

1. Report No. SWUTC/03/167822-2	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle CREDIT-BASED CONGESTION PRICING: TRAVEL, LAND VALUE AND WELFARE IMPACTS		5. Report Date October 2003	
		6. Performing Organization Code	
7. Author(s) Kara M. Kockelman and Sukumar Kalmanje		8. Performing Organization Report No. Report 167822-2	
9. Performing Organization Name and Address Center for Transportation Research University of Texas at Austin 3208 Red River, Suite 200 Austin, Texas 78705-2650		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. 10727	
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas Transportation Institute Texas A&M University System College Station, Texas 77843-3135		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes Supported by general revenues from the State of Texas.			
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17. Key Words Credit-Based Congestion Pricing, Integrated Transportation-Land Use Models, Travel Demand Modeling, Transportation Policy		18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161	
19. Security Classif.(of this report) Unclassified	20. Security Classif.(of this page) Unclassified	21. No. of Pages 34	22. Price

**CREDIT-BASED CONGESTION PRICING:
TRAVEL, LAND VALUE AND WELFARE IMPACTS**

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Research Report SWUTC/03/167822-2

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October 2003

ABSTRACT

This study explores the possible transportation and land-rent impacts of a new congestion management policy called credit-based congestion pricing (CBCP). Integrated land use-transportation models provide short- and long-term estimates of travel demand, network operations, location choice, and land use patterns. Using destination, mode and departure time choice models sensitive to changes in travel times and costs, household travel demands were simulated in order to appreciate the transportation effects of a CBCP policy for Austin, Texas. Changes in land use, locational accessibility and land rents as a result of CBCP also were simulated. Together, the transportation and land value benefits and costs The trip-based welfare impacts of such a policy were compared for three scenarios (full network pricing, major highway pricing only, and no pricing), in order to identify households and neighborhoods that will benefit most and least from such policies. The results corroborate prior results and hypotheses about the potential of a CBCP policy to alleviate congestion and generate benefits across the region income groups and traveler types.

Key words: Credit-based congestion pricing, integrated transportation-land use models, travel demand modeling, transportation policy

EXECUTIVE SUMMARY

This study explores the possible transportation impacts of a new congestion management policy called credit-based congestion pricing (CBCP). CBCP is a revenue-neutral policy where road tolls are based on the negative externalities associated with driving under congested conditions; its generated tolls are returned to all licensed drivers in a uniform fashion, as a sort of driving “allowance”. Surveys in Austin region indicate that the public is open to the concept of CBCP. A CBCP policy has immense potential to alleviate congestion and also generate benefits across income groups and traveler types. It is of interest to practitioner to be able to quantify these impacts.

Before implementation of any policy such as CBCP, the planners, public, and policy makers generally desire for reliable predictions of travel demand, land use, air quality, and welfare impacts. Modeling of these impacts can also help in comparison and evaluation of network-wide and corridor-specific alternatives, CBCP and standard marginal-cost CP strategies, and other scenarios. In this study, choice models destination, mode and departure time - sensitive to changes in travel times and costs were calibrated. Joint multinomial logit models for mode and time of day were calibrated considering four modes (drive alone, shared ride, transit, and walk/bike) and five time periods. In the multinomial logit destination choice model, the variability of destination attractiveness across mode and time of day was captured using logsums of travel times, travel costs and alternative-specific constants obtained from the mode-departure time model. Static equilibrium models of traffic assignment were used to predict changes in traffic volume and corresponding travel times and costs under two CBCP scenarios: system-wide pricing and pricing on main roads only.

A regression model for residential home values was calibrated using on residential sales data for Austin’s Travis County, recognizing that land’s underlying value depends, in part, on neighborhood accessibility. Consumer surplus at the destination choice level after the policy change has been used as the welfare measure in this study since it provides an excellent holistic/comprehensive measure of impact, capturing impacts on destination, mode and departure time of day choices. The trip-based welfare impacts of such a policy were compared for three scenarios (full network pricing, major highway pricing only, and no pricing), in order to identify households and neighborhoods that will benefit most and least from such policies. The results of the model application to various policy scenarios suggest that most Austin residents would be better off under policies that employ CBCP, whereas relatively few would benefit under a policy of congestion pricing, without beneficial revenue redistribution. Using the home values model and results from the travel demand models, predictions were made about changes in home values following a CBCP application. While central Austin property values decreased slightly following CBCP, home values increased moderately everywhere else.

The study results corroborate prior results and hypotheses about the potential of a CBCP policy to alleviate congestion and generate benefits across the region income groups and traveler types.

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ACKNOWLEDGEMENTS

The authors recognize that support for this research was provided by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the Southwest Region University Transportation Center which is funded 50% with general revenue funds from the State of Texas.

We wish to thank Sriram Krishnamurthy for his valuable input during every stage of the work. Many thanks to Alex Marks for leading the CBCP focus groups and for his contributions toward the property value and land rent model. Thanks are due to CAMPO's Daniel Yang, the City of Austin Spatial Analysis Group's Paul Frank, and Parsons Brinkerhoff's Karen Smith for assistance in obtaining data and resolving data issues. Thanks also go to Sriharsha Nerella, for useful discussions during different stages of this work.

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CHAPTER 1 – INTRODUCTION

Users and planners of transportation systems alike have long been grappling with the problem of increasing road congestion. Road congestion is an externality that results in substantial time losses¹; and it is no surprise that Americans consistently rank it among the top three regional policy issues, along with education and crime. (See, e.g., Scheibal, 2002, Knickerbocker, 2000 and Fimrite, 2002.) During peak-periods of demand, drivers tend to over-utilize the common road resource without paying for or even noting the associated, marginal costs borne by fellow travelers. As a result, a wide variety of demand management policies (intended to control congestion) have been proposed. Congestion pricing, a popular policy with researchers and economists, (e.g. Vickrey, 1963 and 1969, Arnott et al, 1993, Button and Verhoef, 1998, Small and Yan, 2001) has only recently garnered significant attention by the public and policy makers (e.g., Hyman and Mayhew, 2002, Litman, 2003).

Congestion pricing (CP) is based on the principle that if people pay the true marginal cost of road use, the congestion externality is internalized and lower but more efficient levels of road use result during peak periods. While there are many advantages to this approach (see, e.g., Vickrey, 1963, and Arnott and Small, 1994), the major criticism has been the adverse equity impacts on low income groups and others with special travel needs. Dial (1999), Viegas (2001), DeCorla-Souza (2000), Daganzo (1995), Nakamura and Kockelman (2002), Poole and Orski (2003) and Rothengatter (2003) have all proposed alternate pricing methodologies for addressing CP equity issues². To tackle the equity issue, Kockelman and Kalmanje (2003) proposed a revenue-neutral policy called credit-based congestion pricing (CBCP), where tolls generated from marginal cost pricing (MCP) are returned to all licensed drivers in a uniform fashion, as a sort of driving “allowance”. Under CBCP, the “average” driver pays nothing, the below-average driver makes some money, and frequent, long-distance and peak-period drivers pay something out of pocket, in effect paying others to stay off congested roads. As CP gains attention and application, CBCP may provide the most equitable and efficient implementation alternative.

Before implementing or even seriously considering a CBCP policy, planners, the public, and policy makers generally desire reliable predictions of travel demand, land use, air quality, and welfare impacts. Models of these impacts help one appreciate and compare network-wide and corridor-specific alternatives, CBCP and standard marginal-cost CP strategies, and other scenarios. In the short term, there may not be substantial changes in many behaviors and conditions. Many travelers are at least temporarily “locked in” to their places of employment and education, as well as to their residences. In the longer term, however, CBCP could have sizable impacts – and differential impacts, based on demographic and other factors. Hence, it behooves us to predict, analyze and plan for short- and long-term changes in a variety of behaviors and responses that emerge following implementation of a CBCP policy.

Texas’s capital city, Austin, makes a valuable case study for appraising policy impacts. With an annual traffic delay of 61 hours per peak period road traveler, Austin ranks 5th among U.S. cities in terms of congestion cost per person (Schrank and Lomax, 2002). Together with an estimated annual fuel loss of 104 gallons per peak-period road user, year-2000 annual time and fuel costs are estimated to total \$1190, per peak-period user³. (Schrank and Lomax, 2002) A recent survey of Austin residents gauged traveler perceptions of and responses to congestion and a hypothetical

CBCP policy (Kockelman and Kalmanje, 2003). Population-weighted results of the 580-person sample suggest that 25% of Austin's driving population would support this new strategy; furthermore, support is strongly, and positively, related to familiarity with the concept of congestion pricing. Thus, education may be key to marketing such policies. Currently, focus group studies are also underway at the University of Texas at Austin, in order to assess perceptions and needs of special groups, such as small business owners.

1.1 Objectives

This study examines network-wide CBCP and major-corridors-only CBCP, and compares these to the status quo. Using Austin-calibrated comprehensive models of household travel demand, based on changing costs to reach different destinations from one's place of residence, across modes and times of day.

1.2 Data Sources and Details

The primary sources for calibrating the travel demand models are the 1998 Austin (Household) Travel Survey (ATS 1998) conducted by the Capital Area Metropolitan Planning Organization (CAMPO 2000, 2001), the Texas Department of Transportation, and the Texas Transportation Institute. Network travel time and background flow results from the CAMPO model (which were used for air quality conformity analysis of the region's 2025 Transportation Plan) also were used. Other data sources include the 2000 Census of Population and the 2000 CAMPO-maintained City of Austin land use and parking data sets, and 2003 home sales data from the Travis County Appraisal District (TCAD). The Census data provided information on vehicle ownership and income, for calibrating the trip generation models. The land use data facilitated calibration of the generation and attraction models.

CAMPO's network travel time data file has travel time and network distance information for each pair of the 1074 Traffic Assignment Zones (TAZ) in the three-county Austin metropolitan planning region. The data vary by time of day and travel mode⁴. For the automobile mode, the two-hour morning peak and 24-hour off-peak period travel times were available. For transit, travel times varied by service type (i.e., University of Texas shuttle buses, Capital Metro standard buses and express buses) and transit access (i.e., by walking or driving). Walk/bike travel times were obtained assuming 6 mi/hr travel speeds on the shortest paths between zones. These data were used to calibrate the destination, mode, and departure time choice models.

ENDNOTES

¹ Schrank and Lomax (2002) estimated that congestion in 75 major U.S. urban areas in the year 2000 cost the traveling public \$68 billion in fuel and time losses. This amounts to an estimated \$1,160 average cost per peak-period traveler in those areas.

² Dial (1999) has made a case for minimal revenue CP in place of marginal cost CP, Viegas (2001) has argued for the creation of “mobility rights” for individuals, and Rothengatter (2003) has pointed out the possibility of transportation becoming a club good (in place of a public good). Daganzo (1995) and Nakamura and Kockelman (2002) explored the possibility of toll-plus-roadspace rationing as a demand management strategy. And De Corla-Souza (2000) has championed the creation of FAIR (Fast and Intertwined) Lanes, while Poole and Orski (2003) have lobbied for the creation of HOT (High Occupancy Toll) lanes.

³ Peak-period users may comprise more than half of the Austin region’s population. Shrank and Lomax (2002) estimate that 60% of person-miles of freeway travel and 65% of arterial miles of travel are made in peak-period, congested conditions. (Schrank and Lomax, 2002).

⁴ Since the travel time data was not available for different times of day, a joint mode-departure time choice model was used and travel times were obtained based on the resulting traffic assignment. These travel times then fed back to the other models, thus offering more more variation in automobile and transit travel times, being based on five (rather than two) times of day. The five times of day are Early morning/Late evening (before 7.15 a.m. and after 8.15 p.m), Morning peak (7.15 to 9.15 a.m.), Noon (9.15 a.m. to 4.15 p.m.), Evening peak (4.15 to 6.15 p.m), and Evening off-peak (6.15 to 8.15 p.m.).

CHAPTER 2 - MODELING FRAMEWORK

2.1 Travel Demand Model Calibration

The travel demand models include a destination choice model that captures accessibilities across modes and time periods, and a joint mode-departure time choice model.

Since year-2000 land use data for Travis County were available, these were aggregated to arrive at zonal level land use proportions. Simple multinomial logit models were used to predict residential, commercial, civic, parking and vacant land use proportions for zones outside Travis County; these other zones lie within Hays and Williamson Counties and form an important part of the Austin TAZ system and regional travel patterns. The resulting land use data were used in the destination models, and in the mode-departure time models. Trip generation (TG) models were developed for four trip purposes (home-based work, home-based non-work, non-home-based work, and non-home-based non-work trips) in order to better appreciate changes in TG that may occur in the long term under CBCP.⁵ The models for TG internal to the region are shown in Table 1. External trip productions and attractions were computed from average daily traffic counts at the external stations.

Table 1. Regression Models for Trip Productions and Attractions (by Trip Purpose)

Table 1.1. Household Level Regression Models for Home-Based Trip Productions

Explanatory Variable	HBW productions	HBNW productions
Constant	0.0495(0.567)	-0.3569(0.086)
Indicator variable for households with no vehicles		-0.7283(0.163)
Indicator variable for households with 2 + vehicles	0.2277(0.007)	
# Workers in household	1.3316(0.000)	-1.4413(0.000)
Household size	-0.0559(0.075)	2.9807(0.000)
HH Annual Income between 25,000 and 60,000\$	0.1127(0.187)	
HH Annual Income between 60,000\$ and 100,000\$	0.2194(0.045)	
HH Annual Income greater than 100,000\$	-0.1454(0.289)	0.7692(0.015)
HH Annual Income between 35,000\$ and 100,000 \$		0.2939(0.102)
# children <5 years		-2.7910(0.000)
Adjusted R-squared	0.4376	0.4433
# Observations	1661	1661

Table 1.2. Zonal Level Regression Models for Non-home-based Trip Productions

Production models		
<i>Explanatory Variable</i>	<i>NHBW</i>	<i>NHBNW</i>
Special Generator(Basic Empl.)	70.1676(0.000)	144.3245(0.000)
Special Generator (Retail Empl.)	-6.1571(0.000)	-12.5282(0.000)
Special Generator (Service Empl.)	1.0450(0.000)	1.0578(0.001)
Basic Empl. (Non-special generator)	0.3115(0.000)	
Retail Empl.(Non-special generator)	1.6606(0.000)	4.1750(0.000)
Service Empl.(Non special generator)	0.6829(0.000)	0.4345(0.000)
# Households		
Adjusted R-squared measure	0.6080	0.4880
# of observations	639	639

Note: Empl. Refers to employment

Table 1.3. Zonal Level Regression Models for Trip Attractions

Attraction models				
<i>Explanatory Variable</i>	<i>HBW</i>	<i>HBNW</i>	<i>NHBW</i>	<i>NHBNW</i>
Special Generator (Basic Empl.)	161.9448(0.000)	485.5708(0.000)	74.0889(0.000)	120.9247(0.000)
Special Generator (Retail Empl.)	-15.2055(0.000)	-47.0838(0.000)	-6.9890(0.000)	-10.2123(0.000)
Special Generator (Service Empl.)	1.2519(0.001)	4.1221(0.000)	0.9553(0.000)	1.1251(0.001)
Basic Empl.(Non-special generator)	0.8977(0.000)		0.2809(0.000)	
Retail Empl. (Non-special generator)	1.8227(0.000)	6.8534(0.000)	1.9083(0.000)	0.6247(0.000)
Service Empl (Non special generator)	1.1994(0.000)		0.5804(0.000)	
# Households		1.8624(0.000)		3.7537(0.000)
Adjusted R-squared measure	0.6410	0.5620	0.5710	0.4800
# of observations	408	526	638	638

Note: Empl. Refers to employment

Joint multinomial logit models for mode and time of day were calibrated considering four modes (drive alone, shared ride, transit, and walk/bike) and five time periods (late night and early morning, morning peak, afternoon, evening peak, and evening off-peak periods). The resulting models (for each of the 4 trip purposes) are shown in Table 2.⁶

Table 2. Joint Mode and Departure Time Choice Models (by Trip Purpose)

Parameters	HBW	HBNW	NHBW	NHBNW
<i>Level of Service</i>				
Time	-0.0548(0.0000)	-0.0755(0.0000)	-0.1808(0.0000)	-0.1067(0.0000)
Cost	-0.0098(0.0000)	-0.0158(0.0000)	-0.046(0.0000)	-0.0273(0.0000)
<i>Constants</i>				
Drive Alone Morning Peak	0.3347(0.0000)	0.0844(0.2224)	1.5704(0.0000)	1.0032(0.0000)
Drive Alone Mid-noon	-0.0685(0.2199)	0.894(0.0000)	3.0372(0.0000)	2.6575(0.0000)
Drive Alone Evening Peak	0.2397(0.0001)	0.1872(0.0054)	2.1967(0.0000)	1.2343(0.0000)
Drive Alone Evening	-1.3938(0.0000)	-0.1143(0.0881)	-0.1151(0.5921)	0.6419(0.0002)
Shared Ride Late Evening/Early Morning	-2.4832(0.0000)	-0.6646(0.0000)	-2.3973(0.0000)	0.1802(0.2706)
Shared Ride Morning Peak	-2.3515(0.0000)	-0.5004(0.0000)	-0.609(0.0116)	0.0949(0.5799)
Shared Ride Mid-noon	-2.3179(0.0000)	-0.232(0.0001)	1.0072(0.0000)	1.5179(0.0000)
Shared Ride Evening Peak	-1.7653(0.0000)	-0.3273(0.0000)	-0.1476(0.4889)	0.9241(0.0000)
Shared Ride Evening	-3.5061(0.0000)	-0.6731(0.0000)	-1.6553(0.0000)	0.5019(0.0016)
Transit Late Evening/Early Morning	-5.156(0.0000)	-4.4493(0.0000)		
Transit Morning Peak	-5.3211(0.0000)	-3.6438(0.0000)		
Transit Mid-noon	-4.773(0.0000)	-2.7827(0.0000)		-6.1271(0.0000)
Transit Evening Peak	-5.2257(0.0000)	-4.0821(0.0000)		
Transit Evening		-5.0853(0.0000)		
Walk/Bike Evening/ Early Morning		-2.1292(0.0000)		-1.4941(0.0000)
Walk/Bike Morning Peak	-2.5062(0.0000)	-1.5052(0.0000)		-1.8209(0.0000)
Walk/Bike Mid-noon	-3.0591(0.0000)	-0.8871(0.0000)	0.9885(0.0000)	0.403(0.0430)
Walk/Bike Evening Peak	-2.7426(0.0000)	-2.1272(0.0000)	-1.0766(0.0046)	-1.3354(0.0000)
Walk/Bike Evening		-2.3116(0.0000)		-1.4941(0.0000)
Log likelihood	-6190.7479	-15998.2086	-2649.8172	-5271.8404
Log-likelihood constants	-8742.4662	-20296.0560	-4653.9277	-7627.1100
Log-likelihood ratio index	0.2919	0.2118	0.4306	0.3088
Number of cases	3196	7260	1877	2836

Note: P-Values are in parentheses. Drive Alone during Late Evening/Early Morning is the base case.

The multinomial logit models of destination choice are shown in Table 3. Since the attractiveness of the destination zone varies across mode and time of day, this variability was captured using logsums of travel times, travel costs and alternative-specific constants obtained from the mode-departure time model calibrated earlier. The (systematic) utility of a destination from a particular origin is given by equation (1).

Table 3. Destination Choice Models (by trip purpose)

Parameters	HBW	HBNW	NHBW	NHBNW
Log(Attractions)	1 (constrained)	1 (constrained)	1 (constrained)	1 (constrained)
Logsum of generalized costs (over all modes and time periods)	-0.2884(0.000)	-0.4681(0.000)	-0.1181(0.000)	-0.3027(0.000)
Log(Employment)	0.0541(0.000)			
Log(Area)		0.1782(0.000)	0.1958(0.000)	0.2126(0.000)
Log-likelihood	-1115.0824	-3964.1085	-2274.7500	-3171.2460
Log-likelihood constants	-3927.0047	-8047.4988	-4315.6313	-6503.2648
Log-likelihood ratio index	0.7160	0.5074	0.4729	0.5124
# observations	1707	3498	1875	2834

Note: P-Values are in parentheses. Attractions refer to estimated trips attracted.

$$V_{des,orig} = \beta_1 LOGSUM_{orig,des} + \beta_s LN(SIZE_{des}) + LN(ATTR_{des}) \quad (1)$$

where $SIZE_j$ is either the area or the employment at the destination zone “j”, $ATTR_j$ is the attraction at the destination zone “j”, and $LOGSUM_{i,j}$ is the logsum⁷ for the origin-destination pair (i, j), computed as shown in equation (2).

$$LOGSUM_{orig,des} = -LN\left(\sum_{m,t} e^{\beta_t Time_{orig,des} + \beta_c Cost_{orig,des} + \beta_{m,t}}\right) \quad (2)$$

where β_t , β_c and $\beta_{m,t}$ are the joint mode-departure time model coefficients (on time, cost and the alternative-specific constants, respectively

All the multinomial logit models for destination and joint mode and time of day choice were calibrated using GAUSS’s maxlik module (Aptech, 1996).

2.2 Model Application

Before applying the destination choice models on the generated trip estimates, external through trips had to be separated (via an external-external submatrix). The procedure outlined in NCHRP Report 365 (Martin and McGuckin, 1998) was followed, and productions and attractions of trips in the remaining, internal zone matrix were balanced, while holding external productions and attractions constant.

By constraining the coefficient on $\ln(ATTR_j)$ to equal one, the structure of the destination choice models becomes similar to a gravity model, offering ease of application in TransCAD. The destination choice models were applied to estimate the production-attraction (P-A) matrices by

trip purpose for all 1117 zones (including external zones) which were then converted into P-A matrices by mode and time-of-day (by applying the joint mode-departure time choice models). Return trip rates across times of days and by purpose were computed from the ATS data set to convert the P-A matrix for the home-based trips into the final Origin-Destination (O-D) matrices by mode and time of day. Using vehicle occupancies by trip purpose, the O-D matrix for auto trips for different time periods was generated.⁸ Finally, the traffic assignment module of TransCAD (Caliper, 2002) was used to arrive at the User Equilibrium (UE) assignment of traffic to the network, for each of the 5 different time periods.⁹

The Bureau of Public Roads (1964) formula (Equation 3) for travel times (as function of volume and “practical” roadway capacity) was used to arrive at the marginal costs of congested travel. In the first scenario studied, tolls equaling the marginal costs of travel were placed on all links in the network during traffic assignment. In another scenario, marginal cost tolls were placed on main roads/highways in Austin.¹⁰

$$t = t_f \left(1 + \alpha \left[\frac{v}{c} \right]^{\beta_{link}} \right) \quad (3)$$

where t_f is the free flow travel time, v is the volume flowing on the link, c is the practical link capacity, and α and β are the link performance parameters.

2.3 Home Values Model

The home value models are calibrated based on residential sales data for Austin’s Travis County, recognizing that land’s underlying value depends, in part, on neighborhood accessibility. Accessibility derives from travel costs, which are affected by the policies under study. Srour *et al.* (2002) used cumulative opportunity accessibility indices (COAI) for parking space, population, retail and total employment while calibrating their property value models for the Dallas region. A similar approach was used here, but with Austin's Travis County Appraisal District records of home sales prices. The variables used are defined in Table 4 and the model results are shown in Table 5. Residences in locations with highly accessible retail employment (i.e., within 20 minutes) have higher property values. Property values are lower in locations which have greater population and employment in the vicinity. The home values model developed also includes basic, retail and service employment accessibility indices. These indices were computed as the aggregate sum of ratios of the particular kind of employment in each zone to the generalized cost of reaching that zone. (see, Kockelman, 1997). Property values are higher in locations which are on average closer to employment opportunities. The model also indicates that property values increase with greater transit and highway accessibilities.

Table 4. Description of Variables in Home values Model

Parameters	Definition
Improvement Area	Area of the improvement in square feet (SF)
IA x Age	Improvement Area in SF * Improvement Age
IA x RetEmpCOAI	Improvement area* Sum of available retail jobs within 20 min of travel time of the TSZ
IA x AllEmpCOAI	Improvement area* Sum of total available jobs within 20 min of travel time of the TSZ
IA x PopCOAI	Improvement area * Population within 20 min of travel time of the TSZ
IA x BasEmpAI	Improvement area * Sum of the ratios of zonal basic employment to generalized travel cost to zone in question
IA x RetEmpAI	Improvement area * Sum of the ratios of zonal retail employment to generalized travel cost to zone in question
IA x SerEmpAI	Improvement area * Sum of the ratios of zonal service employment to generalized travel cost zone in question
IA x CBD	Improvement area * Distance in miles from Travis County CBD
Transit within 1 mile	Indicator for properties with a transit stop within 1 mile
Highway within 2 miles	Indicator for properties with a highway within 2 miles

IA- Improvement Area, COAI – Cumulative Opportunity Accessibility Index, AI – Accessibility Index, CBD- Central Business District

Table 5. Home Value Regression Model

Parameters	Coefficient	P-Value	Coefficient	P-Value
Constant	-9.377E+04	0.0000	-106459.99	0.000
Improvement area	1.424E+02	0.0000	187.01	0.000
IA * Age	-2.877E-01	0.0000	-6.373E-02	0.247
IA*COAI				
IA * RetEmpCOAI	7.237E-03	0.0000	8.846E-03	0.000
IA * AllEmpCOAI	-5.639E-04	0.0000	-4.002E-04	0.000
IA * PopCOAI	-6.994E-04	0.0000	-7.541E-04	0.000
IA*AI				
IA x BasEmpAI	4.881E-04	0.0279		
IA x RetEmpAI	3.423E-03	0.0000		
IA x SerEmpAI	2.058E-04	0.0006		
Transit within 1 mile	2.161E+04	0.0114	38069.37	0.000
Highway within 2 miles	3.000E+04	0.0004	27442.30	0.002
Adjusted R square	0.6681		0.666	
Number of observations	3093		3093	

Peak travel times and costs were used while computing the COAI and AI. The COAIs measure accessibility to employment or population within 20 minutes of the zone while the AIs measure total accessibility to employment.

ENDNOTES

⁵ Trip productions for home-based trips were modeled at the household level (using the ATS data set) and then aggregated to the zonal level. Trip productions for non-home-based trips and the trip attractions were all modeled at the zonal level.

⁶ Nested logit models of mode and time of day also were attempted, but these specifications refused to converge, regardless of nesting structure and trip type.

⁷ The logsum is the negative of the maximum utility derived across all mode and departure time combinations for that particular destination and is a measure of accessibility of that destination from the concerned origin.

⁸ Transit trips were too few to be factored in while computing the automobile-trip matrix.

⁹ A value of $\alpha = 0.15$, $\beta = 4.0$ were used when link specific values were not available. The final travel times compared favorably with the travel times provided by CAMPO with an average variation of -2% (s.d. =6.05) for off peak values and -8% (s.d.=11.53) for peak values.

¹⁰ These marginal cost pricing scenarios are applied by altering the volume flow functions for the marginally priced links by replacing the α in the BPR formula by $\alpha+\beta$.

CHAPTER 3 –RESULTS

3.1 Transportation System Impacts

Based on the mode-departure time choice models (which involved travel time and cost variables, average Austinite values of travel time (VOTTs) were estimated to range from \$2.35 to \$3.36, across each the four trip purposes. These values seem quite low, but they do represent an average for *all* travelers in the region. (Choices by youths and non-working individuals certainly can bring down the estimates.) Moreover, the models were calibrated using off-peak travel time values obtained from a 24-hour assignment by CAMPO and an automobile operating cost assumption had to be made¹¹. Recognizing the low values from the mode-departure time models, an \$8 per *vehicle*-hour toll was used to actually compute the MCP tolls.¹² Because of this, the MCP tolls may be more severe than optimal, reducing congestion more than necessary.

From Table 6 one observes that total revenue generated from the MCP of all roads is around \$372,000 per day. As expected, the revenues generated during the off-peak periods are quite small, compared to the peak periods. Under system-wide MCP, it is observed that average peak travel times decreased by roughly 1.6% (3.3% on main roads), with tolls averaging roughly \$1.5/mi on main roads during peak congestion. This extremely high *average* toll comes from Interstate 35 (I35). I35 is a key Austin corridor and extremely congested at present. It is chock-full of through (external zone-to-external zone) trip-makers who cannot be priced off the corridor under present assumptions. Given some assumptions about demand responsiveness on this corridor, the I35 (and average) tolls will fall.

Table 6. Daily CBCP Revenue from Marginal Cost Pricing (MCP) on All Roads

<u>Time period</u>	<u>Total Revenue in \$</u>
T0 (Early morning/late night)	\$359.17
T1 (morning peak)	92479.96
T2 (noon)	1935.87
T3 (evening peak)	277970.80
T4 (evening off-peak)	102.00
Total Revenue	\$372,847.79

Note: Revenue from MCP on all roads using a VOTT = \$8/hr. for toll computation.

3.2 Policy Impacts on Welfare and Property Values

Those unable to afford the tolls under CP and therefore forced to change trip making substantially are generally perceived as “losers” under conventional CP. Compensation in the form of cash travel credit allowances under CBCP should substantially increase welfare for such people and also for the whole community. Using Schrank and Lomax’s (2002) estimate of 730,000 road users in Austin, the revenue returned by CBCP per user per day comes to around

50¢, if system wide pricing were to be applied, and around 20¢, if MCP applied only to the main roads¹³. Under CBCP, this amount is given as a “rebate,” in the form of a monthly allowance.

Consumer surplus at the destination choice level after the policy change has been used as the welfare measure in this study since it provides an excellent holistic/comprehensive measure of impact, capturing impacts on destination, mode and departure time of day choices¹⁴. Equation (4) gives the expression for consumer surplus under a policy change; it is the *difference* in the expected maximum utilities before and after the policy change. It is based on a given origin, assumed to be one’s neighborhood of residence, and it is computed as a logsum of utilities of all destination choices from that origin with $U_{i,j}$ denoting the utility of destination “j” (see equation 1) and C denoting the full choice set of all possible destinations.

$$CS_{orig} = \frac{1}{\alpha} \left(E(\text{Max}(U_{des})_{orig})^n - E(\text{Max}(U_{des})_{orig})^o \right) \quad (4)$$

$$E(\text{Max}(U_{des})_{orig}) = \log \left(\sum_{des \in C} e^{U_{des,orig}} \right) \quad (5)$$

where n and o denotes the new and old policies/environments (i.e., CBCP versus the status quo) and α is the destination choice model’s marginal utility of money, in this case equaling the multiple of the coefficients on cost (in the mode-departure time model) and generalized cost or logsum (in the destination choice model).

Consumer surplus under CBCP has been calculated for an average individual located in various zones around Austin for each trip purpose using the corresponding destination and mode-departure time choice models. The rebate per trip was calculated by dividing the daily allowance by the number of trips made by the individual on that day. Average daily trip making of 4.6 trips/individual (from the ATS survey) was assumed to calculate the average CBCP allowance for each trip, and a trip-weighted average of the trip-based welfare measures produced the final measure. Results of the welfare analysis for both the CBCP policies tested are shown in Table 7.

Figures 1 and 2 illustrate the geographical variation in aggregate consumer surplus across equal-area quartiles around Austin for system-wide CBCP and main-roads-only CBCP. It has to be pointed out that the potential “winners” under these two policies can be very different. While users near the central business district (CBD) are predicted to gain from pricing only the main roads, users living in northwest Austin (close to several major employers) gain the most under system-wide CBCP.

Table 7. Consumer Surplus (\$) for the Average Individual, Located Across Austin: CBCP on All Roads and CBCP on Main Roads Only Scenarios

Trip Purpose	HBW		HBNW		NHBW		NHBNW		Aggregate	
<i>CBCP Policy</i>	<i>All Roads</i>	<i>Main Roads</i>	<i>All Roads</i>	<i>Main Roads</i>	<i>All Roads</i>	<i>Main Roads</i>	<i>All Roads</i>	<i>Main Roads</i>	<i>All Roads</i>	<i>Main Roads</i>
Mean	-\$0.04	-0.01	0.06	0.02	0.08	0.03	0.07	0.03	0.20	0.09
Median	-0.04	-0.01	0.05	0.03	0.08	0.03	0.07	0.03	0.19	0.09
Std. Dev	0.04	0.04	0.02	0.01	0.01	0.03	0.01	0.01	0.11	0.08
Minimum	-0.32	-0.23	-0.15	-0.11	-0.01	0.00	0.00	-0.01	-0.60	-0.46
1st Quartile	-0.07	-0.03	0.04	0.02	0.07	0.03	0.06	0.02	0.13	0.05
2nd Quartile	-0.04	-0.01	0.05	0.03	0.08	0.03	0.07	0.03	0.19	0.09
3rd Quartile	-0.01	0.01	0.08	0.03	0.09	0.04	0.09	0.03	0.29	0.12
Maximum	0.05	0.24	0.10	0.10	0.10	0.33	0.11	0.15	0.44	0.76

Note: The Consumer surplus for the two scenarios have both been computed versus the “no pricing” status quo scenario

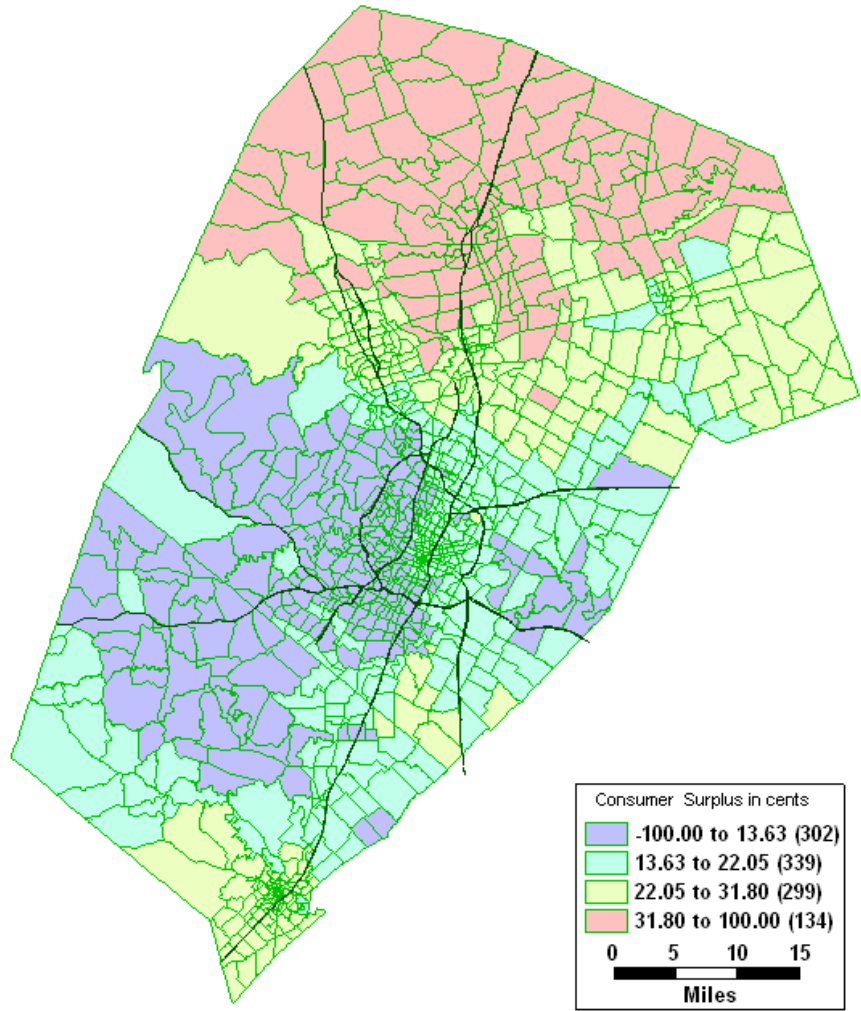


Figure 1. Welfare (of destination choice) for a Typical Austin Resident under CBCP on All Roads – versus Status Quo

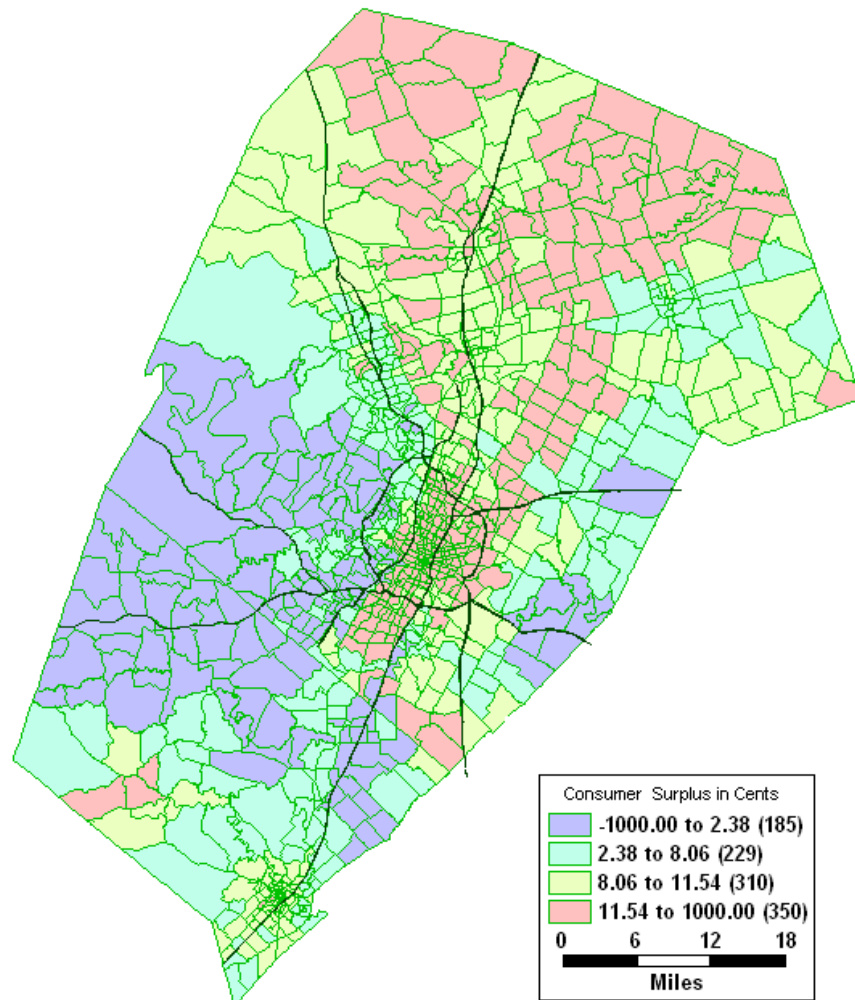


Figure 2. Welfare (of destination choice) for a Typical Austin Resident under CBCP on *Main Roads Only* – versus Status Quo

The Home values Model was used to predict changes in average property values across Austin locations upon implementing CBCP. It is observed that for average Austin dwelling units (2580 square feet and 9.23 years old) located at the zonal centroids, property value dropped in almost all areas in and around Austin. While central Austin property values faced drops in property values between 15% and 41%, the drop in property prices decreased as we move farther away from the CBD areas. Most zones in Williamson and Hayes counties show home value increases of around 10%. Figure 3 shows the distribution across Austin of the predicted property value changes.

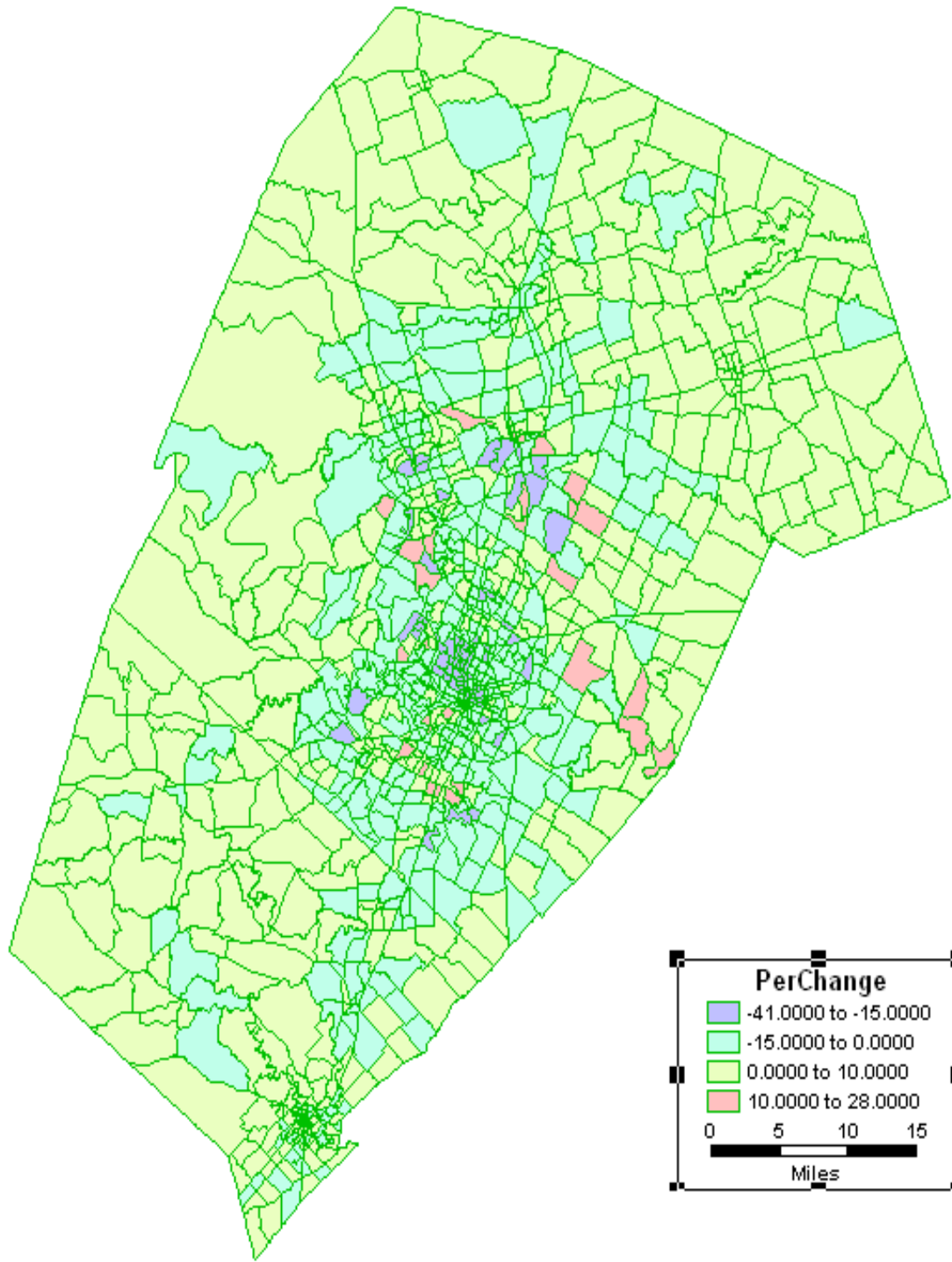


Figure 3. Predicted Percentage Change in Home Value of an Average Dwelling Unit across Austin Locations upon Implementing System-wide CBCP.

ENDNOTES

¹¹ The travel cost by automobile was assumed to be 30¢/mile, which is probably high, in marginal terms (since most travelers already have access to an insured vehicle and therefore are only considering gasoline and some other variable costs). A higher assumed travel cost, however, will result in a higher VOTT prediction for the model (since the parameter on cost will fall, and the ratio of the time and cost coefficients, the VOTT, will rise).

¹² Average automobile vehicle occupancy varies from 1.18 for home-based work trips to almost 2 for non-work auto trips. Vehicle occupancy for automobile “shared ride” trips, which comprise around 39% of all person trips made in Austin region, varies from 2.38 to 2.70. Charging a value of \$8 per vehicle for every hour of vehicle congestion caused may be slightly on the higher side if we consider the low value of personal travel time from our mode and departure time choice models, but this vehicle toll should serve to recapture the operation costs of electronic tolling.

¹³ The main roads subject to MCP are US-183 (Research Blvd.), IH-35, Loop 1 (Mopac), Loop 360 (Capital of Texas Highway), Highway 71 (Ben White) and US 290, as specified in Kockelman and Kalmanje’s (2003) surveys of Austinites.

¹⁴ The changes in transit level of service under the policies also have been recognized. Transit travel times were adjusted for changes in peak and off-peak travel times under the various policies, according to the shift in the corresponding auto travel times.

CHAPTER 4 –CONCLUSIONS AND EXTENSIONS

Credit-based congestion pricing (CBCP) has the potential to address a variety of redistributive impacts that are likely under congestion pricing policies. This work investigates the travel demand and land use impacts of such a policy, under a variety of pricing scenarios for the Austin, Texas, region. It uses a standard four-step travel demand modeling approach, calibrated on the basis of the most recent Austin Travel Survey (ATS, 1998), and relying on logit models of departure time, mode, and destination. It then applies the policy to the entire network and to main highways at different times of day and at different levels of charges, in order to appreciate the variety of applications and impacts that could arise in practice.

The results of the model application to various policy scenarios suggest that most Austin residents would be better off under policies that employ CBCP, whereas relatively few would benefit under a policy of congestion pricing, without beneficial revenue redistribution. In the end, the most likely CBCP policies for Austin or any other region may be a CBCP policy with approximate, relatively stable MCP on all arterial links, thereby providing some price certainty and avoiding overuse of unpriced arterials. Pricing of all network links provides further gains, but the costs (and other impacts) of providing roadside detection (and enforcement) along all such corridors may be prohibitive in the near term. Residential property prices upon implementing CBCP are predicted to decrease slightly in the areas near CBD and increase moderately in the farther areas.

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