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Credit-based congestion pricing: A Dallas-Fort Worth application

Pradeep K. Gulipalli[a,1], Kara M. Kockelman[b,*]

[a]Marketing and Planning Systems, 201 Jones Road, Waltham, MA 02451, USA
[b]The University of Texas at Austin, ECJ 6.9, Austin, TX 78712, USA

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Abstract

Under a credit-based congestion pricing policy, net revenues are distributed uniformly among qualifying travelers, to partially offset toll payments. This work predicts the traffic impacts, air-quality changes, welfare effects, and system implementation costs of such a policy, as applied to the Dallas-Fort Worth (DFW) region of Texas. Joint destination-mode choice models were estimated and applied. The status quo and two marginal cost pricing (MCP) scenarios were simulated for the short and long terms, with full feedback of trip costs and times. Monetarized logsum differences suggest that marginal cost pricing of congested freeways in this urban region, followed by travel credit distribution to all workers, is welfare improving for the great majority of such travelers. Moreover, high levels of recurring congestion (V/C ratios exceeding 1.5) are predicted to practically disappear.

Keywords: Congestion pricing; Marginal cost pricing; Travel demand models; Traveler welfare; Transportation policy

1. Introduction

Building new roads or increasing capacity of existing roads to alleviate congestion is generally expensive. Moreover, capacity increases can allow latent demand to consume much of the travel time savings. Many agree that regions cannot build themselves out of congestion, so demand management is key. Strategies include making the trips shorter and fewer, and spreading them over different modes, routes and time periods. This may be achieved by tolling congested roads, or congestion pricing (CP). Early work in CP includes that by Vickrey (1963), who observed that efforts were made to differentiate peak and off-peak demand in several markets (e.g., hotels, telephone, and theatres), and that something similar for transportation would be useful. Following Vickrey (1963), researchers have extensively discussed the potential of CP for congestion mitigation. However, there are many issues at play, including adverse equity impacts. Small (1992) proposed commuter travel allowances, Parry and Bento (2001) recommended income tax reduction, and DeCorla-Souza (2000) suggested toll credits for regular drivers via FAIR (Fast and Intertwined Regular) lanes.

Kockelman and Kalmanje (2005) proposed another version of CP, called credit-based congestion pricing (CBCP), to counter CP's adverse effects. CBCP provides eligible travelers (to be defined) with travel budgets that can then be used to travel on priced roads. Individuals who exhaust their monthly travel budgets must pay out of pocket to keep driving. The budgets are determined by the previous month's net revenues. Kockelman and Kalmanje (2005) polled the Austin, TX public and found that CBCP may compete reasonably well with transportation policy alternatives, particularly once users become more familiar with such policies—and experience tolling firsthand. Kalmanje and Kockelman (2004) predicted Austin trip-based welfare impacts and land value changes under CBCP (travel budgets were assumed to be provided to all the residents with a valid drivers license in this case) and f ound that this policy benefited most residents, whereas standard CP (without revenue redistribution) benefited relatively few. However, the above analysis does not consider benefits from CP revenue for the standard CP scenario. Gulipalli et al. (2005) interviewed transport economists, toll technology experts, administrators,

*Corresponding author. Tel.: +1 512 471 0210; fax: +1 512 475 8744.
E-mail addresses: pradeepg@gmail.com (P.K. Gulipalli), kkockelm@mail.utexas.edu (K.M. Kockelman).
[1]Tel.: +1 781 642 6277; fax: +1 781 642 9508.

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policy-makers, and commercial users to gauge their opinions and concerns about CBCP. Based on expert feedback, they concluded that CBCP may be politically and technologically viable and provided recommendations for its implementation.

This work studies the impacts of a CBCP policy for the Dallas-Fort Worth (DFW) region of Texas. Joint destination-mode (DM) choice models were estimated and applied to the 1999 DFW road network (using 1999 trip productions) for five times of day. Three scenarios were simulated: the status quo (which includes flat tolls on many existing freeway links), marginal cost pricing (MCP) on freeways, and MCP on all roads. The impacts of a CBCP policy in the DFW region were studied in terms of predicted traffic, air-quality, and welfare changes. Kockelman et al. (2005) and Gulipalli (2005) discuss all the above in substantial detail. Due to space limitations, the focus of this paper is on predicted impacts. The following sections summarize the travel demand model estimation and application procedures, predicted traffic impacts in terms of changes in vehicle miles traveled (VMT), mode shares, congestion levels, speeds, and tailpipe emissions. This is followed by a discussion of revenues, costs, some "typical" commute tolls, and travel budget estimates. The welfare changes for various demographic groups also are discussed. Limitations of this work and opportunities for enhancements are described before concluding the paper.

2. Joint destination-mode choice model estimation

Joint DM choice models predict the trip-end (attraction zone) choice of an individual traveler and also his/her travel mode. Various zonal attraction and demographic variables were used to model choice of 4874 destination zones and four modes for three trip purposes based on 32,799 trips in the 1996 DFW household survey dataset and Dallas Area Rapid Transit on-board survey dataset as provided by the North Central Texas Council of Governments (NCTCOG). The four modes include drive alone, shared ride, transit, and walk/bike, and the three trip purposes are home-based work (HBW), home-based non-work (HBNW), and non-home-based (NHB). Assuming independence of irrelevant alternatives (IIA), multinomial logit models were estimated with nine destination alternatives (the traveler chosen destination zone plus eight randomly selected zones). A non-linear-in-parameters specification was used. The choice set was limited for some observations since all the modes were not available for all origin–destination (OD) pairs.

Land area, population, and total employment were included in the model in a log-linear fashion. Three income categories and two vehicle ownership categories were used. Departure time choice models could not be estimated since there were only peak and off-peak travel times to start with (not enough to differentiate the five time periods). Also, the transit on-board survey data did not have time of day information.

The values of travel time (by income group and trip purpose) were constrained in the joint DM choice models since the coefficient on the cost turned out to be positive indicating a negative value of travel time, which is unreasonable. The constrained values ranged from \$4 to \$10 per hour, depending on the trip type and the demographic group. The model structure and the estimation procedure are discussed in greater detail in Gulipalli (2005). These models were applied to the DFW region.

3. Travel demand model application

Joint DM choice models were applied to the DFW region to simulate three scenarios: the status quo, MCP-on-freeways, and MCP-on-all-roads. The zonal trip productions for each trip purpose were available for six demographic groups based on income category and vehicle ownership. They were split across five time periods (per day) based on percentages observed in the 1996 DFW household survey: night off-peak (9:00 p.m. to 6:00 a.m.), AM peak (6:00 a.m. to 9:00 a.m.), day time off-peak (9:00 a.m. to 3:30 p.m.), PM peak (3:30 p.m. to 7:00 p.m.), and late PM (7:00 p.m. to 9:00 p.m.). The joint DM choice model was used to compute the probabilities of different mode-destination alternatives, which were used to compute the production–attraction matrices. OD trip tables were obtained from the production–attraction matrices using trip return rates and average vehicle occupancy information, obtained from the survey. Trip return rates give the number of trips starting at home as a proportion of total home-based trips.

TransCAD's multi-mode multiple-user module with stochastic user equilibrium assumptions was used for assigning OD trip tables (weighted by joint DM model probabilities) on to the 1999 DFW road network. Separate networks were used for shared ride and non-shared ride trips, in order to account for HOV lanes. The following standard Bureau of Public Roads formulation was used to define volume–delay relationships on the links:

$$t = t_f\left[1 + \alpha\left(\frac{v}{c}\right)\right]^{\beta},$$

where t is the link's travel time, t_f is its free-flow travel time, v is link volume, c is link capacity, α and β are calibration parameters. The standard formulation was used here, with values of 0.15 and 4 for α and β, respectively. The generalized cost expression (involving travel time and cost) for the MCP cases was derived from the Bureau of Public Roads function (using first derivatives of a link's total travel time [tv] as an efficient toll).

In order to obtain system equilibrium, OD travel times and costs resulting from estimated travel patterns must be consistent with those used to obtain the travel patterns. Boyce et al. (1994) have noted opportunities for convergence issues when using basic feedback across the travel demand modeling system (where network skims of all travel times are fed back simply and directly, to upstream models of trip distribution and mode choice). To overcome