.

### **Modeling the Behavior Responses of Freight Carriers towards Time of Day Pricing in a Competitive Urban Freight Market**

Qian Wang; José Holguín-Veras

*qw6@buffalo.edu*

*University at Buffalo, The State University of New York; Rensselaer Polytechnic Institute*

With the introduction of various congestion pricing strategies in urban areas, one important "actor" of urban transportation systems, i.e., freight carriers, need special attention. Compared to passenger car users, freight carriers have a higher value of time, higher sensitivity to the scheduled time windows and different components of the generalized travel cost, which determines their different responses to congestion pricing schemes. Meanwhile, due to the diversity of business operations, freight carriers may adopt more types of changes in response to congestion pricing strategies. For instance, they may change the shipping frequency, shipping schedules, tour length, routes, vehicle types, or any combination of them. Moreover, the involvement of multiple participants, such as carriers, shippers, and receivers, makes it very difficult to explain why some responses are made instead of others. These characteristics challenge the impact studies of congestion pricing, particularly on commercial vehicle flows in urban areas.

This paper is intended to assess the behavior responses of freight carriers towards congestion pricing using discrete choice modeling. The survey data used for the modeling purpose was collected for the Port Authority of New York and New Jersey (PANYNJ) in 2004. In this survey, 200 carriers who had been the regular users of the major PANYNJ's toll facilities to Manhattan were asked about their behavioral changes following the implementation of the PANYNJ's Time of Day Pricing initiative in 2001. Among them, 36 carriers changed behavior because of the Time of Day Pricing initiative. They responded by implemented multi-dimensional responses involving: (1) cost transfers to the customers; (2) change in facility usage such as changing the frequency through the toll facilities; and (3) productivity increases by adjusting vehicle types, delivery routes, shipment size and so on. In general, the carriers who have more market power when interacting with their customers tend to transfer toll costs while the ones who have less market power will absorb the impact of tolls by adopting the second and third types of changes.

Two types of discrete choice models were developed to assess the impacts. The first group of models focuses on carriers' choices of whether to make a change or not in response to the Time of Day Pricing by using binary Logit modeling while the second one looks into the specific changes adopted by carriers using ordered Probit modeling. As found, in terms of decisions of whether to change or not, longer the carriers had been using the toll facilities, more likely they would make changes in response to the Time of Day Pricing initiative. Meanwhile, if carriers were aware of the off-peak toll discounts, they tended to make changes, most likely to either switch to or increase the use of E-ZPASS. In terms of the specific changes, carriers who visited more customers along their journeys or had larger shipment size were more likely to directly transfer tolls to their customers. However, if they were aware of the off-peak toll discounts, they would prefer switching to or increasing the use of E-ZPASS to cost transferring.

## **A Behavior-Based Simulation Tool for HOT Lane Operations**

Di Wu; Yafeng Yin; Trey Tillander; Mark Plass

*wudi@ufl.edu*

*University of Florida; Florida Department of Transportation*

High occupancy toll (HOT) lanes have gained a lot of interests in US as a way to reduce traffic congestion. At least seven HOT lane projects are operational in US since the first HOT implementation in 1995 on State Route 91 in Orange County, California. Currently, there are three different pricing strategies being considered for different HOT projects: flat rate, time of day and dynamic tolling. However, there is little research on the overall benefit of different pricing strategies in the HOT managed lane systems. Most, if not all, research to date considers hypothetical and idealized situations in which analytical solutions can be derived. In this paper, a behavior-based simulation model is developed based on the 95express project in Miami, Florida to analyze the travelers' response to the pricing strategies in the managed lane systems. The simulation model captures users' day-to-day learning, departure time and lane choice behavior in reaction to the travel time and toll rate. A macroscopic cell transmission model is adopted to calculate the traffic flow condition based on the aggregation of users' choice decision. The simulation model is used to analyze the HOT lane demand under different price strategies. The result of our model shows that the current pricing method is effective in reducing travel time of the managed lanes. However, when the total demand for the freeway segment is high, the travel demand on HOT lanes may exhibit a hysteresis-like behavior where travelers periodically shift their departure time and lane choice on a day-to-day basis.

## **Price and Investment Competition in an Oligopoly Market**

F. Xiao; H.M. Zhang

*fxiao@ucdavis.edu*

*University of California at Davis*

This paper studies a static model of oligopoly in which there is only one stage of competition interaction and firms take their actions simultaneously. Following the definition of static oligopolistic competition, every firm takes the other firms strategies as given, and then makes its own decisions based on profit maximization. Equilibrium is reached when no firm can substantively increase its profit by changing its current strategies. In the research literature of oligopoly markets, different choices or combination of choices of independent variables that firms can control usually lead to different specific oligopoly models and findings. Unlike basic oligopoly models including only one variable (e.g. price of the product in Bertrand model or quantity of the product in Cournot model), considering a set of variables in a strategy set makes the model more complicated. This paper considers oligopoly competition in service industries with two independent variables in one strategy set, the price and the capacity of the service. We assume that firms provide exactly the same type of service and they compete for identical customers, i.e. every customer has the same valuation of the service. Since there is congestion effect, adding more people to the service will cause external cost on others who have already been using it. The demand of people using the service provided by a firm is determined by the generalized total cost of using this service, comprising the price given by the firm and the congestion cost which can be transferred equally to monetary cost. Now to attract more customers, a firm has two choices, lowering the service charge or reducing the level of congestion by investing more to expand the capacity of the service. Many applications can be found for such a model in real life, for instance, the competition among privately owned and operated roads when they are parallel with each other and controlled by different private firms, or internet telephony companies competing by providing the same calling service through data networking.

While looking into the interrelations among pricing and capacity choices, a restrictive assumption is usually made in previous studies: The market exhibits constant returns to scales in capacity production. In this study we develop a more realistic model to adopt different returns to scale in investment (increas-

ing, decreasing or constant) in which cost structure determines the market outcomes and firms perform differently leading to different equilibria. General situations are studied including asymmetric markets, general demand functions and nonincreasing returns to scale in investment. The paper will be organized as follows: First we provide the definition of returns to investment and sensitivity analysis results as preliminaries; then we compare the market outcomes of social optimum and Nash equilibrium. We discuss what causes the difference between them and when this difference disappears; in the last part we bound the efficiency loss of symmetric market with nonincreasing returns to investment by considering general inverse demand functions. In addition to the analytical results, exact bounds are provided for some specific cases.

### **Private Toll Road Financing and Regulation on a General Network**

Lei Zhang

*lei@umd.edu*

*University of Maryland*

The objective of this paper is to develop a methodology for analyzing optimal regulatory policies on private-sector transportation investment, and demonstrate its applicability in real-world situations. In order to optimally leverage private-sector investment resources in road financing, the analytical tool must jointly consider pricing choice, capacity expansion, mixed ownership, and regulatory decisions on large-scale networks (i.e. the Network Regulation Problem, or NRP). In reality, these four categories of decisions are usually made on different time scales. Equilibrium models developed for the reduced optimal pricing or joint pricing-investment problem already suffer from computational complexity issues in large-scale applications. The introduction of two additional dimensions, namely mixed ownership and regulation, implies the presence of both welfare-maximizing and profit-maximizing objectives in the modeling process with additional regulatory constraints.

In terms of research design, this paper overcomes the aforementioned modeling difficulties by combining the strengths of mathematical programming models in representing optimizing behavior and the advantages of agent-based techniques in simulating dynamic interactions on dissimilar time scales in large complex systems. This methodology produces an evolutionary model in which each agent (e.g. user, private road, public road) at any given decision time adjusts its own optimizing behavior based on available historical system information. These micro-level optimizing decisions collectively drive the macro-level dynamics of the mixed-ownership road system. The proposed model considers user choices in an multi-agent demand module, econometric cost structures, pricing and capacity choices by public and private roads, market entry decisions by private roads only, and optimal regulation. Each agent is modeled with unique characteristics and preferences. Private investors base their market entry decisions on the estimated returns of investment on candidate private road projects, which requires the determination of long-run profit-maximizing capacity levels and short-run profit-maximizing user charges. This evolutionary model of network regulation has been calibrated with primarily cross-sectional data and limited stated-preference data for a large-scale real-world road network system with almost 8,000 nodes and more than 20,000 roadway links.

Regulatory policies on private toll roads considered in this paper include:

1. Price ceiling: The user charge or toll on private roads cannot exceed a certain level;
2. Revenue/Profit Sharing: Private toll roads share a certain percentage of their profits with the public authorities;
3. Concession Agreement: Private toll roads transfer the ownership to the public authorities after a pre-determined concession periods;
4. Shadow Toll: Private toll roads do not directly charge their users, but receive payments from the public authorities based on traffic volumes served.

From a welfare-maximizing point of view, a ceiling toll of \$0.21/Kilometer produces the optimal price-ceiling regulation on the test network; while user benefits measured by consumer surplus are maximized at a ceiling price of \$0.16/km. Under profit-sharing regulation, social welfare and user benefits are both maximized with a 70% profit-sharing agreement. It is interesting to note that multiple local optima exist in network regulation problems, which interestingly offers the public sector advantages in contracting negotiations. Concession agreements are less effective than profit-sharing in maximizing user benefits, but are more effective than price-ceiling in this regard. Shadow toll is the least effective policy of all four regulatory tools examined, which significantly hurts users when applied at the system level because it creates incentives for over-investment by the private sector.

### **A National System of Variable Distance-Based User Charge for Revenue Generation, Congestion Mitigation, and Sustainable Transportation**

Lei Zhang; Jasmy Methipara; Andrea Robitallie; Yijing Lu

*lei@umd.edu*

*University of Maryland*

The Congressional Budget Office (CBO) has made astute observations over the past few decades regarding the potency of the Highway Trust Fund and its ability to provide funding to not only complete the highway system but to maintain it as well. The CBO Interstate Highway System – Issues and Options Reports provide an ominous picture of accumulating repairs, escalating construction costs, and declining revenue sources as vehicles become more fuel efficient. These reports continuously identify these problems over time as “major problems.” Two commissions were also created by the U.S. Congress under the Safe, Accountable, Flexible, Efficient Transportation Equity Act – a Legacy of Users (SAFETEA-LU): The National Surface Transportation Policy and Revenue Study Commission and the National Surface Transportation Infrastructure Financing Commission. After comparing dozens of future transportation financing options, both Commissions have recommended distance-based user charge, i.e. vehicle mileage fees, as the medium- to long-term financing mechanism. The successful design and implementation of distance-based user charge schemes requires information on user responses, revenue generating potentials, distributional effects (by region, state, household types etc.), and its impact on other major transportation issues including congestion and sustainability.

This paper develops analytical tools for designing and analyzing a national system of variable distance-based user charge with revenue generation as the primary objective that also considers distributional effects, congestion mitigation, and energy and environmental issues. Data sources for the modeling efforts include national-level household surveys, historical link-by-link vehicle miles traveled information, vehicle fleet fuel efficiency, and vehicle emission ratings.

The effectiveness, equity, and sustainability implications of the following distance-based user charges are examined and compared at the national and state levels:

1. Nation-wide flat vehicle mileage fee with fixed rates;
2. Variable vehicle mileage fee based on vehicle fuel efficiency;
3. Variable vehicle mileage fee based on level of congestion;
4. Variable vehicle mileage fee based on vehicle emission ratings;
5. More sophisticated variable fee structures designed with multiple objectives.

## **Congestion Pricing under Travel Time Uncertainty: A Game Theory Perspective**

Peng Zhang; Qian Wang; Jun Zhuang

*pzhang5@buffalo.edu*

*University at Buffalo, the State University of New York*

The optimal toll design problems, as a key component of congestion pricing initiatives, remain as a challenging topic. The major issues come from the complexity of transportation systems, including dynamics of traffic flows, behavioral heterogeneity of multiple participants, diversity of application cases, and so on. To solve these issues, many research and studies have been done to look for best tolling strategies from both the theoretical and application sides. However, another important issue, i.e., travelers' diverse responses towards travel time uncertainty and the effects of them on congestion pricing strategies have been paid much less attention compared with the efforts on mean-travel-time-based pricing.

To solving this issue, this paper develops a game-theoretic framework that is aimed to design effective tolling schemes given travelers' different attitude towards travel time uncertainty. This approach solves the optimal toll design problems as a sequential game played by multiple players (road authorities, and various types of road users who value travel time uncertainty differently) in the system. The conceptual framework is a feedback process that dynamically updates toll schemes: in the upper level of the game, road authorities choose toll schemes based on their knowledge of traffic conditions and travelers' potential responses; then, in the lower level, travelers determine their routes based on their perceived mean travel time, travel time uncertainty, and the amount of toll charge of each route alternative; furthermore, travelers' responses result in new traffic flow patterns in the transportation network, and affect road authorities' next-period tolling decisions. The iterative procedure continues until the system reaches its equilibrium. The research outcomes from the framework are the optimal toll schemes that achieve the system optimization.

To assess the effects of travel time uncertainty on pricing strategies, three groups of people are defined, i.e., risk averse, risk neutral, and risk seeking people, according to their different responses towards travel time uncertainty. Among the three groups of travelers, risk neutral people are most likely to choose route alternatives with least uncertainty while risk seeking people is on the opposite. Different utility functions are developed for the three groups of travelers respectively to represent this behavioral heterogeneity.

A small network including one OD pair and two potential routes is used to test the feasibility of the game-based approach. As found, in a static situation, the toll charges resulted from the proposed approach are generally higher than the tolls from the approaches that don't consider the effects of travel time uncertainty. In a dynamic situation in which both the mean travel time and travel time uncertainty evolve with time, the resulted tolls are initially higher, but will guide travelers in a more efficient way that the reliability of the network is improved continuously while the toll charge is reduced eventually.

# Conference Map

