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16. Abstract

The use of credit-based value pricing (CBVP) is an innovative method of value pricing and may solve several transportation problems, such as traffic congestion and excessive vehicle emissions. This value pricing idea would involve travelers receiving an allocation of credits every period. Different travel behaviors would then require (cost) different numbers of credits. Travelers frequently choosing high-cost credit trips (for example, driving alone on a congested freeway during rush hour) would find themselves short of credits prior to the next period and needing to purchase additional credits from travelers choosing low-cost credit options (for example, transit trips). The cost of the credits would be set in a free market system (much like a stock market) by the buyers and sellers. This research examines technical, administrative, economic, and political issues surrounding several forms of CBVP.

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EXAMINING THE FEASIBILITY OF CREDIT-BASED VALUE PRICING IN TEXAS

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The U.S. government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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EXECUTIVE SUMMARY

Market forces such as congestion (or peak-period/value) pricing have successfully been employed in many industries to regulate the demand for goods and services. Based on the findings from a small list of implemented value pricing projects in transportation, market forces also have the potential to significantly improve the efficient use of the transportation system. The use of traveler credits is an innovative method of value pricing and may solve several transportation problems, such as traffic congestion and even excessive vehicle emissions. This value pricing idea would involve travelers receiving an allocation of credits every period. Different travel behaviors would then require (cost) different numbers of credits. Travelers frequently choosing high-cost credit trips (for example, driving alone on a congested freeway during rush hour) would find themselves short of credits prior to the next period and needing to purchase additional credits from travelers choosing low-cost credit options (for example, transit trips). Buyers and sellers would set the cost of the credits in a free market system (much like a stock market).

This research investigated the technical and political feasibility, as well as the economic and administrative issues, associated with implementing traveler credits for 10 different scenarios. These scenarios vary based on two levels of analysis: (1) system wide and (2) single facility, as well as five goals for each of these areas: (A) congestion relief, (B) person movement, (C) emissions reduction, (D) social equity, and (E) construction or expansion of highways. Researchers focused on two scenarios with the highest likelihood of implementation: single facility congestion relief and single facility construction/expansion.

The technology exists today to implement either of these options. Either electronic toll collection (ETC) or global positioning system (GPS) would be the most likely technologies to provide the charging and tracking mechanisms. Additionally, the costs of the technologies are decreasing, and an ever-increasing percentage of vehicles have factory-installed GPS. Administratively, there are some challenging issues to overcome, but none that would be

impossible. From an economic standpoint, this form of value pricing can be shown to increase the net societal benefits of travel on the facility. However, this form of value pricing is unlikely to be able to overcome opposition from travelers and politicians alike.

Through focus groups it was not surprising to find drivers were opposed to the idea of credit-based value pricing (CBVP)—particularly due to its complexity. The requirement that drivers buy and sell credits and therefore "think about their driving behavior" required too much thought and advanced planning. If financing methods other than the gas tax are necessary, then tolls were readily accepted. Even the use of variable tolls was more palatable than CBVP.

The irony exists in that while creating a more complex value pricing program capable of overcoming many of the traditional obstacles to implementation, the complexity of the scheme itself became a considerable obstacle. CBVP would require the users to think about optimizing their travel behavior based on their value of time and preferred arrival time. Although CBVP may optimize user benefits, it also requires considerable effort on the part of each driver—more effort than drivers were willing to expend. Therefore, the radical change from current operations and, more importantly, the credit accounting burden on the drivers, make the CBVP scenarios examined here extremely difficult to implement from a political standpoint. There is even extra effort required from the user over more traditional forms of value pricing, making CBVP a very difficult to implement form of value pricing.

A simpler version of CBVP, possibly one which would have the agency sell credits at a set price, might be more palatable to travelers. However, simpler forms of CBVP would eliminate some of the welfare and equity benefits derived from the CBVP scenarios examined here. Therefore, the researchers recommend focusing on more traditional forms of value pricing for use on Texas roadways—with particular attention devoted to equity concerns.

CHAPTER 1. INTRODUCTION

With rapid increases in the cost of construction, the fuel efficiency of gas-powered vehicles, and the use of non-gas-powered vehicles, the current fuel tax system is quickly becoming insufficient for funding our transportation infrastructure needs *(1, 2)*. This lack of funding is leading many transportation authorities to examine (value) pricing alternatives to both mitigate congestion and provide revenues *(2, 3)*. Despite some political reluctance to toll or value price facilities, there are 11 value priced facilities in the United States and many more under consideration *(3, 4)*. Although increased pressure due to traffic congestion and revenue shortfalls is encouraging the use of value pricing, a significant stumbling block toward implementation is the issue of equity. Many value pricing methods can be argued to be detrimental to drivers with low values of time or to low-income drivers. Although experiences from implemented projects have not conclusively settled this argument, it remains an important consideration as highlighted in these quotes from the Eno Foundation's report *(2)*:

> "Equity is an issue in any new pricing scheme, but it is important to remember that the current system is also inequitable. Gas taxes and flat tolls discriminate against the low-income travelers because they tend to travel less during the times that place the greatest expense on the system—peak periods. Although they place less stress on the system, they are required to pay the same amount. Low-income travelers also tend to use older, less fuel-efficient cars, which under a gas tax system means they are paying more per mile." –p. 17

> "In any pricing project, it will be necessary to ensure that negative effects of the project do not disproportionately affect minority and low-income populations or result in the 'denial of, reduction in, or significant delay in the receipt of benefits by minority and low-income populations.' Any project that results in a new charge for access to previously free transportation service comes under environmental justice concerns." –p. 17

One potential method of value pricing, CBVP, may overcome these inequity problems. This research examines the potential of this innovative method of value pricing.

VALUE PRICING

The concept of value pricing, where users are charged more for goods or services during periods of peak demand, has existed for hundreds of years. Currently many industries use this practice to help regulate the demand for their product. For example, hotel rooms are more expensive during peak tourist season, movies are less expensive during matinees, and even airlines adjust their prices based on the expected demand for specific flights. The potential benefits of value pricing on roadways are primarily derived from reduced congestion during peak periods leading to increased travel speeds and reduced delays. Despite the potential benefits and the applicability of value pricing to the toll road/bridge industry, there have been relatively few applications of this form of pricing in the industry (see Table 1).

The toll road and bridge industry exhibits the ideal characteristics for value pricing *(5)*:

- increasing capacity occurs in large and expensive steps;
- demand is not uniform; and
- there are well-defined peak periods that occur at predictable, regular intervals and cause considerable congestion. In the case of the 68 largest cities in the United States this congestion equated to $78 billion in waste in 1999 *(6)*. Several of the most congested cities are in Texas: Houston is ranked fifth, Dallas sixth, and Austin seventh in annual person hours of delay.

Despite having these ideal characteristics, there are numerous reasons why only 23 toll road/bridge facilities in the world today have employed some version of value pricing (see Table 1). These reasons include policy administration, concern over the use of revenues *(7, 8)*, the cost of toll collection, and, most importantly, political objections *(9, 10, 11, 12)*. Political opposition has ended several large and seemingly worthwhile projects. Projects in Hong Kong, London, and on the Bay Bridge in San Francisco are notable examples where considerable time

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and effort were spent in developing a value pricing project only to have it abruptly halted due to political objections. Note that London finally implemented a value pricing project in February 2003 after several unsuccessful attempts.

An important aspect of the political opposition to these projects comes from arguments that any proposed value pricing program will adversely impact low-income and disadvantaged drivers. This claim has not been conclusively proven or disproved. By examining the mature U.S. value pricing projects it can be seen that on I-15 in San Diego participants had significantly higher incomes than non-participants but the equity issue was not a concern among either group *(13)*. Similar results were found on SR 91 *(14)* and the Katy high-occupancy/toll (HOT) lane project *(15)*. No equity concerns were evident in the Lee County project *(16)*. However, the concern over inequity is a powerful political tool that can stop a project in its tracks. As a result, less traditional forms of value pricing are being considered where the negative impacts on disadvantaged groups (in other words, equity concerns) can be minimized. Traditional forms of value pricing that are currently in use, include:

- tolls that vary by time of day (the traditional approach),
- tolls that vary by time of year,
- high-occupancy/toll lanes with flat or variable tolls, and
- cordon pricing with flat or variable tolls.

Table 1. Variable Priced Facilities.

Location	Name of Facility	Rate Description	Website
1) Melbourne, Australia	Melbourne CityLink	Night discount for trucks	http://www.transurban.com.au
2) France	A1	Regular toll, Sunday shoulder toll, Sunday peak toll	http://www.sanef.com/siteSanef/fr/info_prat/peages/moduler.htm
3) France	A14	Peak and off-peak tolls	http://www.sapn-autoroutes.fr/default.asp?LANG=EN
4) Marseille, France	Tunnel Prado-Carénage	Day toll and night toll	http://www.tunnelprado.com/
5) Seoul, Korea	Namsan #1 and #3 Tunnels	Day toll, nights and Sundays free	
6) Trondheim, Norway	Toll ring around city	Peak toll, off-peak toll, and free at night	
7) Bergen, Norway	Toll ring around city	Toll during day, free at night	
8) Singapore	Area-wide pricing	Multiple peak-period pricing rates	http://www.lta.gov.sg/index.htm
9) Spain	Autopista del Sol	Summer and winter rates	http://www.autopistadelsol.com/PrincipalIng.htm
10) Florida, USA	Cape Coral and Midpoint Bridges	Regular toll and shoulder period toll discounts	http://www.leewayinfo.com/
11) California, USA	SR 91	Variable toll with HOV discount	http://www.91expresslanes.com/
12) California, USA	San Juaquin, Foothill, and Eastern Toll Roads	Peak-period, peak-direction premium	http://www.thetollroads.com
13) Houston, USA	I-10 (Katy Freeway)	HOT lane with single toll rate	http://www.ridemetro.org/services/quickride.asp
14) Houston, USA	US 290	HOT lane with single toll rate	
15) Missouri, USA	Lake of the Ozarks Bridge	Summer and winter rates	http://www.funlake.com/commbridge.html
16) New Jersey, USA	Garden State Parkway	ETC and off-peak discounts	http://gspkwy.state.nj.us/
17) New Jersey, USA	New Jersey Turnpike Authority Roads	Cash toll, off-peak toll, peak toll, and weekend toll	http://www.state.nj.us/turnpike/
18) New Jersey and New York, USA	Port Authority of New York and New Jersey Crossings	Cash toll, peak toll, off-peak toll, night toll, and an HOV discount	http://www.panynj.gov/
19) New York, USA	Tappan Zee Bridge	Peak-period surcharges for trucks, HOV (3+) discounts	http://www.tzbsite.com/
20) San Diego, USA	I-15	HOT lane with variable toll rate	http://argo.sandag.org/fastrak/
21) Virginia, USA	Dulles Greenway	Cash toll, ETC toll, and weekend discount	http://www.dullesgreenway.com/
22) Rome, Italy	East of Tiber area	Cordon pricing. Entry fee during weekday daytime and Saturday afternoons.	
23) London, England	Central London	Daytime fee for travel anywhere in central London	https://www.cclondon.com/

Several other forms of value pricing are currently under investigation, most of which are seeking to minimize equity concerns while deriving most of the potential benefits of value pricing. These projects include *(17)*:

- car sharing;
- convert traditionally fixed costs (insurance, registration, etc.) to variable costs;
- priced queue-jumps; and
- cash out of cars.

CREDIT-BASED VALUE PRICING

One method of value pricing that has only begun to be investigated is the use of "tradable credits" or CBVP that can be used toward roadway use. Basically, credits would be allocated on a regular basis to a pre-determined group of people. Traveling on certain facilities would then require travelers to use their credits—more credits during peak periods and fewer during off-peak periods.

In the case of trading, infrequent travelers and travelers who travel off-peak would then be able to trade (sell) their excess credits to those drivers who regularly commute during the peak period and have used all of their allocated credits.

A tradable credit system is an incentive-based policy tool that has been used primarily in the environmental industry. The historical origins of tradable permit systems can be traced back to the works of Pigou, Coase, Crocker, and Dales *(18, 19, 20, 21, 22)*. Within the context of environmental targets, limits or caps are imposed on sources of pollutants, and incentives are created through a trading mechanism in order to achieve desirable emissions levels. The economics literature indicates that tradable permits have been widely analyzed from both a general and theoretical perspective in many areas (SO_2 emissions, water quality, acid rain) *(23)*. Tradable permits have been shown to have some success over traditional "command and control" approaches in pollution-creating industries by offering incentives for technological innovation and leading to cost savings for companies. In terms of application areas, a recent survey found

nine applications in pollution control, 75 applications in fisheries, three applications in water resources, and five in land use control *(24)*. The use of tradable credits in combination with value pricing experiments should be considered as an innovative means of combining economic instruments with transportation markets to achieve broader societal goals. In theory, the use of highway facilities can be optimized by the users as they determine the price they are willing to spend (and receive in the case of credit selling) on credits in order to travel.

In the transport arena, there are several applications of permits issued for achievement of environmental goals. Examples include: LEV/ZEV Program in California; Singapore's Vehicle pollution permit system, where certificates of entitlements are issued to vehicles; ECOPOINT in Austria; Environmental Protection Agency (EPA) Ecommute program; and Texas Clean Fleet program. These applications can be divided into three categories: (1) upstream applications (those that are supply based like ZEV California), (2) downstream applications (those that are demand based like ECOPOINT), and (3) a mix of both supply-based and demand-based aspects. Ecommute is a special third party application that mixes supply-based aspects by targeting companies who gain from emissions reductions and demand-based aspects (by targeting individual travelers to telework instead of commute to work).

In 1998, the Bureau of Transport and Communications in Australia conducted a study that explored the potential of tradable permits in transport for individual users *(25, 26)*. This study is the first of its kind to explore the possibility of implementation of tradable permits to individual travelers and discussed some of the issues that might arise in application. The agency did not pursue this route because at that time there was no system in place to facilitate road user charging. The lack of a system was recognized as both a problem and an opportunity for tradable permit applications in the Australian transport sector. The theoretical concept, however, was proposed much earlier for the regulation of road transport externalities *(27)*. More recently they have been suggested in specific corridors for congestion relief *(28, 29, 30)*. Kornhauser and Fehlig suggest a permit scheme on New Jersey's Route 1 Corridor with free trade across users, while Kockelman suggests a version where trade occurs only with the agency. None of the papers explain the details or have a proposed theory to link trading to demand for road use. While part of the emissions literature is applicable for addressing issues, the behavioral basis

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driving the market linkages are clearly different and require further examination. The most important point is that while there are many proposals on tradable permits for users, the theory to link trading to demand for road use is not in place. Existing theories are useful when the goal is emissions reduction but are not completely transferable to transportation situations.

This report examines the potential feasibility of five different methods of CBVP, employed on both an area-wide level or on a single facility. The differences in each scenario are primarily in how much different travel behaviors cost in credits. These five scenarios are briefly described below (detailed descriptions can be found in Chapter 3):

1. Congestion relief. The number of credits required to travel on a congested facility varies with the amount of congestion on the facility.
2. Person movement. The number of credits required for travel would likely vary in much the same way as in the congestion-relief scenario. However, as the number of vehicle occupants increases, the number of credits required decreases.
3. Emissions reduction. The number of credits required would vary directly with the amount of emissions produced by the vehicle.
4. Social equity. The number of credits required for travel would likely vary in much the same way as in the congestion-relief scenario. However, extra credits would be provided to persons with low incomes.
5. Construction and/or expansion. In these scenarios the drivers would have to purchase credits from the toll authority (where in the other scenarios the credits are given for free). The number of credits required for travel would likely vary in much the same way as in the congestion-relief scenario.

Benefits of Traveler Credits

As previously outlined, this form of value pricing has not been investigated for use in the toll road or bridge industry but does have some similarities to the EPA's pollution allocation program. The potential benefits of this form of value pricing are significant for several reasons:

- Market forces control the use and sale of credits, and drivers will alter their travel behavior based on market forces *(31, 32)*. This provides incentives for drivers to find and use the most cost-effective and efficient method to travel. Weitzman first raised the discussion of the relative efficacy of controlling price versus quantity *(33)*. Since then researchers have been drawing attention to ways of combining the benefits of both approaches by proposing hybrid policies mostly in the arena of global climate change. Hybrid policies are those that combine both price and quantity aspects. In the specific case of global climate change, Pizer suggests that hybrid policies are sub-optimal but superior in terms of efficiency *(34)*. This is likely the case for transportation and road usage, in particular. CBVP could in principle, be more beneficial to travelers.

- Drivers who take alternative modes of transportation or travel at off-peak times are rewarded for these behaviors. In addition, the reward is provided by the drivers traveling via single-occupant vehicle (SOV) during the peak period. Value pricing in this form is likely to be a very progressive form of income redistribution as persons taking alternative modes of transportation often have lower incomes than SOV travelers *(35, 8)*. Therefore, it may overcome equity concerns that so often derail value pricing projects.

- With the proper allocation of credits, the authority in charge of the program can greatly reduce congestion and, potentially, increase vehicle flow. The program allows for the authority in charge to accomplish different goals by offering various incentives for driving behavior and possibly type of vehicle driven, such as low-emissions vehicles. The five goals examined here include congestion relief, person movement, emissions reduction, social equity, and construction and/or expansion of highways.

The form of CBVP discussed above, and examined in this research, may be termed a full implementation version of CBVP. It is the most complex form of CBVP as it allows for trading (buying and selling) of credits among users. Simpler forms of CBVP are also possible but would not provide optimal benefits and are not examined in any depth in this report. (See Chapter 4, Can the Users Buy and Sell [Trade] among Themselves, pages 70 to 74, for a brief description of a simpler form of CBVP.)

EXAMPLES OF CREDIT-BASED TRADING SYSTEMS

The Clean Air Act

Examples of successful credit trading programs include the Clean Air Act which implemented SO_2 emissions trading. The SO_2 program began in 1990 to reduce emissions primarily from utilities using a cap and trade format. Its goal is to reduce SO_2 emissions by 40 percent to meet 1980 levels (the cap). To facilitate trading, the EPA conducts annual emissions auctions where participants can buy and sell SO_2 permits. The program is successful because it allows participants flexibility in managing their emissions. According to a White House press release, the trading scheme achieved the same emissions reductions as a traditional command and control scheme but at two-thirds the cost. It is run with approximately 75 EPA employees. This program was extended and enhanced by the Clear Skies Act of 2002. This newer program intends to cut emissions by 70 percent.

British Petroleum (BP) and Royal Dutch/Shell Corporate Programs

In 1998, British Petroleum set a goal of reducing greenhouse gases (GHG) to 90 percent of 1990 levels by the year 2010. This program is internal to BP as BP business units are each allocated an initial amount of emissions credits and can trade them with each other to meet their business unit specified cap. The success of the program can be seen in BP's estimated cost savings and the volumes traded. During 2001, BP's total reported emissions were 80.5 million tons of GHG emissions. It estimates that on a total net present value basis over eight years, it will save $650 million. In 2001 over 4.55 million tons of CO_2 were traded.

In 2000, Shell launched its own internal program called the Shell Tradable Emissions Permits System (STEPS). The goal was to reduce GHG (particularly CO_2 and CH_4) emissions 2 percent below 1998 levels by 2002. As in the case of BP, business units were allocated emissions credits and a cap. The cap was initially set at 95 percent of its 1998 emissions with the remaining 5 percent auctioned off among the units. They were allowed to trade with each other. As with

BP's program, STEPS demonstrates that it is possible to implement an emissions trading program on a corporate-wide scale efficiently and effectively.

Ecopoint System

In 1992, the European Union reached a transit agreement with Austria to reduce the level of nitrogen oxide (NOx) air pollution caused by heavy vehicles (maximum authorized weight greater than 7.5 tonnes) traveling through Austria. To accomplish this goal, a system of "ecopoints" was introduced for heavy vehicles. Each of the 18 member countries was issued a number of ecopoints based on 1991 travel by heavy vehicles from that country. The number of ecopoints required to undertake a trip was determined by the NOx rating of each vehicle. One ecopoint corresponded to the emission of 1 gram of NOx per kilowatt hour of a heavy vehicle *(36)*. Vehicles registered before October 1990 are charged a maximum of 16 ecopoints per trip. Vehicles registered later than 1993 are generally charged a maximum of 8 ecopoints per trip.

The system started January 1, 1993, and expires at the end of 2003 *(37)*. The system had a target of reducing emissions 60 percent below 1991 levels. At the end of 2000, the system achieved a reduction of 55 percent below 1991 levels *(38)*.

Texas Clean Fleet Program

In 1990, the Clean Air Act established the federal Clean Fuel Vehicle Fleet Program to reduce air pollution. This program requires fleet owners in areas that exceed the National Ambient Air Quality Standards (NAAQS) to purchase a percentage of low-emissions vehicles when adding or replacing vehicles in their fleet. States have an option to implement this program or to implement a substitute program that would reduce emissions by the same amount. In response, Texas developed the Texas Clean Fleet (TCF) program.

The TCF program covers all local government fleets with more than 15 vehicles, private fleets with more than 25 vehicles, and mass transit fleets in the Dallas-Fort Worth (DFW), Houston-Galveston, and El Paso non-attainment areas. It allows for any vehicle/fuel combination,

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including gasoline or diesel fuel that is certified by the EPA, to meet or exceed the federal low-emissions vehicle standards to demonstrate compliance. Local government and private fleets subject to the TCF program must acquire fleet vehicles certified by the EPA to meet or exceed the low-emissions vehicle (LEV) standards in accordance with the following compliance schedule:

- 30 percent of fleet vehicle purchases after September 1, 1998, or 10 percent of the fleet vehicles in their total fleet as of September 1, 1998;
- 50 percent of fleet vehicle purchases after September 1, 2000; and
- 70 percent of light-duty fleet vehicle purchases and 50 percent of their heavy-duty fleet vehicle purchases after September 1, 2002.

Fleets can earn mobile emissions reduction credits (MERCs) or program compliance credits (PCCs) by acquiring LEVs earlier than required, by acquiring more LEVs than required, or by acquiring fleet vehicles which are certified to meet an emissions standard more stringent than the LEV standard. Surplus PCCs can be traded, transferred, or sold to another fleet in the same non-attainment area. Each September 1st on even years, local government and private fleets are required to submit reports to the Texas Commission on Environmental Quality (TCEQ) on the status of their fleets' compliance. Credits generated have a life of two years. The TCEQ acts as a clearinghouse for buying and selling credits. The dollar value of PCCs or MERCs depends upon the demand for credits.

The Houston-Galveston (Nonattainment) Area

The Mass Emissions Cap and Trade Program (MECTP) was established by the TCEQ for certain stationary sources of NOx emissions in the Houston-Galveston non-attainment area (HGA). The initial cap was implemented on January 1, 2002, with mandatory reductions increasing over time. Allowances are allocated each year and deposited in the compliance accounts on January 1. Existing emitters were given an initial allowance equal to their 1997 NOx emissions levels, while new emitters must purchase emissions allowances from facilities already in the program. Companies that pollute less than their allowance can either bank this difference for their use in

later years, or they can sell the credits to a new company or a company not meeting their NOx restrictions.

Emission Reduction Credits (ERCs), Discrete Emission Reduction Credits (DERCs), and Mobile Source Discrete Emission Reduction Credits (MDERCs) created within the HGA can be used to offset emissions beyond the allowance allocations. Baseline emissions were calculated based on historical emissions levels. For all boilers, auxiliary steam boilers, and stationary gas turbines within an electric power-generating system, the adjustment will result in the allocation of allowances consistent with the following:

- 44 percent reduction beginning April 1, 2003;
- 88 percent reduction beginning April 1, 2004; and
- 90 percent reduction of NOx emissions from these facilities by April 1, 2007.

These reduction percentages are based on the baseline emissions as reported in the 1997 emissions inventory. Additionally, the adjustment will result in overall reductions of NOx emitted from non-utility (i.e., all other) facilities by:

- 35 percent by April 1, 2004;
- 60 percent by April 1, 2005;
- 70 percent by April 1, 2006; and
- 90 percent by April 1, 2007.

California LEV Program

In 1990, the California Air Resources Board (CARB) approved standards for low- and zero-emissions vehicles that would apply from 1994 to 2003. These were based on the progressive introduction of four classes of vehicles, each with increasingly strict emissions requirements:

- TLEV: transitional low-emissions vehicles,
- LEV: low-emissions vehicles,

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- ULEV: ultra-low-emissions vehicles, and
- ZEV: zero-emissions vehicles.

Currently automakers are required to comply with a Fleet Average Non-methane Organic Gas (NMOG) standard which is tightened each model year. In the period up to 2003, manufacturers may certify vehicles in any combination of the LEV categories in order to satisfy this standard.

In November 1998, the CARB approved new proposals labeled LEV II. These proposals strengthen regulations beginning in 2004. The new standards require light trucks, sport-utility vehicles (SUVs), pickups, and small cars to meet the same emissions standards as passenger cars. Other requirements of the LEV II program are that automakers must reduce fleet average emissions levels each year through 2010. NOx standards for low- and ultra-low-emissions vehicles will be reduced by 75 percent from the LEV level. The program also permits credits for vehicles that achieve near zero emissions, that is, a new super-low-emissions vehicle (SULEV) standard.

eCommute

In fiscal year 2000 Congress enacted HR 2084, Section 365 of the Department of Transportation and Related Agencies Appropriations Act. This legislation proposed five pilot studies aimed at reducing vehicle miles traveled (VMT) of commuters by offering incentives to employers. The premise is that companies can earn emissions credits by reducing VMT by their employees. VMT reduction is accomplished through a teleworking arrangement between the company and the employee. The credits earned can be sold, banked, or used for baseline adjustments or donated for use in the State Implementation Plan (SIP) or for use in transportation conformity plans. The five metropolitan areas chosen for the pilot program include the District of Columbia (Washington, D.C., Northern Virginia, and Maryland), Los Angeles, Philadelphia, Houston, and Denver. The EPA has designated each of these areas as non-attainment with the exception of Denver.

The EPA charged the National Environmental Policy Institute (NEPI) with designing and implementing the pilot program. The specific objectives of the program are to:

1. Develop and evaluate methods for calculating reductions in emissions achieved as a result of reduced VMT.
2. Develop the design for a pilot program.
3. Determine whether the program:
    - could provide significant incentives for increasing the use of telecommuting or
    - could have positive effects on national, state, and local transportation and infrastructure policies, and on energy conservation and consumption *(39)*.

In the summer of 2002 NEPI closed. It has since been replaced by the Global Environment and Technology Foundation (GETF). GETF has hired a consultant to begin work on Phase III of the program. This phase will provide further training assistance to employers in the five pilot cities.

The project was divided into two phases. The first phase proposed a framework for the pilot cities to follow. The second phase was implementation of the program. NEPI established a national steering committee to oversee the design of the program and to evaluate potential incentives to make teleworking attractive to employers. The steering committee designed a model to serve as a framework for each of the pilot areas to use while developing their individual programs.

The generic model allows for credits to be created by operating a telework program that results in quantifiable and surplus emissions reductions. Certain criteria must be met before credits can be generated. These criteria include:

- Companies that wish to participate must notify the locally designated agency of their intent to begin or expand a telework program.
- Participating companies must provide sufficient information to document the creation of credits.

- Companies that wish to claim credits must periodically submit documentation to the designated agency for certification.
- The local designated agency may establish verification requirements as needed.

Once credits are generated, they may be:

- used by the creator to comply with other emissions reductions requirements;
- sold by the creator to another firm to meet the other firm's emissions reduction requirements;
- sold, donated, or otherwise granted to the state to meet the state's SIP requirements;
- sold, donated, or otherwise granted to the state or another public agency to meet transportation conformity requirements;
- held or banked by the creator to be used in the future for any of the purposes above;
- retired by the creator, grantee, or purchaser as an environmental benefit; or
- any combination of the above.

eCommute in Houston

For illustrative purposes, this section documents the experience of Houston, Texas, in this program. Prior to program implementation a local design team developed a model to operate the program in the Houston area. The Houston-Galveston Area Council (HGAC) was designated as the local agency to implement the program. The EPA classifies Houston as a severe non-attainment area, so the design team chose to focus on a program that could assist in compliance with the federal requirements. HGAC has been offering free consulting and training to area employers for implementation of a telework program since 1999, and several companies have initiated pilot programs. Data were collected at the beginning of the program and included typical mode of travel to and from work; year, make, and model of vehicle; whether the vehicle had passed an inspection test; the typical route and time of commute; the distance traveled to and from work; and any other relevant information. The second data set was limited to teleworking days and was collected after six months. All data were collected using an Internet-based system. The EPA's MOBILE5b model was used to estimate the emissions reductions and credits earned.

Because of the relatively small number of participants and since participation in the program is considered "voluntary measures" for use in the SIP or for transportation conformity, the EPA's Commuter Choice Spreadsheet Model may be a simpler tool that can also be used for this purpose.

Previous research adopted by the national steering committee assumed that the average teleworker avoids one trip and approximately 33 VMT for each day of telework and participants telework 1.8 days per week. Estimates indicated that if 200,000 employees teleworked 1.8 days per week, this would result in 3 tons per day (tpd) reduction of NOx. Estimates in Houston assumed a reduction of 55 VMT per telework day resulting in a savings of 3.96 tpd per 100,000 participants.

HGAC is continuing to administer the program while the EPA attempts to re-launch the program with another non-profit organization. No formal program results have been documented as the program continues.

HGAC has implemented several emissions reduction programs that include earning credits. These programs are included in the SIP after reductions have been verified by TCEQ. The telework program is one program that is included in the Commute Solutions program. HGAC has formed the Air Emissions Reduction Credit Organization (AERCO), a 501c3 corporation that administers many of the credit programs now allowed by federal and state law. The role of AERCO is to promote the generation of emissions credits, select emissions reductions programs, provide local policy options, and sell or transfer credits.

AERCO, working with Commute Solutions, has refined the teleworking program and established the Telework Resource Center. This center offers technical assistance to employers interested in participating in the eCommute program including information about emission credits. Specialized software has been developed that allows employers and employees to document their work and commuting patterns. This web-based proprietary software is capable of tracking and validating auto emissions reductions resulting from teleworking. Companies then use the reports that are generated to obtain credits. The credits are validated by the TCEQ. After validation the

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credits may be sold or traded either directly, through AERCO, or through any other organization acting as a broker for emissions credits.

Stuttgart MobilPASS

In the Stuttgart MobilPASS Field Trial project in Germany *(40)* 400 drivers put a specified amount of money on a smart card each month. Three weeks later that entire amount was reimbursed by the researchers, making the experiment free to the participating drivers. Money was deducted from the smart card account based on the driving behavior of the participants. Driving during off-peak hours, carpooling, and taking public transit all cost less than driving during the peak period. If the drivers altered their travel behavior to avoid SOV peak-period travel, then they would be left with some money on the smart card at the end of the month, which they were allowed to keep (up to 200DM over the life of the project). This project did not allow drivers to sell or trade their credits, but it did provide some information on how drivers reacted to the opportunity to make money by changing their driving behavior.

The results of the Stuttgart MobilPASS field trial indicated that a significant number of participants changed their driving behavior due to the time-dependent pricing schemes *(41)*. Route-dependent pricing schemes caused significant behavior change as well. The results also showed that "they primarily tended to seek behavioral alternatives with their cars and only secondarily changed to another mode of transport" *(41)*. Although drivers were more likely to simply change their time of travel than use transit, the results showed that the increased levels of transit use were maintained after the trial was completed, indicating that use of transit is better accepted after it has been experienced. An increase in the number of carpools and combined trips was observed as well.

Summary

These programs allow flexibility in how targets (caps) are reached. Thus countries, companies, internal business units of a company, or even a driver can maximize their resources through their choice to:

- minimize emissions and selling unused emissions credits,

- not altering emissions and buying the required number of credits, or

- some combination of these two options.

This research examines how a similar scenario might help drivers to maximize the effective use of roadway facilities. With each driver deciding on his or her optimal use of the credits and, in turn, his or her optimal travel behavior, CBVP could greatly reduce peak-period congestion and encourage more efficient use of the roadway system.

Some of these programs represent an initial step in transferring the concept of credit-based controls (cap and trade programs) from the environmental arena to transportation. However, the focus was primarily on emissions and fleets/fleet owners (with the small MobilePASS trial the one exception). The next step would involve using credits to modify travel behavior on an individual level. This step faces a large number of difficult obstacles, as outlined in this report.

CHAPTER 2. POTENTIAL TECHNOLOGIES FOR USE IN CBVP

A successful implementation of a CBVP system will require modern technologies to accomplish the different requirements of the CBVP scenarios. For example, pricing based on the goals of congestion relief and construction/expansion requires knowledge of where and when drivers are traveling. The goal of social equity requires the number of credits allocated to each person to vary based on household income. In order to determine the most feasible technological solutions to these problems, researchers analyzed the use of various types of technology.

AUTOMATIC VEHICLE IDENTIFICATION (AVI)

AVI has been in use for nearly 15 years in electronic toll collection applications. One of the first applications of AVI in ETC was in Dallas in 1989 *(42)*. Electronic identification tags (also called transponders) and readers are used to identify vehicles on the roadway. The transponders are usually issued by an agency to highway users. The most common type of tag used is a radio frequency (RF) tag. RF tags are typically mounted inside the windshield and are read by an RF reader/antenna as the vehicle passes the antenna. There are three types of RF tags in use: type I, type II, and type III. Type I tags are read-only and are encoded with a unique identification number. Type II tags are read/write, and type III tags can read/write and also communicate information to the driver. When a tag passes a reader/antenna, the host computer obtains the information stored in the tag. This information is then used to deduct the toll from the user's prepaid account. As described in the administration section of this report, the current account balance (both cash and credits) plus pending buys/sells of credits would be stored in a central database—not on the transponder.

Costs of readers/antennas are approximately $10,000 per unit. However, the total installation cost is higher because the reader/antenna would have to be mounted on some type of structure and hardwired to a central processing location. Table 2 shows the cost of AVI equipment for a single lane from several toll agencies. The average cost of a type I transponder is approximately

$25. However, new transponders being developed may cost as little as $5 *(42)*. Table 3 shows the cost of several transponder tags that are currently being used by toll agencies.

Table 2. Cost of AVI Equipment for One ETC Lane.

Source	Cost	Source
Kansas Turnpike Authority	$8,568	Telephone interview, June 2002
Transcore iServer	$8,664	http://www.transcore.com/iserver
Lee County, Florida	$10,839	
North Texas Tollway Authority	$11,000	Telephone interview, Feb. 2003
Harris County Toll Road Authority	$11,500	Telephone interview, Feb. 2003

* These costs do not include costs for mounting infrastructure or communications cabling.

Table 3. Cost of Transponders.

Source	Cost	Website
EZ-Pass	$23.00	http://www.ezpassnj.com/static/signup/ind_app_terms.shtml
North Texas Tollway Authority	$25.00	https://tagstore.ntta.org/tagstore
Orlando/Orange County Expressway Authority	$25.00	https://www.expresswayauthority.com/online_app.html
Kansas Turnpike Authority	$34.00	http://ksturnpike.com/ktag/ktagappi.pdf
Oklahoma Turnpike Authority	$30.00	http://www.pikepass.com/2003-05-12%20Pikepass%20Application.pdf
Florida Department of Transportation	$26.50	https://www.sunpasssecure.com/create_account_how_many.cfm
Lee County, Florida	$26.50	http://leewayinfo.com/forms/license_agreement.htm
Harris County Toll Road Authority	$25.00	http://www.hctra.com/eztag/EZtag_Application.pdf
Transcore (eGo transponder—under development)	~$5.00	http://www.transcore.com

AVI equipment is already in use in Texas for ETC operations. The North Texas Tollway Authority (NTTA), Harris County Toll Road Authority (HCTRA), City of Laredo, and City of Pharr currently use AVI equipment to collect tolls. It is conceivable to use this equipment to manage traveler credits as well. The transponder would identify the driver, and depending on the driving behavior, the correct number of credits would be deducted from that driver's account.

Detection of violators of ETC systems is generally accomplished with video enforcement systems (VES), which are essential to ETC operations. Presence detectors are installed at the same location as the AVI readers/antennas. If a vehicle is detected but no transponder is detected by the reader/antenna, a camera takes a photograph of the vehicle's license plate. The photograph can then be used to identify the vehicle owner, who can then be sent a notice of violation. The cost of VES varies depending on the number of lanes being enforced and the expected speed of the vehicles. A single lane entrance or exit ramp is much less expensive than a multi-lane express toll collection plaza. The average cost of a VES per lane enforced is about $50,000. Table 4 shows the cost of complete VES installations according to the NTTA and the HCTRA.

Table 4. Video Enforcement Systems.

Source		Cost
North Texas Tollway Authority	Single lane (ramp plaza)	$25,000
	Express lane (2 lanes)	$92,000
	Express lane (3 lanes & shoulder)	$176,000
Harris County Toll Road Authority	Any lane type	$75,000

Total equipment costs for ETC systems should range between $40,000 and $100,000 per lane based on the information discussed above and shown in Tables 2 and 4. Costs for installing an ETC system will vary depending on the available infrastructure. Sign bridges for hanging AVI readers and VES, communication networks for sending information to the CBVP administrator, and power supplies may or may not be available along an existing corridor. Costs for infrastructure items that may be needed for implementing an ETC system can be found from the TxDOT unit cost website: http://www.dot.state.tx.us/business/avgd.htm.

Interoperability of AVI Systems

A standard AVI system would allow drivers to access any tollway with a single transponder and simplify the administration for multiple toll agencies. A CBVP could also use this standard AVI system. A standard tag could allow drivers who are not part of the CBVP system but do have a transponder from another system to access the CBVP facility without need of a CBVP tag or CBVP account. By using the vehicle ID obtained from the standard tag, the CBVP administrator

could simply contact the statewide database and charge the appropriate amount for the credits used by the out-of-system driver. Currently, there are no such AVI standards, but NTTA and HCTRA are working on an interoperability system in Texas in cooperation with the Transportation and Expressway Authority Membership of Texas (TeamTx) organization.

TeamTx is made up of the primary toll authorities in Texas, including NTTA, HCTRA, the Texas Turnpike Authority (TTA), the Fort Bend County Toll Road Authority, the Central Texas Regional Mobility Authority, and the San Antonio Mobility Coalition. The organization provides "a forum for those engaged in, or associated with, the development, operation, financing, and planning of limited access expressways, toll roads and bridge facilities to discuss issues, and to exchange information, experiences and technical data *(3)*." One of the primary goals of the organization is to develop an interoperable tolling system for the state of Texas so that toll customers can use one tag, with one account, anywhere in Texas *(43)*.

NTTA and HCTRA have developed and are implementing a peer-to-peer interoperability system so that toll tags from either authority can be used to pay tolls on either authority's tollways *(44)*. The system also includes DFW airport parking. A peer-to-peer system requires each tolling or parking authority to have separate agreements with other participating authorities to validate visiting tolltags and to process financial transactions. The system is designed to use existing AVI system hardware. Both toll authorities use AVI systems provided by Amtech, and both use type I read-only tolltags. However, the tags are different in how they are read at toll plazas. The NTTA tolltag is a passive tag which reflects a signal containing the toll tag number back to the tag reader or antenna in the toll plaza. The HCTRA tag is an active tag, which is battery powered and sends a more powerful signal back to the reader which allows for a less sensitive tag reader. The NTTA tag may be missed by the HCTRA readers, and the HCTRA tag may be read by all the readers in an NTTA toll plaza. In April of 2003 the interoperability pilot project tested select tags. The testing phase went well in Dallas, and HCTRA tags will soon be read on NTTA roads. The HCTRA readers will need additional adjustment prior to reading NTTA tags properly, but work continues.

AVI Used in Commercial Vehicle Operations

CBVP projects would allow for commercial vehicle operations (CVO) where appropriate. Some projects may exclude heavy trucks in the same manner as existing HOV facilities. Commercial vehicles (CV) will need to be identified in the same manner as other vehicles that will use the CBVP facility. Through the Commercial Vehicle Information Systems and Networks (CVISN) program the federal government has recommended standards for CVO which include AVI standards for transponders. Trucks equipped with one of the various transponder tags that have been developed for CVO should be able to access a CBVP facility without needing a dedicated tag for that facility. By knowing the identification of a truck, the CBVP administrator can contact the organization that provided the truck its transponder and charge the appropriate amount for the credits used by the truck.

CVISN is the collection of information systems and communications networks that support CVO. CVISN includes the information systems of governments, motor carriers, and other stakeholders such as toll authorities. The goal of CVISN is to improve the safety and efficiency of CVO.

CVISN is composed of three major elements: Safety Information Exchange (SIE), credentials administration, and electronic screening. SIE allows public agencies to quickly identify vehicle inspection data as well as notify other public agencies of vehicles with identified problems or past problems. This information allows a tolling authority to identify vehicles that exceed the state height and weight standards. These vehicles may be prohibited from using certain facilities and thus need to be diverted.

Credentials administration includes both motor carrier or private systems, and state or public systems. Electronic credentialing systems automate the payment, application, and receiving of credentials which include taxes, applications, registrations, fees, and permits. The ability for motor carriers to pay fees electronically should allow toll authorities to use the same methods for payment of tolls and CBVP.

Electronic screening involves roadside communication with vehicle transponders to confirm that vehicles are safe or have passed a previous inspection, eliminating the need for the vehicle to stop. CVISN has open standards for dedicated short range communication (DSRC) for electronic screening. Open DSRC standards are used to allow a single transponder to work for multiple applications including tolling throughout the United States and eventually North America *(45)*.

In the 1990s several operational tests demonstrated the feasibility and benefits of using electronic screening systems for CVO. These tests showed that DSRC technologies can provide reliable communication between moving vehicles and roadside operations. Most of the growth in electronic screening has occurred with the development of three programs: Heavy Vehicle Electronic License Plate (HELP) PrePass, North American Preclearance and Safety System (NORPASS), and Oregon's Green Light. The PrePass system is the most widely used *(46, 47)*.

The PrePass electronic screening system is operated by HELP, Inc., a non-profit partnership between motor carriers and state agencies. PrePass is an AVI system that allows transponder-equipped commercial vehicles to bypass designated inspection facilities. Vehicles are pre-certified, and the motor carrier's safety record and credentials are routinely verified with state agencies. The data on each vehicle could be extended to include the number of credits available for use.

GLOBAL POSITIONING SYSTEM/TELEMATICS

The global positioning system consists of 24 Earth-orbiting satellites. By reading the signals from just four of these satellites, a GPS receiver can determine its location on Earth. However, a greater number of signals results in a more precise location determination. The 24-satellite system ensures that a GPS unit will be in contact with at least four satellites regardless of its position. GPS units have a horizontal accuracy of 15 to 25 meters (50 to 80 feet) *(48)*.

Telematics is the combination of GPS technology with wireless communications. Telematics systems are currently being used for tracking vehicles or other mobile assets. GPS units onboard

the vehicles are equipped with wireless communication devices that report the vehicle's location to a fleet management center or to an individual's home computer. By installing these devices in cars, travel profiles of each individual vehicle could be monitored. Thus, traveler credit charges dependent on time and location of travel could be accomplished by using such a system. This capability is particularly important if CBVP were to be implemented on an area-wide basis.

Telematics systems for tracking vehicles are available from a wide variety of manufacturers and providers. These tracking devices are currently used by trucking companies, transit agencies, emergency services providers, rental car agencies, and individuals for monitoring the locations of their vehicles or other assets. The price of telematics systems varies depending on the application desired and the communication devices used for transmitting or recording the GPS data. Real-time active vehicle tracking devices are currently available in the $500 to $700 price range *(48)*.

Although a very advanced technology, GPS is not without problems. Certain obstacles such as tall buildings, rugged topography, and dense tree cover can lead to loss of a GPS signal *(49)*. However, the use of interpolation and extrapolation would likely be able to compensate for the loss if it is relatively short *(49)*. In some cases the loss of signal may be caused by the deliberate blocking of the GPS unit by the user. Security devices must also be developed to discourage this fraudulent behavior.

Another issue with GPS units is their respective accuracies. Accuracy data are often reported by the manufacturer and typically reflect the accuracy under optimal conditions *(49)*. The typical accuracies of these units will likely be less than those reported by the manufacturer. If the accuracy is not high enough, problems can arise in determining the precise location of each vehicle and could lead to charging errors.

SMART CARDS

A smart card is a credit card sized plastic card with an embedded microprocessor. A smart card can be read or written to either through a card reader or through a contactless electromagnetic

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interface. A contactless interface usually has a range of only 2 to 3 inches for non-battery-powered cards. A contactless smart card is ideal for mass transit, which requires a fast card interface. Smart cards have seen widespread use around the world in a wide number of applications with transit agencies, the financial industry, with pay phone systems, and national health care systems *(50)*. In Hong Kong nearly all transportation systems and many businesses and vending machines accept the Octopus smart card *(51)*.

Transit agencies use smart cards for fare collection systems to decrease boarding times and for passenger convenience. The cards contain a stored value for fare payments, and the fare is deducted from the card when scanned by the transit agency's reader system. Additional information such as the identity of the passenger is not needed or necessarily desired by the transit agency. However, a smart card can contain additional identity and other information including CBVP account number. Drivers using a CBVP system could be issued smart cards to encourage them to use transit. The smart card would be linked to the driver's account maintained by the CBVP administrator. When transit is used instead of driving on the CBVP facility, the smart card will identify the passenger as he or she pays the transit fare and charge the appropriate amount of credits for the trip from the person's account. Note that the charge, in credits, for transit use would be relatively small (see Figure 9). Thus the CBVP system would be designed so that frequent transit users would have excess credits that could be sold.

Houston METRO, the transit provider in Houston, has awarded a contract to Cubic Transportation Systems to provide Houston METRO with a smart card-based fare collection system for the city's public buses. Cubic will upgrade Houston METRO's fareboxes and will provide devices to allow transit users to purchase and reload their smart cards. The smart card system in Houston will allow transit customers to link their smart cards to credit cards for automatic restoring of value to the smart card. Also, the Houston smart cards may be used for other government or private sector services *(52)*. With this smart card system in place, inclusion of transit users in a CBVP system would be relatively straightforward.

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VIDEO

While less common than AVI or GPS systems, some facilities use video systems to collect road use charges. These systems operate by capturing a photograph of a vehicle's license plate as it passes the toll collection point. Typically, the license plate number is then matched to a database and a bill is mailed to the registered owner of the vehicle. The technology used for these systems is very similar to the equipment used by toll agencies to catch violators in the ETC lanes. While there are many facilities that use video technology to identify violators, there are currently only two systems that use video technology to charge for road use: Toronto's Highway 407 and the central London congestion pricing scheme.

Toronto's Highway 407

Highway 407 is a privately operated open-access toll highway *(53)*. There are no tollbooths on Highway 407 because all transactions are made electronically. Drivers who use the highway regularly can obtain a transponder account from the company and have their tolls recorded automatically. Those users are then sent invoices on a monthly basis. ETC readers placed along the roadway read the transponder identification numbers as the vehicles pass that location. Charges are calculated on a per-mile basis, using the transponder reads to determine the total distance traveled.

Although this ETC system is in place, visitors and occasional users who do not have transponder accounts still have access to the roadway. These drivers are charged using the video detection system. Video cameras are located along the highway at the same points as the transponder readers. If a transponder is not detected, the camera photographs the vehicle's license plate. The entry and exit points are then determined with the photographs and are used to calculate the toll. Computer software then analyzes the picture to determine the license plate number. Once this is determined, the registered owner is sent a bill for the per-mile toll charge plus a per-trip premium to cover the additional costs associated with the video system. These drivers are also sent invoices on a monthly basis. Agreements with neighboring provinces and states allow the toll authority to send bills to most people who drive on the road regardless of their home province/state.

Pricing in Central London

In February 2003, the city of London began charging a fee of five pounds (~$8) to motorists driving in the central portion of the city during weekdays in an effort to combat congestion problems *(54)*. Some vehicles, such as motorcycles, taxis, and emergency vehicles, are exempt from the fee, and residents who live within the pricing district receive a 90 percent discount. The fee must be paid during the day of travel, and there are a number of locations in the district where the fee can be paid, such as shops, gas stations, and kiosks. Additionally, the payments can be made by mail, on the Internet, and by cell phone text message. However, motorists also have the option of paying on a weekly, monthly, or yearly basis. In order to verify which users have to pay the fee, a system of video cameras placed around central London records the license plate numbers of the vehicles using the roadways. These numbers are then matched with a list of users who have paid their fee for the day. Those who are in violation are sent notices of fines of 80 pounds (~$127).

The use of video cameras could be used as an effective means of collecting credits, but it will likely require a substantially greater amount of human involvement than other methods. A small, but significant, percentage of license plate photographs must be manually inspected in order to determine the license plate number. This greatly increases the administrative cots of the program over a fully automated GPS or ETC system. The probability of error is also greater. Although video systems have proven effective in some applications, another type of system is probably better suited to handle the magnitude of a CBVP system.

LESS ADVANCED TECHNOLOGIES

Some less advanced technologies may also meet the requirements of certain CBVP scenarios. In some cases, a simple periodic odometer reading may be used. This choice is desirable because odometers are standard equipment on all vehicles. Another type of simple technology is the hubodometer. A hubodometer is a mechanical or electronic device that is attached to the axle hub of a vehicle and records the number of miles traveled. Unfortunately, the limitations of these technologies restrict their application. They are only feasible in situations where total vehicle miles can be used to charge to credits, limiting their use to very large system-wide

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applications. Additionally, manual reading of the odometers increases cost and administrative problems. There are also problems with tampering with the equipment to evade charges, making enforcement very difficult and costly.

TECHNOLOGIES USED IN VALUE PRICING PROJECTS

Since a CBVP system is essentially a complex value pricing project, many of the same technologies used for value pricing projects may prove applicable for use with CBVP. Therefore, it is useful to examine technologies that are currently used in variable pricing projects. Table 5 lists the fee collection technologies used in value pricing projects around the world, while Table 6 lists the technologies that are used in U.S. applications.

The technology used in these applications is almost exclusively by a combination of ETC and AVI. With the expansive growth of ETC, AVI has become increasingly common and inexpensive to implement. However, a few facilities have implemented alternative technologies including GPS and license plate capture.

Table 5. Technologies Used in Value Pricing Projects around the World.

Location	Facility	Technology	Website
Melbourne, Australia	CityLink	ETC	http://www.transurban.com.au
Toronto, Canada	Highway 407	ETC & License Plate Capture	http://www.407etr.com
Copenhagen, Denmark	Area-wide trial	GPS	
London, England	Central London	License Plate Capture	
France	A1	ETC	http://www.sanef.com/siteSanef/fr/info_prat/peages/moduler.htm
France	A14	ETC	http://www.sapn-autoroutes.fr/default.asp?LANG=EN
Marseille, France	Tunnel Prado-Carenage	ETC	http://www.tunnelprado.com/
Rome, Italy	Tiber area	ETC	
Seoul, Korea	Namsan #1 & #3 tunnels	Cash Only	
Trondheim, Norway	Toll ring around city	ETC	
Bergen, Norway	Toll ring around city	ETC	
Singapore	Area-wide pricing	ETC	http://www.lta.gov.sg/index.htm
Spain	Autopista del Sol	ETC	http://www.autopistadelsol.com/PrincipalIng.htm

Table 6. Technologies Used in Value Pricing Projects in the United States.

Location	Facility	Technology	Website
Lee County, FL	Cape Coral and Midpoint Bridges	ETC	http://www.leewayinfo.com/
California	SR 91	ETC	http://www.91expresslanes.com
Houston, TX	I-10 (Katy Freeway)	ETC	http://www.ridemetro.org/services/quickride.asp
Houston, TX	US 290	ETC	http://www.ridemetro.org/services/quickride.asp
Missouri	Lake of the Ozarks Bridge	Cash Only	
New Jersey	NJTA Roads	ETC	http://www.state.nj.us/turnpike/tr2000.htm
NJ/NY	Port Authority of NY/NJ Crossings	ETC	http://www.panynj.gov/
New York	Tappan Zee Bridge	ETC	http://www.tzbsite.com/
San Diego, CA	I-15	ETC	http://argo.sandag.org/fastrak//index.html
Virginia	Dulles Greenway	ETC	http://www.dullesgreenway.com/

SUMMARY

This research found numerous technologies capable of achieving the technological requirements of a CBVP system. However, factors such as installation cost, ease of implementation, and operation and maintenance costs must be considered when determining which type of technology is best suited for a particular CBVP scenario.

AVI is the most common technology used among current value pricing projects, but GPS/telematics is much better suited for a large-scale application. Cost plays a major role in the decision between using AVI or GPS. In small, single facility scenarios AVI works well because of the low cost of transponders, which would be required in each vehicle. However, on a larger scale the cost increases rapidly due to the high cost of the readers that must be placed along the roadway. In this case, GPS is often more economical, despite the per-vehicle cost being

significantly higher, because all vehicles can be monitored from a central location, eliminating the need for readers along the roadway.

Another option, smart cards, works well for transit operations but is inefficient for motor vehicle use. Smart cards could be issued along with transponders or GPS units in order to encourage transit use. Video cameras have also been shown to work efficiently, but their high cost could inhibit their use in all but very specific projects.

For most options, the most feasible solution is to use either an AVI or GPS system, depending upon the size of the CBVP scenario. AVI is best suited for small, single facility operations, while GPS works well on a larger scale. However, future benefits must also be considered. If GPS were used in a small, preliminary application, it would make expansion to a large-scale system much easier. A transition between AVI and GPS would be quite expensive. In addition, vehicle manufacturers are including GPS systems as original equipment on an increasing percentage of vehicles. At some point in the future, the market penetration of GPS may make it the most cost-effective option in all cases.

CHAPTER 3. EVALUATION OF CREDIT-BASED VALUE PRICING (CBVP) SCENARIOS

In developing the concept of CBVP, the research team generated 10 potential CBVP scenarios (five area-wide scenarios and the same five scenarios on a single highway facility). These 10 scenarios will vary significantly in their cost of implementation, political palatability, and technological feasibility. These differences make certain scenarios much more feasible for implementation than other scenarios.

In this section of the report the research team documents the qualitative evaluation of the 10 CBVP scenarios for their relative technological feasibility, administrative challenges, and political palatability from the perspective of the governing agency. Only those scenarios that were least costly, were least politically objectionable, and were possible to implement with current technology were examined in depth in Chapters 4 and 5 of this report. The remaining (least feasible) scenarios were not considered further since the likelihood of any CBVP project being implemented is rather small, but if any scenario is to become reality it will most likely be a scenario that faces few technological, political, and administrative hurdles.

DESCRIPTION OF EVALUATION METHODS

Administration

The literature review on emissions trading applications provides the underlying administrative issues that can arise in any program. The same basic issues arise in all CBVP scenarios, as there are commonalities in the pure application across trading systems. However, since the focus is on individual travelers themselves, and not at the company level like most emission trading programs, there are additional administrative aspects that are likely to vary across different application scenarios. In principle, the proposed scenarios can be divided into three main categories regardless of implementation scale: (1) those that quantify metrics (emission credits), (2) those that involve social metrics (credits that involve equity), and (3) those that are need based (person movement, congestion reduction, construction/expansion). Administrative aspects

of credits issued for quantity metrics will generally be higher than other scenarios because of the extra cost of actual measurement of the metric itself.

Costs

The cost of technology varies widely based on the specific technology employed. With less sophisticated technologies (for example, pricing based on odometer readings plus tailpipe emission estimates) the technology costs are minimized—but at the expense of greatly increased administrative costs. The relative cost scale indicated in Tables 2 and 3, and discussed in this document, is based on the technology deemed most appropriate and not necessarily the least expensive for that CBVP scenario.

The Bureau of Transport and Communications Economics identifies the following cost categories for a large-scale tradable permits scheme *(25)*:

- implementation costs;
- costs of in-vehicle/personal equipment;
- centralized electronic system;
- scanning equipment for broker's reading, debiting, trading, and crediting machines;
- administrative costs to government or agency in charge; and
- public outreach costs.

The first two categories are associated with start-up costs. The next three are primarily related to monitoring and enforcement (M&E), and the last is related to marketing. In this research, start-up plus monitoring and evaluation costs tend to vary across goal scenarios. However, these costs will generally be much higher for system-wide applications relative to facility specific applications. The technology requirements for value pricing applications like ETC systems and transponders for individual travelers will likely form the minimal requirements for traveler-related CBVP. Other low-tech solutions are unlikely to work effectively.

All CBVP applications will entail other costs such as scanning equipment for brokers who will be involved in trading and supplying credits. Public outreach costs will likely be similar across options. These costs, which are relatively consistent across all scenarios, are not included here since this analysis focuses on the relative cost differences between scenarios.

Politics

In the same vein, since each scenario involves a different goal with different criteria for credit issuance and travel cost, the political aspects are also likely to vary. Value pricing applications have demonstrated that politics can play a large part in making or breaking a project *(55, 9, 10, 11, 56)*. In the results presented here, researchers anticipated public and political reaction to each scenario. Any scenario that involves the pricing of currently free road usage will receive a strong negative reaction. This reaction is generally tempered when the pricing:

- includes only very congested roadways where drivers may recognize the need for rationing road space and those who pay the toll receive improved travel conditions;
- is revenue neutral, in the case of adding variability to a current toll, or is a means to address the gap in funding, enabling projects to be implemented sooner rather than waiting for available funding; and
- occurs on only part of a facility (for example, high-occupancy/toll lanes, SR 91, or the fast and intertwined regular (FAIR) lanes concept, which allow for the use of specific lanes for a price but other lanes remain free).

Based on the above, plus the literature review and the researchers' experience with public/political acceptance of tolling, the relative political palatability of each scenario was developed.

Evaluation Method

In the following sections, and Tables 7 and 8, a 10-point scale is used. A one indicates the most feasible (easiest to administer, lowest cost, and least political opposition), while a 10 would indicate the option was practically impossible (extremely expensive, an administrative

nightmare, and political suicide). These ratings were based on the literature review, discussions with technology experts and politicians, and the judgment and experience of the project team.

CBVP SCENARIO DESCRIPTION AND EVALUATION (SYSTEM-WIDE APPLICATION)

System-wide application implies multiple streets in a given area. For this analysis it was assumed that it would generally include all streets and highways in a specific metropolitan area. Certain scenarios lend themselves to this concept. For example, to reduce emissions it would logically include travel on all roads in an area regardless of functional classification. Conversely, it would be unlikely for travel on local roads, and possibly collector roads, to be priced for the congestion-reduction scenario. Where the scenario would not include all streets in the given area, this exception is noted.

The size of the assumed metro area is also a factor in each scenario. For this analysis a congested Texas metro area, for example Dallas-Fort Worth or Houston, was envisioned. The system-wide scenario could be expanded to a statewide or even country-wide level, for example, to replace the existing gas tax structure. However, more realistically, CBVP would occur at a local level first and, if successful, be copied on a larger scale. Therefore, we examined this option at the metropolitan area level. Table 7 summarizes the results.

Table 7. Evaluation of System-Wide CBVP Scenarios.

Criteria	Goals—System Wide				
	Congestion Relief	Person Movement	Emissions Reduction	Social Equity	Construction /Expansion
Administration	7	9	8	8	X
Costs*	8	10	9	8	X
Politics	6	3	5	3	X
TOTAL	21	22	22	19	X

* Including monitoring and enforcement

Congestion Relief

Congestion relief is the primary goal of most of the world's existing value pricing projects *(4)*. The goal is achieved by raising the price of travel during the peak periods in an attempt to spread demand on a congested facility. In this scenario, travel on more congested roadways during congested periods would require a higher number of credits. All interstate and arterials in a given metropolitan area would be included.

Most of the variable pricing projects operating today use AVI to collect fees from users (see Tables 5 and 6), and that technology has proven very successful for single facilities or limited cordon tolling. However, AVI is not the best option for a system-wide application. System-wide application would require every road in the system to be equipped with readers, which would be excessively costly. The best solution for a large-scale project would be a GPS-based system. GPS systems have grown in popularity and are now standard on some vehicle models. The use of GPS eliminates the need to place readers on every road, but it can be quite costly as well. A research study performed by the Oregon Department of Transportation found that retrofitting GPS units into vehicles for a system-wide application would be too expensive unless slowly phased in over a long period of time *(1)*. Road use could then be monitored from a central location.

Administration (score 7): Administration is relatively easy once everyone is equipped with a GPS or ETC system on all impacted roadways. However, the following issues add complexity to administration of such a large-scale application:

- Treating transient customers (tracking, payment, and credit issue method) on a region-wide basis is difficult.
- The technology exists, but enforcing the requirement that all travelers be equipped with transponders or GPS systems would be extremely difficult.

Costs (score 8): The number of GPS units is linked directly with maintenance costs. Other cost issues include:

- Tracking violators is costly.
- Monitoring costs to ensure all vehicles are properly equipped and that there are no violators would be extremely high.

Politics (score 6): It is tough politically to get all travelers in a region to agree. This is exacerbated because so little is known about its success in involving actual individuals. It would probably require extensive outreach activities to educate people.

For freeways that traverse multiple jurisdictions it could be problematic and require extensive institutional agreements. There is a need to establish boundaries and stipulate rules for those that fall within the boundary. Implementation on freeways that traverse multiple jurisdictions may also raise equity concerns between neighborhoods or jurisdictions. Shifts in travel time would be more likely than shifting to alternate routes, likely making this scenario more politically acceptable.

There are also political problems if local and collector streets are excluded. There would be a perception of drivers increasing their use of local streets for through trips in an attempt to avoid using their credits on the arterials and freeways. Communities are very sensitive to commuter use of neighborhood streets.

Person Movement

The person movement scenario is somewhat similar to congestion relief in principle, the primary difference being that in this goal the cost of travel (in credits) is linked to the number of people transported. Therefore, transit, which moves large numbers, would require even fewer credits. Carpools and vanpools would also travel for fewer credits, while SOV trips would require the maximum number of credits. As with congestion relief, travel during congested periods on congested facilities would require more credits than in off-peak periods or on uncongested facilities.

For this person movement idea to be successful, it is necessary to know the number of occupants in each vehicle. To date, no technology exists which can accurately monitor vehicle occupancy although several are under development. Video technology was successfully tested on the I-30 HOV lane in Dallas, but the images still had to be reviewed by humans *(57)*. Near-infrared technology is currently being tested to determine vehicle occupancy by researchers at Honeywell and the University of Minnesota *(58)*. Researchers at the Georgia Tech Research Institute are also performing occupancy detection tests with near-infrared technology *(59)*. Both studies have shown promising results, but the technology is not yet ready for implementation.

Administration (score 9): Without technology to detect, monitor, and enforce vehicle occupancy, these items would require a massive amount of manpower. The manpower requirement could be a tremendous problem for a system-wide application.

Costs (score 10): The enforcement of vehicle occupancy would make this an extremely costly application. The technology needs for carpools (for example, smart cards for all people and readers in every car) are also expensive.

Politics (score 3): The transit component is a favorable aspect and should minimize equity-related concerns, making it more politically acceptable than the congestion-relief scenario. Care would have to be taken to ensure the administrators of the program do not know exactly who you are traveling with, just the number of vehicle occupants. If the system required the administrator to know whom you were traveling with at all times the "big brother" issue would likely be insurmountable.

Emissions Reduction

The cost of travel, in credits, would be directly related to the amount of emissions from the vehicle. Emissions could be measured either in real time on the road or in a stationary test at a testing facility.

The first method, real-time charging, would use sophisticated GPS and roadside emissions sensing technology to determine individual vehicle emissions in real time. On-road testing allows a vehicle's emissions to be profiled while in motion. On-road testing equipment can measure the instantaneous emissions of vehicles in a single lane of traffic. An infrared and ultraviolet light source is used to measure the emissions. Because only an instantaneous profile of emissions is obtained, this type of testing does not give a complete profile of a vehicle's emissions output *(60)*. A stationary test must be used to obtain a complete profile including emissions during acceleration, deceleration, idling, and cruise conditions.

The second method would entail measuring emissions from each vehicle tailpipe and multiplying it by the miles traveled by the vehicle since the last reading and charge based on this. The stationary test is performed using exhaust analyzers as a vehicle is driven on a dynamometer, a treadmill-like device used to simulate typical driving conditions. A sensor is placed in the tailpipe, and a computer profiles the vehicle's emissions. This test is already in use in Texas. Drivers in Dallas, Tarrant, Harris, El Paso, Collin, and Denton Counties are required to undergo a stationary vehicle emissions test on a yearly basis as part of the annual inspection *(61)*. For newer vehicles it might be possible to simply use the manufacturer's emissions estimates.

On-road testing would be very difficult to use in a system-wide application. Equipment would have to be placed at every point of entry into the system. For this reason, and because of the equipment's unreliability, its use is infeasible. The stationary emissions test is a much better option for system-wide use. Each user would be required to undergo the emissions test, with credits being charged based on the emissions profile and number of miles traveled. This testing could be done during the yearly car registration process. Recording of miles traveled could be accomplished with AVI or GPS technology. Again, because of the high cost of installing readers on every road in the system, a GPS system is likely the best option. Alternatively, the yearly change in odometer reading could be used to calculate the miles traveled. However, this method would clearly penalize those drivers who traveled outside the "system" as defined in this scenario and would render the trading scenario nearly impossible.

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Administration (score 8): It is similar to congestion relief. It would require all cars be installed with GPS units.

- It is easier to measure congestion than emissions.
- Roadside emissions monitoring equipment has limited accuracy. Therefore, stationary testing facilities must be used.

Costs (score 9): It costs more than congestion relief because of measuring and calculating emissions.

Politics (score 5): There is likely to be some support for emissions reduction, particularly in non-attainment areas. Since this method is tied directly to vehicle ownership, it may not be an equitable allocation method as many low-income drivers drive older, more polluting vehicles.

Social Equity

Equity is defined as the state, quality, or ideal of being just, impartial, and fair *(62)*. The goal of social equity is to make the cost of, and access to, transportation fair among all social classes. In an attempt to achieve this goal, credits would be distributed partially based on the income or needs of travelers. Those with lower incomes would be allocated a larger number of credits. This method of distribution helps compensate for the fact that for lower-income travelers, transportation costs generally comprise a higher portion of their total expenditures. The cost of travel (in credits) would likely be similar to the congestion-relief scenario, where peak travel requires a greater number of credits. In this scenario, equity is taken as an explicit goal in itself, assuming a vertical equity definition. However, other scenarios may have beneficial social equity effects as well.

Users would be required to provide financial information to determine the number of credits to be issued. Because of the large scale of system-wide application, AVI is not the best technology for credit collection. GPS would be best suited in this situation.

Administration (score 8): There is a need to identify suitable criteria to group individuals who qualify for additional credits. If income is the basis, then there is a need to define objective criteria of "low income" or a credit distribution equation with income as the independent variable. The system would still need to track travel of all vehicles (as with congestion reduction), so a GPS system would still be required.

Costs (score 8): This scenario is similar to the congestion-relief scenario. The cost of GPS systems would be considerable.

Politics (score 3): Less political opposition exists due to the deliberate attempt to help low-income travelers. The political problems lie in the definition of suitable criteria for sorting of individuals.

Construction and/or Expansion

This is not applicable for system-wide application. See the "facility specific" version of this scenario in the next section for a description of the scenario.

CBVP SCENARIO DESCRIPTION AND EVALUATION (FACILITY SPECIFIC APPLICATION)

This section examines the feasibility of CBVP on a single facility or part of that facility. Rankings are as before, with 10 indicating extremely difficult or costly, dropping to one for a relatively easy to implement scenario. Table 8 summarizes these results.

Table 8. Evaluation of Single Facility CBVP Scenarios.

Criteria	Goals—Single Facility				
	Congestion Relief	Person Movement	Emissions Reduction	Social Equity	Construction /Expansion
Administration	1	2	7	2	1
Costs*	2	3	4	2	2
Politics	2 → 8	2 → 7	10	3	2
TOTAL	5 → 11	7 → 12	21	7	5

* Including monitoring and enforcement

Congestion Reduction

This scenario can take two different forms: either all lanes require credits for travel or only specific lanes would require credits. The technologies and costs would remain the same, but political palatability would be significantly higher if not all lanes required credits.

Administration (score 1): Credit charging would work much like a toll road that accepts only ETC payments. Users would therefore need transponders and a method to obtain and trade credits. Allowing transient customers to use the road/lane would increase complexity considerably (for example, Toronto's Highway 407).

Costs (score 2): Costs are a function of the exact system used. However, the system is likely to be ETC technology which is a relatively mature, inexpensive system. Enforcement and administration costs are the only significant operating costs.

Politics (score 2-8): The political aspect would be very similar to the politics of a toll road. CBVP would have the advantage of additional equity. However, political palatability will be driven by whether the road/lanes are new (very acceptable rating = 2) or existing (unacceptable rating = 8).

Person Movement

This scenario would have several similarities to a high-occupancy/toll lane, although it may be applied to a single lane or the entire roadway. Determination of the number of passengers in a vehicle could be achieved with a transponder/smart card combination. If passengers had a smart card, they would each insert it into the transponder upon entering the vehicle. The transponder could then communicate the number of passengers to the host computer where the charge would be calculated accordingly. However, the requirement that every passenger have a smart card makes this very difficult to achieve. Another possibility would be to equip a similar transponder with a magnetic stripe reader. The reader would allow driver licenses and ID cards issued by the Department of Public Safety to be used as identification. An even simpler method would be a type III transponder that allows the driver to simply input the number of passengers aboard. While all of these methods are technically feasible, the issue of enforcement makes them difficult. However, in the case of a single facility, manual enforcement is a reasonable option.

Administration (score 3): It would require everyone who wants to use the lane(s) to pay in credits. It is somewhat more difficult than the facility specific congestion-reduction scenario as it may require travelers to sign up in advance as well as additional enforcement to monitor vehicle occupancies. If smart cards are not used, then only the driver is charged credits, placing the driver at a disadvantage compared to other carpool occupants.

Costs (score 3): Monitoring will increase the cost over congestion reduction but can be done manually since it is only one roadway/lane. As stated previously, technology is not sufficiently advanced to do this automatically.

Politics (score 2-7): Politics are similar to the congestion-reduction scenario including new versus existing facility trade-offs. As with the system-wide person movement scenario there should be slightly less political backlash due to the transit component.

Emissions Reduction

It is feasible to use on-road emissions testing on a single facility. Emission detectors could be placed at every point of entry to obtain the instantaneous emissions of each vehicle as it enters the facility. AVI or GPS could then be used to monitor the vehicle's travel in the facility. Upon exit of the facility, the user would be charged credits based on the estimated emissions and the number of miles traveled. Although feasible, the unreliability of on-road testing could hinder its use *(60)*. A stationary emissions test could also be used for single facility application. When obtaining a transponder or GPS unit from the agency, the user could be required to undergo the emissions test. Facility use could then be monitored via the AVI or GPS systems, with credit charges based on the emissions profile and number of miles traveled.

Administration (score 7): This scenario is easier on a single facility than system wide, but the requirement that users need to register in order to use the facility remains. Therefore, it would be illegal to be on the road without an inspection and knowledge of emissions from the vehicle. The inspection could be done in conjunction with the transponder application.

Costs (score 4): Agency costs would be lower than system-wide application.

Politics (score 10): The same political issues arise as in system-wide application, particularly those related to equitable allocation. Compliance is likely to be much better at the system-wide level. It is difficult to envision political support for reducing emissions on particular facilities when most facilities would remain credit free.

Social Equity

For application to a single facility, users would be required to provide certain financial information. The agency would then use this information to determine the number of credits to be issued. The same technology as used in other scenarios is applicable for this scenario. As with the congestion-reduction scenario on a single facility, AVI would likely be the best technology for charging credits.

Administration (score 2): All facility users would need to be issued transponders. The same administrative issues exist as in system-wide application. The need exists to identify suitable criteria to group individuals who qualify for credits. If income is the basis, then there is a need to define the objective criteria of "low income." With the attempted San Francisco Bay Bridge value pricing, users would have had to prove that they were on federal assistance to obtain the reduced toll rate.

Costs (score 2): Once the groups were identified, the costs would be similar to the congestion-reduction scenarios.

Politics (score 3): Politically it is very positive and easy to sell. The only problem is that this option may be very low on air quality benefits because giving credits to the poor may encourage more trips with users who might use older cars that pollute more.

Construction and/or Expansion

For this goal (and any goal that requires financing) it is assumed drivers must pay at the beginning of each period for their allotment of credits. Although construction and expansion are treated as one goal, CBVP would be administered somewhat differently for each. For example, consider the following scenarios:

CONSTRUCTION: Assume there is no direct road from location A to location B.
Based on travelers' current origins and destinations, those travelers who would benefit from a new, more direct route from A to B would be charged credits. These credits would contribute to the initial financing for the new road. Once the road was constructed, drivers using the road would be charged credits to pay for the remaining costs of construction. Thus the government obtains the initial start-up funds from drivers who will likely benefit from the road and the remaining construction funds from drivers who are benefiting from the road. A GPS system would be used to determine which trips would benefit from the new road, and travelers on those specific routes would be charged credits for those trips.

EXPANSION: Peak-period travelers are charged credits. These charges would fund the initial costs of road expansion. Once additional lanes are completed, peak-period travelers would continue to pay credits until the entire construction cost was covered.

Administration (score 1): It is similar to congestion relief except for the added necessity of determining which vehicles will use (benefit) from the new lanes/road. In the case of expansion these drivers are readily identified as the peak-period travelers on the current road. For new construction, the vehicles would likely have to be tracked (via GPS) from their origin to their destination. This tracking would increase the complexity of administration.

There are also questions regarding who issues credits, communities that surround the areas, development zones where the new roadway is being planned, and tax increment finance districts.

Costs (score 2): Costs may be similar to those of congestion relief, with additional vehicle tracking costs in the case of construction.

Politics (score 2): The user still pays, so politics associated with toll roads apply. However, the credit aspect does reduce some of the negative political aspects.

RANKINGS OF CBVP SCENARIOS

From the previous discussion and the relative difficulty of each scenario (see Tables 7 and 8), it was clear that system-wide CBVP was much more difficult to implement than CBVP on a single facility. Therefore, the likelihood of a system-wide scenario being the first CBVP project implemented is extremely remote and will not be examined further.

In addition, certain CBVP single facility scenarios are much easier to implement than others. The added complexities and political obstacles of a CBVP scenario that prices based on emissions reduction and person movement renders those scenarios less likely to be implemented.

Thus, three single facility scenarios remain for investigation:

- congestion relief,
- social equity, and
- construction/expansion.

The congestion-relief and social equity scenarios are very similar in all aspects (pricing, technologies required, enforcement needed, etc.) except one—initial distribution of credits. In the social equity scenario, more credits are distributed to persons with lower incomes. This distribution is the only difference the research team focused on when developing the congestion-relief scenario, but they note that this scenario could readily be converted to a social equity scenario by changing the distribution of credits. Therefore, the following chapters in this report will detail the administrative, economic, technological, and political aspects of the congestion-reduction and construction/expansion CBVP scenarios on a single facility.

CHAPTER 4. CONGESTION REDUCTION CBVP SCENARIO

This chapter provides a detailed analysis of the issues surrounding the congestion-reduction CBVP scenario. The goal of congestion relief is achieved by charging users a higher amount of credits during periods of peak traffic demand. This method of charging is called variable pricing, and it is used on various tolled facilities around the world. The most common form of variable pricing is to charge a higher toll during peak travel times. Dynamically varying tolls based on current traffic congestion is less common. I-15 in San Diego, California, is the only facility in the world with this type of dynamic pricing system.

To begin, general administrative issues that CBVP would have in common with existing value priced facilities are examined to document successful administrative practices. Next the administrative complexities of CBVP not found in any existing toll facility are examined. Economic issues are then examined, and this is followed by an economic example of a credit-based pricing strategy to combat congestion. A brief recap of appropriate technologies is provided, followed by an in-depth look at political issues with this CBVP strategy. The political analysis includes results from focus groups of the general public and discussions with politicians.

GENERAL ADMINISTRATIVE ISSUES

Currently, the administration of most pricing projects involves the use of transponder technology (see Tables 2 and 3). Effective administration of a single facility credit-based value pricing scenario will also require the use of a transponder. A review of the basic systems employed in California, Florida, and Texas will provide useful information.

FasTrak™, California

State Route 91 (SR 91) Express Lanes require that users be registered in the FasTrak program. There are no tollbooths on the Express Lanes. FasTrak is the moniker given to the electronic toll collection system operating on various roads in California. This program allows for three different types of plans and special access:

- **91 Express Club™**—Members of the club pay a monthly membership fee of $20 per transponder. In return, members receive a $1 discount per trip on the 91 Express Lanes. The club is only open to credit card accounts. The name is trademarked by the Orange County Transportation Authority.
- **Standard Plan**—This plan requires no monthly membership, and customers are charged the full price of the current toll rate. There is a $7 monthly minimum in tolls paid required for each transponder on this plan. If the $7 minimum is not met, the user will be charged the difference between the tolls paid and the $7 minimum for each transponder.
- **Convenience Plan**—This plan does not require a monthly membership, a minimum toll expenditure, nor toll discounts. Full price is paid for each toll, and there is a non-refundable $75 enrollment fee per transponder.
- **Special Access**—This plan is available for people that always drive with three or more people in the car, drive a motorcycle, drive a zero emissions vehicle, or have a disabled veteran or disabled person license plate. These accounts are issued transponders, but they travel free of charge on the facility.

Customers have the option of paying by credit card, cash, check, or money order. When the balance falls below $10, credit card customers' accounts are automatically replenished by charging $30 or the equivalent of one month's usage. Customers paying with cash, check, or money order agree to replenish their accounts with a minimum payment of $50 when the balance falls below $25.

The 91 Express Lanes have negotiated interoperability agreements with other toll roads so that the transponder may be used to pay tolls on other facilities. Currently, these agreements apply to any facility designated with the FasTrak logo, such as Bay Area bridges, the Orange County toll roads, and others. However, special discounts and value pricing only apply to the 91 Express Lanes.

I-15 in San Diego also utilizes electronic toll collection through transponder technology. This program is also marketed under the FasTrak trademark. The FasTrak program on I-15 allows SOVs to pay a toll for access into the barrier-separated high-occupancy vehicles (HOV) lanes;

thus the lanes become HOT lanes. The tolls are adjusted dynamically in response to the congestion on the HOT lanes.

The FasTrak program on I-15 does not have a variety of payment plans to choose from but otherwise is very similar to SR 91 Express Lanes. If paying by credit card a charge of $40 replenishes the account each time the account balance falls below $10. This applies to each transponder that is issued for a particular account.

If paying by check or money order the customer must make a deposit of $50 for each transponder requested. Additionally, a minimum payment of $50 must be made each time the account balance falls below $20. The agreement also stipulates that a payment must be made before the account balance reaches $0. If a customer fails to maintain a proper account balance, toll transactions may be processed as violations subject to additional fees and fines. For each of these options there is an additional $40 refundable transponder deposit.

The I-15 value pricing demonstration project is a cooperative venture between the Federal Highway Administration (FHWA), the California Department of Transportation (Caltrans), and the San Diego Association of Governments (SANDAG). However, a private company, TransCore, through subcontracts with SANDAG, provides account maintenance, customer service, and billing services.

QuickRide, Houston, Texas

The QuickRide program in Houston allows vehicles with only two occupants to use the HOV lane for a $2 toll during the times the lane was restricted to vehicles with three or more occupants. The HOV lane becomes a HOT lane during the morning and afternoon peak periods on I-10 (Katy Freeway) and only in the morning peak period on US 290 (Northwest Freeway).

The account setup is very similar to the FasTrak program in California. Participants are required to register and establish a pre-paid account that is associated with a specific ETC transponder. There is a $15 deposit for the transponder. However, if participants already have a transponder for use on the toll roads in the area, they are not required to get another transponder but the ID of

the transponder must be provided. There is also a $2.50 monthly administrative fee for program participants. Once the account is approved, a transponder and/or an Auto ID (hangtag) are issued. The Auto ID allows enforcement personnel to quickly identify participants of the QuickRide program. An initial payment of $40 is charged to the account holder's credit card. When the account balance falls below $10 the credit card is charged again to bring the account balance back to $40.

Lee County, Florida

A slightly different pricing program is operated in Lee County, Florida. The Cape Coral and Midpoint Memorial Bridges in Lee County typically serve a high volume of commuter traffic. Value pricing was implemented on the bridges as a proactive measure against future traffic congestion and to determine the effects of pricing on driver behavior. The electronic technology, dubbed LeeWay, allows for a variable toll structure. A 50 percent discount on the toll is given to drivers who travel during the shoulders of the peak periods, 6:30 a.m. – 7:00 a.m., 9:00 a.m. – 11:00 a.m., 2:00 p.m. – 4:00 p.m., and 6:30 p.m. – 7:00 p.m. The discount is only available to drivers who have established an account and have been issued a transponder.

Drivers may open an account by pre-paying or linking the account to a credit card or debit card. When the balance in the account drops below $10 customers must replenish the prepaid account by cash or check. If the account is linked to a credit card or debit card, the card is automatically charged $30.

The entire LeeWay system, including the service center and ETC database, is operated by Lee County employees. The operations were originally handled by TransCore, the technology vendor. TransCore is the same company that installed the system hardware and software. The cost is approximately $0.15 per transaction. LeeWay processes approximately 80,000 manual and electronic toll transactions each day; therefore, total costs for customer service and back-office expenses is roughly $4 million per year.

Summary of Administration Issues with Electronic Toll Collection Accounts

The evolution of transponder technology has made toll collection a dynamic process. This same technology can be used to implement a credit-based pricing program. As with ETC, there is a seamless integration of the systems. These systems are designed to reduce costs of administration and enforcement in some situations, and provide superior customer service. The technology is available that can provide for control and monitoring of each lane of a facility in real time. Because the technology allows for real-time management and can be done on an individual facility or on certain lanes within a facility, CBVP can be effectively administered to achieve specific project goals.

In each of the previous examples, the toll collection system is an integrated system that includes transponders, readers, processors, and data transmitters that relay information. Interoperability agreements are the mechanisms by which information is shared among the agencies. These agreements are the result of multi-agency cooperation and strive to enhance the seamlessness of the transportation network to the customer. The interoperability agreements allow for a transfer of information and/or funds to the appropriate agency. This transfer may be accomplished in two ways. Information may be transferred to a central processing center where the transponder number is matched to an account number and any other relevant information is input to determine the appropriate charge for a particular transaction. Alternatively, several separate databases may be linked together in what is known as a peer-to-peer network. In this scenario, each agency maintains its own database, but information is shared via a communication link. This method is the way interoperability has been structured for the toll agencies in Texas.

The toll authority may automatically send a quarterly statement of transponder usage or motorists may pay extra to receive a monthly statement of their account. Toll agencies may also have agreements with the state to search motor vehicle registration databases in the event of a violation.

The administration of a CBVP plan would involve issuing a specific number of credits each month to an account holder. The number of credits would be determined based upon a complex

relationship between the capacity of the facility, the cost in credits of different travel options, and the behavior of the traveler. As the account holder travels on a facility that is operating on a credit-based system, an appropriate number of credits would be deducted from his or her account. Additionally, account holders could buy and sell credits, and their accounts would be updated automatically.

ADMINISTRATIVE ISSUES FOR MOTORISTS

The distribution of credits is an important issue and could be accomplished in a number of ways. Credits may be distributed monthly, staggered over the month, or possibly based on last names, license plate numbers, vehicle registration dates, or any other measure. Credit distribution should be staggered over the period since if all credits were distributed at the same time, there could be a glut of credits at the beginning of the period (when everyone receives them) creating an artificially low price and, conversely, a lack of credits near the end of the period, creating artificially high prices. A staggered distribution helps to minimize artificial fluctuations in the pricing of credits in the marketplace.

Additionally, a determination must be made regarding who receives credits. This item is discussed in depth in the "Economic Issues" section of this chapter. Briefly, it is likely the issuance of credits would be based on "grandfathering" current users of the system, with possible allowances for additional recipients who move into the area.

Each driver on the facility would be required to establish an account. The account information that would be required would be very similar to what is currently required when establishing an ETC account. Information includes vehicle license number, vehicle description, and driver's license number, in addition to other personal information such as name and address. A deposit is typically required for each transponder issued. The deposits currently required by toll agencies range from $10 to $40. A motorist may use cash, check, or credit card to open an account. A monetary minimum balance would be required for each account. The minimum balance requirement of most toll agencies is $10. This money would be deducted from the account in the event of a shortfall of credits or a violation. The amount deducted would be determined by the price of market credits being bought and sold at the time of transaction. Cash or check

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customers would be required to replenish their account before the balance reaches a higher minimum balance.

The transponder may signal when a customer's balance is low. This signal can happen either in a vehicle with a light on the transponder or as the motorist passes the reader; a signal light may indicate a low balance. Credit card customers authorize an automatic charge to their credit card when their account balance drops below a minimum balance. Figure 1 is a sample application from the North Texas Tollway Authority.

The system described above is typical of a toll road system that utilizes electronic toll collection. A credit-based system would operate in the same fashion. However, at the beginning of each period customer accounts would be credited with, for example, 400 credits free of charge. The credits would be issued in a staggered fashion in an effort to minimize any unfair effects of a particular distribution or cause artificial price swings. Credits would act like units of currency. Motorists that travel on a facility that has implemented credit-based pricing are charged a number of credits based on the rate at their time of travel.

North Texas Tollway Authority

TollTag Application
(Fax completed application to 972-991-4636)

(For Internal Office Use Only)

Account Number _____ Clerk ID _____

Last Name			
First Name		**Middle Initial**	
Address			
City			
State		**Zip Code**	
Home Phone		**Work Phone**	
Drivers License State		**Drivers License Number**	

Monthly Itemized Statement ☐ No ☐ Yes ($1.50 postage & handling charge per month)

Method of Payment ☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover ☐ Cash/Check

Credit Card Number	
Expiration Date (Mo/Yr)	
Deposit Amount	

License Plate		Vehicles Needing TollTag					TollTag No.
License Plate #	State	Year	Color	Make	Model		(For Office Use Only)

I hereby acknowledge that I have read and accept the terms and conditions of the TollTag License Agreement as presented on the NTTA Website for TollTag applications. I understand that my use of the Tag means that I agree to comply with all terms of the License Agreement which, among other things, requires that I (I) maintain a prepaid account with the NTTA to cover tolls and charges for the use of the Tag; (II) notify the NTTA immediately if my Tag is stolen, lost, damaged, or defective; (III) notify the NTTA of any changes in my address, vehicle assigned to the Tag, or credit card account information; (IV) abide by the traffic controls, rules, and posted speed limits on the NTTA toll lanes and facilities; and (V) indemnify the NTTA against all damage, loss, cost, expense, or liability that, in any way, relates to the use or the performance of the Tag, and to pay all costs, including attorney's fees, incurred by NTTA to enforce this agreement. I also understand that I may be held responsible for paying the costs required to replace lost, stolen, or damaged Tags. I further understand and agree that the NTTA is not liable for the performance of the Tag.

Signature (and title, if applicable) _____ **Date** _____

Company (if applicable) _____

Figure 1. Sample Electronic Toll Collection Application (www.ntta.org).

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Credit Commerce

Administratively, a credit-based system would allow for the buying and selling of credits. The market would determine the price. By requiring travelers to create an account to participate, information is stored in a central database. This is the case for both transponder users and SmartCard users. Users would be able to access their account in much the same way as done with bank accounts, credit card accounts, or other electronic toll collection accounts. The access may be through the Internet, via an integrated telephone system, or via a kiosk. The telephone access would utilize a touch-tone system that allows users to access their account through an automated system. Additionally, an 800 number available for customer service calls and kiosks at gas stations and convenience stores located conveniently in the corridor may also enable participants to manage their accounts.

Current technology allows for the adding and deleting of monies on transponder accounts as well as SmartCards. This technology can also be used with credits. The ability of account holders to buy and sell credits will utilize the information that is stored in the central database. A central database can employ software that allows for transfer between accounts. The types of systems used in the toll industry today require the processing power of several systems of servers, routers, work stations, web servers, shared drives, file storage system, and usually a tape backup system. Customers will be able to buy and sell through this system. The system will also keep track of the latest value of credits in much the same way as the New York Stock Exchange. A customer may log in to the system, either by phone or Internet, at any time to check the status of the current market price and decide whether to place an order to buy or sell at a price specified by the customer. The order can be a market order good for a period of time or good until filled or cancelled. Figure 2 shows an example of a transaction. An account holder may phone in or log on to administer his account. Information is sent to the central processing center where the databases are maintained. This central processing hub records and performs the requested functions among the accounts. If a person decides to sell credits for the current cash value, the processing center communicates with his financial institution and makes a deposit to his bank or credit card account.
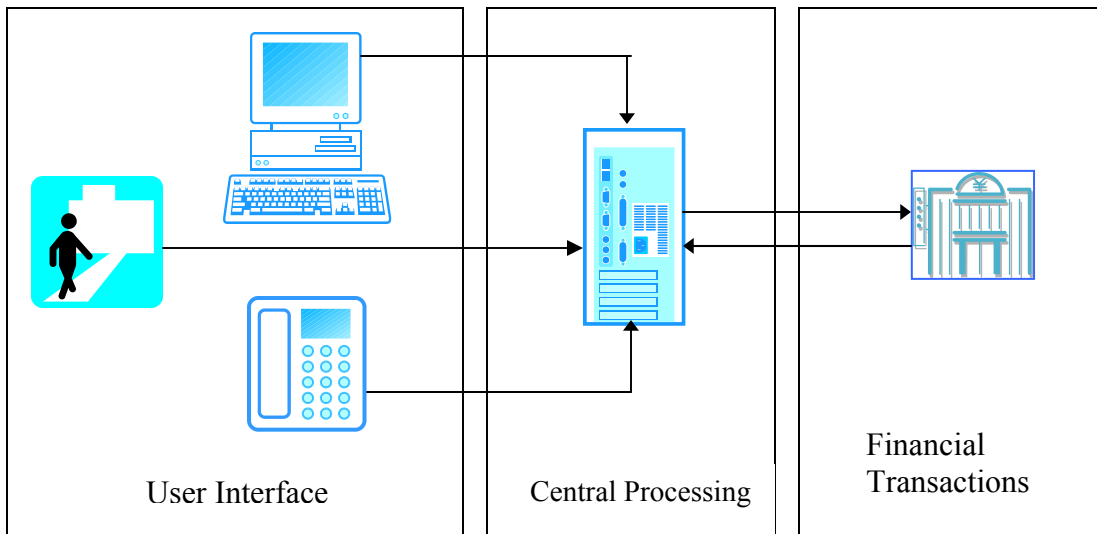
Figure 2. Sample Transaction.

Administrative Issues for Transit Riders

Transit riders on routes that use this facility would participate in the program by obtaining a "smart card." Many transit agencies are currently experimenting with this technology through electronic fare payment (EFP) systems. The use of smart cards results in improved customer satisfaction, seamless regional transit travel, reduced collection costs, additional revenue, and an enhanced ability to modify fares, among other benefits *(63)*. The card may be inserted into a reader as a rider boards a bus, or it may be "passed by" the reader without actually having to insert the card. Transit providers currently prefer the contactless card because it facilitates boarding and requires less time *(63)*. Considerably fewer credits would be required for transit riders than for automobile drivers. It is important to note that the credits being charged are in addition to regular fare payment. This practice ensures that the transit agency retains the original revenue generated from servicing this particular route. The benefit to transit riders is that even frequent transit riders may have excess credits that they may sell, thus benefiting monetarily.

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Administrative Issues for Carpools/Vanpools

Carpools and vanpools traveling on the facility would also be required to pay credits. Two different scenarios are possible for determining the amount of credits needed to travel on the facility at any given time: preferential treatment and equal treatment.

If preferential treatment is given to carpools and vanpools, by way of reduced credits required, a separate bypass lane could be utilized for carpools and vanpools to enter the facility (see Figures 3 and 4). The transponder is read, and a lesser number of credits are debited than for single-occupant vehicles. This strategy would have the effect of encouraging carpooling, reducing the number of single-occupant vehicles, and reducing overall congestion. Although vehicle occupancy detection technology is advancing rapidly, it is still in its infancy and could not be used to automate enforcement of this scenario. Thus enforcement costs would be considerably higher when offering carpool and vanpool discounts than if carpools and vanpools are charged the same amount of credits.

Figure 3. Example of Signage and ETC for a Special (Discount) Lane for HOVs.
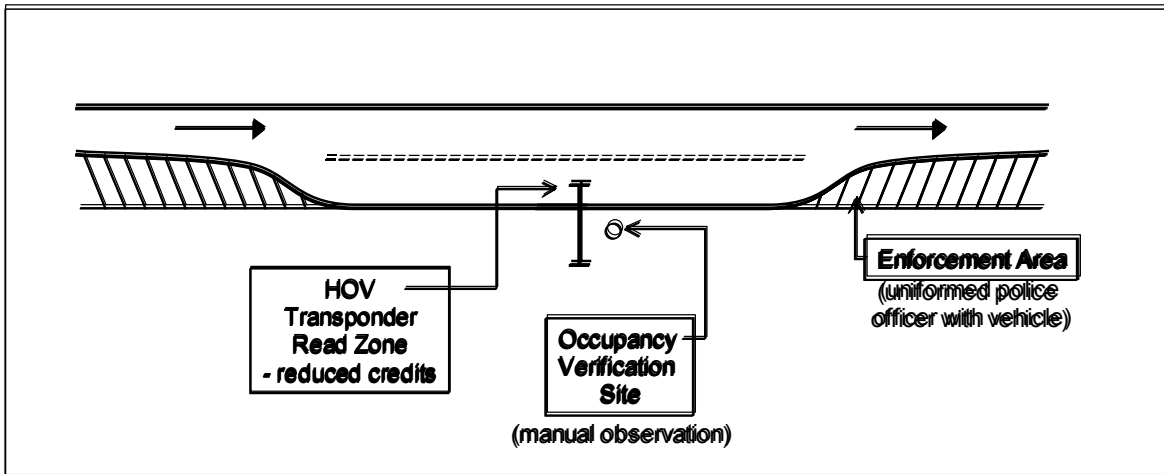
Figure 4. Example of the Enforcement Area for an HOV Discount Lane.

Conversely, carpools and vanpools may be charged the same number of credits as a single-occupant vehicle. Since travelers will have the ability to buy and sell credits, passengers in the carpools and vanpools may sell their unused credits and give the proceeds to the driver as their cost contribution to the carpool or vanpool. This scenario still encourages carpool and vanpool use although not specifically outlined as a goal of the CBVP scenario.

Other Issues

The congestion-reduction scenario involves two possibilities. The program could be implemented on a set of managed lanes, essentially a freeway within a freeway. The other lanes could remain under conventional operation. If the lanes are operated in this manner, all motorists always have an adjacent freeway alternative. However, if an entire facility is operated using CBVP, other issues arise. For example, infrequent or out-of-town travelers will be excluded from using the facility. Because the credits will only be issued to travelers within the corridor, other travelers, most likely, will not have established an account. Additionally, adequate driver information must alert travelers of the need for a transponder well in advance of the facility and offer alternate routes.

Implementation of a CBVP scenario requires special attention to certain circumstances that will arise. Out-of-town travelers and commercial truckers will need to be accommodated. The

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system must also alleviate any disadvantage that is imposed on residents and businesses located inside the corridor. Below is a brief discussion of how these issues may be handled.

Occasional or Out-of-Town Travelers

Out-of-town travelers will need to be accommodated if CBVP is implemented on an entire facility. For full facility CBVP, travelers from other areas as well as those that do not utilize the facility very often should be readily afforded an alternative. Accommodating these motorists will not be an issue if the CBVP is implemented on only a lane or a few lanes within a facility.

One method for accomplishing this task is to allow out-of-town travelers and the occasional user to purchase a special one-time or "limited use" trip tag. This tag may be purchased at area convenience stores, gas stations, kiosks, or the customer service center. The price of the tag will be determined by current market prices for the credits needed plus a processing fee.

It is important to note that the system constructed for this program would include several integrated systems that work in concert with one another to make the transactions seamless to the participants. For example, advance traveler information systems would be critical to the out-of-town traveler if CBVP is implemented on an entire facility. System integration would allow dynamic message signs to alert transient travelers to the need for a tag and the current cost of the tag. Additionally, information could be broadcast on AM traveler information stations. The systems integration would allow the electronic reader to acknowledge a valid limited use trip tag. These tags could have special identifiers that acknowledge their limited use to the central processing unit. For occasional users that have a local area toll tag (not directly affiliated with the CBVP system) the system could identify the tag and make an appropriate charge to their account with the appropriate institutional arrangements. This charge would be for the market price of credits plus a processing fee.

Likewise, precautions must be taken to ensure that this system is not abused. The price of the tag must be high enough to deter people from making large purchases and then selling the tags at a profit.

Commercial Vehicles

Current interoperability efforts may also be used in a CBVP scenario mitigating the need for commercial truck drivers to obtain additional transponders (see).

Residents and Businesses

A CBVP plan should not cause excessive negative impacts on the businesses and residents within or near the corridor. It will be important to address the situation on a facility specific basis. In the case where the facility is used for many short trips by local residents, there may be an argument to offer a higher number of credits to certain individuals but only in extreme circumstances. Many factors need to be considered before this determination could be made. For example, frontage roads may provide a useable alternative, or the adjacent arterial network may be sufficient to support the local travel. How to handle individuals within the corridor will ultimately be determined based on local characteristics and the project goals.

Special Access Accounts

Special access accounts such as disabled veterans, handicapped, and inherently low-emitting vehicles (ILEVs) may be accorded special access to a CBVP facility. If so, these groups would establish an account and be issued a transponder for identification purposes, but these accounts would not be issued or charged credits. This process allows the special use vehicles unlimited, free access but does not allow these drivers to profit from the sale of unused credits.

Administrators

The credit commerce described above may be administered in several different ways, with the following method being the most likely scenario. The agency that is operating the facility would be the most logical administrator of the program. If this is a toll agency using ETC, which would likely be the case, those agencies could modify their operations to include credits with minimal adaptation. To facilitate trading, the most logical step would be for the administrating agency to bring in a brokerage house to coordinate trading the new commodity of traveler credits.

ECONOMIC ISSUES

This section of the report examines many of the economic questions that arise when developing a CBVP system. These questions and answers are focused on the congestion-relief scenario, but most are equally applicable to the construction/expansion scenario. The few differences that exist are mentioned here and in the next chapter of the report: "Construction/Expansion CBVP Scenario." After addressing these questions, a simple theoretical model is developed to describe how the system would work in lessening traffic congestion and encouraging trading (buying and selling) credits among travelers.

Are Credits to Be Paid or Issued Free of Charge?

In principle, credits may be issued to travelers for free, or the agency may wish to charge for credits issued. Given a limit on maximum allowable trips, both options will alter the choice sets of travelers and will impact travel choices, but the extent of impact is highly dependent on current use/demand patterns relative to the limit. If the credits are distributed for free, then the public acceptability is likely to be much higher than if they are sold. The primary concern if credits are issued to travelers for free is the market size. Markets have to be wide in order to ensure that the widest representation of peak-period driving preferences are captured and combined with a well-defined credit charging strategy so as to provide opportunities for behavioral adjustments. For example, capturing all transit, walking, biking, and automobile trips results in many different preferred travel behaviors and more likely opportunities for trading of credits.

From the perspective of the traveler, free credits enhance overall welfare as paying for credits may cause some negative equity issues with lower-income travelers. From the perspective of the agency, free credit distribution will involve less visible costs and reduced political control over effects of the program.

If travelers must purchase credits, then revenue distribution becomes a key question. Revenue distribution can be done by spending revenues from credit sales on corridor-related

investments/improvements. This approach is used for many toll-road and HOT lane applications. However, due to the political challenges already associated with CBVP, even with free credits, and the equity issues that arise with charging for credits, *free credit allocations are recommended* for the congestion-reduction scenario.

Determination of the Recipients of the Initial Allocation of Credits

A grandfathering method of initial allocation can be used to determine the initial allocations of credits. This approach relies on historical criteria and has been the most commonly used for allocating permits in the emissions trading applications (see Table 9). It will lend political support for implementation because this method is more difficult to contest or manipulate.

Surveys should provide guidance in identifying the pool of existing users who would be "grandfathered" into the system. Surveys would also prove beneficial in identifying hard to identify travelers such as transit riders and carpoolers. It is preferable to observe behavior over a couple of different points in time to capture the diversity in facility usage. Special cases include transient passengers, new users, and occasional users who were not included in the initial allocation round. All these users would need to purchase credits and limited use transponders prior to using the facility. Purchasing locations would have to be conveniently located just prior to entering the designated roadway area along with other payment options such as ordering by telephone or over the Internet.

Table 9. Initial Allocations under Existing and Proposed Domestic Cap and Trade Programs.

Program	Initial Allocation Method		Allocation Time
	Auction	Grandfathering	
U.S. Ozone-Depleting Substances (ODS) Phase-Out		Yes	Single year.
U.S. SO$_2$	Yes	Yes	3-year period based on the annual average of heat input.
California RECLAIM (SO$_2$ and NOx)		Yes	Based on peak activity over the period 1989–92.
U.S. OTC NOx		Yes	Baseline emissions.
Massachusetts Ozone Transport Commission (OTC) NOx		Yes + updating	Based on average of 2 highest electricity output years between 1994–98. Allows for updating of allocations.
U.S. NOx Emissions Trading under EPA's SIP Call		Yes + updating	Proposed program to start in 2004. Based on heat input over a 4-year period. Grandfathering and updating methods.

The following allocation methods have been observed in the emissions literature:

- Random access (lotteries): Credits would be randomly given out. To do so would be problematic because of possible distributional effects and the need to give all users some credits.
- First come first serve: Similar to random access, this method would also be problematic because of possible distributional effects.
- Rules based on eligibility criteria (grandfathering): In this scenario, permits are given to existing users. This method is a politically easy option because it confirms the current operation of the facility. In addition, if permits are given free, then it explicitly recognizes the property rights of existing travelers for the use of that roadway.

- Auctions: Credits are awarded to the highest bidders. This method has the potential of generating significant revenue, along with generating significant public and political opposition.

A grandfathering allocation rule is therefore recommended for this CBVP scenario. It is important to identify the entire pool of existing users for wide markets. Hence facility specific surveys conducted over several points in time are ideally suited to determine the current users of the facility.

Steps Involved in Setting Initial Allocations

1. Decide who will receive the credits (market size determination) for grandfathering. The decision-making process could be accomplished through surveys of travelers and license plate identification of automobiles.

2. Decide a truncation point in terms of the threshold maximum number of trips or maximum density that will be allowed. That maximum will determine the maximum number of credits to be issued for the corridor. This report recommends that the maximum number of credits be divided equally between all existing users. However, it is important to know that individual user groups have their own internal thresholds or cut-offs which are dependent on parameters like values-of-time and elasticities of demand for peak-period use as well as barriers/constraints. These define a demand function for road use for each user group. An understanding of these internal thresholds is required for the facility in question to assess behavioral shifts associated with each group in the presence of credits.

3. Decide how to use revenues from the initial sale of credits (only for the construction /expansion scenario where credits have to be purchased). With trade, there will likely be few unused credits, and only the distribution of the proceeds from the initial sale needs to be determined. In the construction/expansion scenario, the funds automatically go to fund the construction or expansion.

4. Decide the number of credits to be charged for travel at different times of day and for different modes of travel.

5.   Communicate the details of the CBVP program.

Determination of the Number of Credits to Be Allocated

Initial credit allocations should be dependent on facility usage by travelers in the area over a pre-specified assessment, or baseline, period. In addition, an estimate of the appropriate, or optimal, flow on the facility is necessary. Once the flow thresholds are established, they need to be converted to the number of permits that should be issued to users.

For example, assume a desired flow threshold of 2000 vehicles per hour per lane (vphpl). To convert this threshold to the number of permits to be issued would require the modal split on the roadway, average vehicle occupancies, the number of lanes, and the length of the peak period. Assume two modes, the automobile, which carries 96 percent of travelers, and transit, which carries the remaining 4 percent. Assume the average automobile occupancy is 1.2, the cost in credits to travel by automobile is 8, the average transit vehicle carries 14 passengers, the cost in credits to travel by transit is 2, there are three lanes in the peak direction, and the peak period lasts for 1 hour in the morning. Using these assumptions, there would be 5979 automobiles carrying 7175 people and 21 buses carrying 294 people at the threshold, for a total cost of 48,420 credits (see below).

2000 vphpl $\times$ 3 lanes $\times$ 1 hour $= 6000$ vehicles

Modal Split:

$$96\% \text{ of travelers use the auto} = \frac{x \text{ cars} \times 1.2 \text{ persons per car}}{x \text{ cars} \times 1.2 \text{ persons per car} + y \text{ buses} \times 14 \text{ persons per bus}}$$

$x = 5979$; cars $y = 21$ buses; $x + y = 6000$ vehicles

5979 cars $\times$ 8 credits required $= 47832$ credits required
5979 cars $\times$ 1.2 persons per car $= 7175$ car travlers
21 buses $\times$ 14 persons per bus $= 294$ bus travelers
294 bus travelers $\times$ 2 credits required $= 588$ credits
Total Credits Required $= 47832 + 588 = 48420$

Therefore, the number of grandfathered users would each receive an equal share of those 48,420 credits for travel. If the number of travelers significantly exceeds the threshold, then each traveler would receive significantly fewer than the 8 credits required to travel by automobile during the peak. This discrepancy would encourage some travelers to switch mode or travel time, or abandon their trip and sell their excess credits to travelers who continue to use their automobile during the peak period. If there happens to be exactly 7469 people traveling in the peak (as in our example), then each would receive 6.48 credits for travel. Therefore, those travelers in automobiles would have to switch to transit, create additional carpools, travel less, travel in the off-peak, or purchase additional credits from travelers with excess credits (such as transit riders). This is an extremely simplified example, as we also need to include off-peak periods and expand the example to be relevant for an entire month. However, the methodology for the full day over an entire month would be a straightforward expansion of this example.

The maximum desirable vehicular flow (or threshold volumes) is readily calculated using speed flow measurements and standard traffic engineering analyses. Alternatively, the threshold volume may be a pre-specified percentage or fraction of the total estimated peak trips for the entire issue period. The difficulty will be in determining the desirable modal split used for the calculations of credits to be allocated. A logical starting point would be the current modal split as used in travel demand models. This methodology could also be easily updated to include trip purpose. Update rules for grandfathered allocations need to be specified in the case of sub-optimal results. These update rules involve comparing initial allocations with actual utilization per person (and the relevant traveler or user group) and adjusting future period allocation to produce desirable traffic flows.

Can the Users Buy and Sell (Trade) among Themselves?

A fully functional system of CBVP implies trading (buying and selling) of credits between the users. The level of complexity increases significantly as one moves from a scenario without trading to a scenario will full trading. There are intermediate scenarios that involve trading within the agency itself but not with individual users. Trading, in this instance, assumes full transferability of authorized credits across users. On economic grounds, trading allows users to

achieve their optimal allocations in time, consumption, and facility usage and hence will have efficiency connotations. In effect, each traveler can customize his or her travel behavior to exactly how he or she values trips and optimize the use of the facility. However, the full trade scenario does raise some important issues including:

- Trading locations are designated places (a physical location, an Internet site, or an automated phone system) for users to buy needed credits or sell excess credits. These locations have to authorize an individual to sell his or her excess credits. The locations must track trading prices, bids, and offers from all locations while maintaining a link with the agency via computerized databases. These requirements increase application costs of the program depending on who sets the system up, which could impact program effectiveness. A public-private partnership with a brokerage house could lead to cost-sharing arrangements that could reduce agency costs. A brokerage house could meet brokerage needs by providing price information and matching partners. In the emission markets, private parties have established locations and helped track trades and prices.
- A free market price for trades will emerge as a result of exchange between parties. This situation also raises a key issue in relation to the link between traded price and credits charged for roadway use. Links between the two markets could complicate pricing schedules and cause excessive variability and complexity for the users. In turn, this could violate transparency conditions for optimal pricing. Thus, it is recommended that the number of credits charged for roadway use not vary dynamically based on traffic conditions (as on I-15, see Figure 5) but rather follow a set schedule (as on SR 91, see Figure 6).

In a partial implementation scenario trade might occur between the travelers and the agency. Acquiring extra credits from the agency at a nominal fixed price can make up a credit shortfall. Surplus credits simply expire at the end of each period if the agency has determined that there will be no temporal transferability. In effect this strategy is much like a variable toll, such as those on the New Jersey Turnpike or on Lee County toll bridges.

Toll Schedules

Morning Period (Southbound)

Maximum Toll	5:45-6:00	6:00-6:30	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-11:00
$4.00				■	■			
$3.00				■	■			
$2.50				■	■			
$2.00			■	■	■	■		
$1.50			■	■	■	■		
$1.00		■	■	■	■	■	■	
$.75	■	■	■	■	■	■	■	■
$.50	■	■	■	■	■	■	■	■

Evening Period (Northbound)

Maximum Toll	12:00-1:00	1:00-3:30	3:30-4:00	4:00-4:30	4:30-5:00	5:00-5:30	5:30-6:00	6:00-6:30	6:30-7:00
$4.00					■	■			
$3.00					■	■			
$2.50					■	■			
$2.00			■	■	■	■	■		
$1.50			■	■	■	■	■		
$1.00		■	■	■	■	■	■	■	
$.75	■	■	■	■	■	■	■	■	■
$.50	■	■	■	■	■	■	■	■	■

Friday Evening Period (Northbound) Only

Maximum Toll	12:00-1:00	1:00-3:30	3:30-4:00	4:00-4:30	4:30-5:00	5:00-5:30	5:30-6:00	6:00-6:30	6:30-7:00
$4.00				■	■	■			
$3.00				■	■	■			
$2.50				■	■	■			
$2.00			■	■	■	■	■		
$1.50			■	■	■	■	■		
$1.00		■	■	■	■	■	■	■	
$.75	■	■	■	■	■	■	■	■	■
$.50	■	■	■	■	■	■	■	■	■

Weekend Toll Schedule (as of 8/23/2003)

Weekend Evening (Northbound)*

Maximum Toll	1:00-2:00pm	2:00-3:00pm	3:00-4:00pm	4:00-5:00pm	5:00-6:00pm	6:00-7:00pm
$4.00	■	■	■	■	■	■
$3.00	■	■	■	■	■	■
$2.50	■	■	■	■	■	■
$2.00	■	■	■	■	■	■
$1.50	■	■	■	■	■	■
$1.00	■	■	■	■	■	■
$.75	■	■	■	■	■	■
$.50	■	■	■	■	■	■

* Includes Labor Day

Note: The actual toll is dependent on traffic and varies every 6 minutes.

Figure 5. Maximum Allowable Toll Schedule on the I-15 HOT Lanes.

Figure 6. Toll Schedule for SR 91 Express Lanes, California.

For example, assume an agency provides 160 credits per month to drive on its facility for free. Additional credits might cost $0.25 each. The agency then charges a variable number of credits based on the user's time of travel—for example, 8 credits in the peak or 4 in the shoulder periods. Therefore, the driver's first 20 peak-period trips are free; from then on peak-period trips cost $2 and shoulder periods cost $1. Assuming an average work month with 22 work days and 44 peak-period trips, the following average tolls are derived:

44 peak-period trips $\times$ 8 credits per trip = 352 credits
352 credits required - 160 free = 192 credits purchased
192 credits $\times$ $0.25 per credit = $48 per month for 44 trips = $1.09 per trip

If the driver traveled half the time in the peak period and the other half in the off-peak, then the following average toll is found:

22 peak period trips $\times$ 8 credits per trip + 22 off-peak trips $\times$ 4 credits per trip = 264 credits
264 credits required - 160 free = 104 credits purchased
104 credits $\times$ $0.25 per credit = $26 per month for 44 trips = $0.59 per trip

A variable toll, without credits, might simply have a peak rate of $1 and a shoulder rate of $0.50. This method would likely obtain similar results with much less confusion and lower costs than using credits and only allowing users to buy excess credits at a set price from the agency.

Therefore, dynamic credit pricing is not recommended—*the cost of travel, in credits, should be fixed and known in advance*. The credit pricing strategy should be set to *induce maximum desired shifts* for a congestion-relief scenario. Theoretically, full trade scenarios are hypothesized to induce maximum goal compliance and may be most effective relative to other scenarios like partial trading scenarios. Therefore, this study examines and recommends full trading among users. However, it is clear from focus groups that this full trade amongst users will require more advanced planning and a more evolved market user group than currently exists.

Temporal Aspects: Banking/Borrowing

The emission permits literature suggests that a fully "value maximizing" trading permit system must have full temporal transferability, implying that emission allowances can be both borrowed and banked *(64)*. With banking, an individual user can save unused permits in one allocation period and use them in another allocation period. With borrowing, a permit holder can use permits earlier than the stipulated date (i.e., from his or her own future allocation), but that of course means that they will no longer be available in the future period. No permit program appears to currently have operational temporal transferability, for example:

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- The emission trading program has allowed banking but not borrowing.
- The lead phase-out program allowed no banking or borrowing to begin but introduced banking eventually.
- The California RECLAIM program did not allow banking or borrowing.
- The SO_2 program allows banking but not borrowing.

Borrowing has not been recommended in emissions trading because it causes temporal clustering of emissions.

This study *does not recommend banking or borrowing of credits* because both may be self-defeating to the goals of congestion relief. If individuals can bank and borrow across periods, then the CBVP scenario will have a lesser impact on traffic, and it will be much more difficult to set the appropriate credit pricing levels. For example, a driver who takes a two-week vacation one period would be able to bank those excess credits and use them to drive alone more often over the next couple of periods. The clustering of vacations could cause significant congestion in the periods after vacationing occurred.

Credit Duration: The Period of Issue

The duration of permits needs to represent a balance between the requirement to allow the agency sufficient control over corridor conditions (for a congestion-relief application) and the need to provide travelers flexibility and sufficient time to alter behavioral patterns. Shorter time frames for permit duration give the agency more control in assessing transition to desired outcomes, while somewhat longer time frames may be more desirable for travelers to plan in advance as it gives them more certainty. This research used a period of one month as it represented a good compromise between these two objectives.

During the first allocation of permits it would be beneficial to allocate credits to all grandfathered users on the first day of operation. From then on, credit allocation would be staggered. In that way gluts of credits at the beginning of each period and shortages at the end would be avoided as users would have different start and end period dates.

CREDIT-BASED PRICING STRATEGY

Pricing Criteria

Hau developed the following criteria that have been applied for road pricing applications *(65, 66)*. Many of those criteria will be applicable in the development of a CBVP strategy. The criteria are as follows and were appropriately modified to reflect the goals of a CBVP policy.

User-Based Criteria

- Convenience/ease of payments: ETC has made it extremely convenient to implement virtually any kind of a pricing strategy with respect to tolls or credits (see Chapter 2).
- Transparency: This criterion implies that it should be very clear how many credits would be charged at any given time of day during the peak. In order for transparency conditions to be preserved in a free trading CBVP scenario, the cost of travel (in number of credits) must be consistent from day to day and not vary dynamically.
- Privacy: This principle has been an issue with electronic road pricing, and it will continue to remain in all pricing-related applications that hinge on use of transponders. In such a case, increased security in account handling is the only way to maintain privacy.

Agency-Based Criteria

- Flexibility: This principle implies that a certain amount of flexibility should be built into the system where, on occasion, the agency can alter the cost of specific travel behaviors to improve system efficiency.
- User cost basis: This criterion requires an understanding of the relevant user cost concepts that should form the basis of a charging system. A better understanding of user costs and travel behavior will result in a system that is more likely able to maximize user benefits.
- Reliability: This implies that strategies should be designed to maximize behavioral shifts for congestion-relief scenarios. For construction-expansion scenarios, revenue-generation goals become important.

- Enhanced welfare (environment, driving conditions, and travel time): This goal implies that credit pricing strategies can either be developed by internalizing welfare or by agencies determining schedules so that welfare, in terms of driving conditions, is maximized.

Components of a Credit Pricing Strategy for CBVP Applications

In addition to satisfying the general criteria mentioned above, a pricing strategy should have the following components.

Rate Structure

- Treatment of time: Time of day (peak, off-peak, weekday, or weekend)
- Treatment of mode of travel: Auto modes, transit modes
  - Within auto-mode: Treatment of single-occupancy mode (SOV users) versus carpoolers is possible.
- Ways to introduce variability (distance based versus per-trip pricing)

Rate Levels

In this section the basis for the formulation of credit schedules (thresholds and costs) is examined. Note that the salient components will be discussed with respect to the two facility specific goals of CBVP, i.e., congestion relief or construction expansion (since these are the two that are being examined in this report). The above sections are common to all scenarios. The discussion below pertains specifically to a congestion-relief application.

Congestion-Relief Rate Structure

The questions of (1) what the credit schedule for off-peak periods should look like in relation to peak and (2) whether the credit schedule should be fixed in advance or variable (dynamic) over the peak period are examined here.

Off-Peak Period

Based on criteria developed by Hau and Vickrey, it is important that fewer or no credits should be charged during the off-peak periods in order to provide enough incentives for some drivers to shift to off-peak periods *(65, 67)*. For a congestion-relief scenario, it becomes essential to provide such incentives. These incentives can be in the form of (a) zero or low off-peak credit charges to maximize the peak and off-peak differences or (b) additional credits added to the transponder account as a reward for off-peak travel. Of these two approaches (a) is easier to implement and simpler to communicate. Additionally, with the proper setting of the cost of travel (in credits) throughout the day option (a) will result in off-peak travelers receiving a subsidy when they sell their unused credits. Therefore, there is no reason to add the additional complexity of offering additional credits for off-peak travel. Therefore, o*ption (a), zero or low off-peak credit requirements, is recommended.*

Peak Period

With respect to peak-period travel, the credit schedule can be either fixed or dynamic, and the morning and afternoon peaks can either be mirror images of one another or completely independent. For the purpose of this report, we will assume that morning and afternoon peaks should be treated as mirror images of one another. However, the schedule would depend on the traffic conditions on the particular facility. For example, SR 91 morning and evening tolls are not mirror images of one another (see Figure 6).

The remaining question is whether or not there should be variability in the credit schedule. Flat credit schedules are predictable and make it very simple to calculate the maximum permits to be issued. However, flat toll structures have been the least effective in impacting peak-period traffic and in inducing shifts in travel behavior. Hence, credit schedules should vary during the peak, with the maximum cost of travel (in credits) at the point of maximum demand for the facility (see Figure 7). This variation is necessary if travel behavior modification is desired.
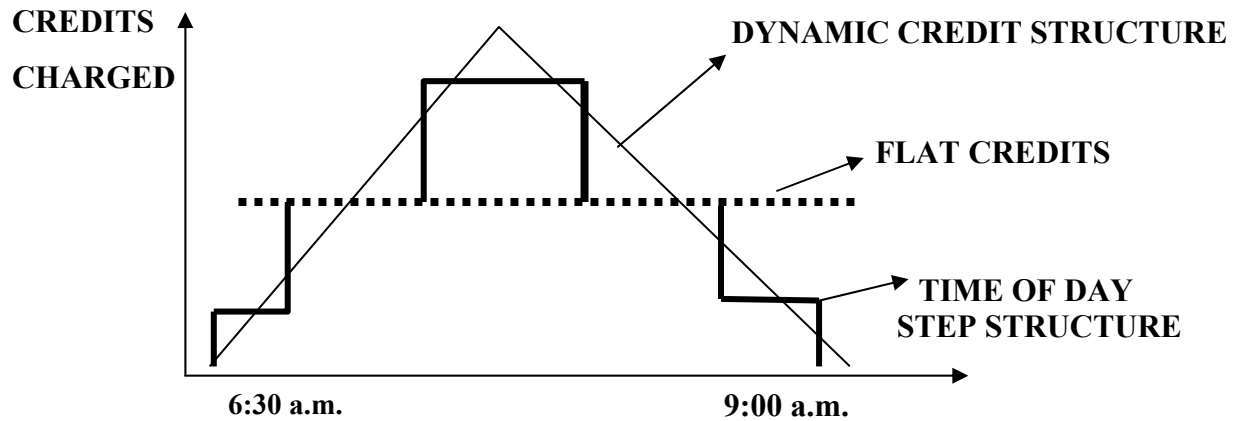
Figure 7. Different Types of Per-Trip Credit Schedules.

Exactly how the credit schedule varies over the peak must also be investigated. At one extreme is SANDAG's I-15 high-occupancy toll lane application. In the I-15 application, tolls can vary every 6 minutes and are disseminated to the user through variable message signs (see Figure 8). Only the maximum tolls are set in advance (see Figure 5). To determine the toll rate, an extensive traffic analysis found a maximum threshold limit of 3200 vph for the two lanes. This threshold limit was developed to maintain free flow conditions on the lanes—similar to the goals of this CBVP scenario. In order to enforce this maximum threshold limit, the traffic entering the HOT lanes is monitored and prices change dynamically to ensure fewer than 320 vehicles for every 6 minutes enter the lanes.

Figure 8. Toll Display on I-15 near San Diego.

More commonly, toll rates are set in advance so that drivers know the exact amount they will have to pay if they arrive at the facility at a given time. For example, SR 91 tolls vary considerably throughout the day, but their exact level is known well in advance (see Figure 6). Similarly, drivers paying with ETC pay only half the regular toll rate if they travel across Lee County's (Florida) Midpoint or Cape Coral Toll Bridges from 6:30 a.m. – 7:00 a.m., 9:00 a.m. – 11:00 a.m., 2:00 p.m. – 4:00 p.m., or 6:30 p.m. – 7:00 p.m. This variable toll rate and hours have been the same for just over five years.

Variable credit schedules, that are set in advance, are recommended for the CBVP scenarios examined here for two primary reasons. The first is that it reduces driver confusion and therefore increases the acceptability of the program. The second reason is that toll variability is already introduced due to the free market buying and selling of credits. In peak periods of demand the price of credits may rise (due to additional buying pressures), thereby creating additional variability and more accurately reflecting the true demand and costs of travel in the period.

Congestion Relief: Ways to Introduce Additional Variability in Credit Schedules

There are at least two ways of introducing variability into the system. The first approach is a distance-based credit schedule. In this case, the rate is flat and derived on a per-mile basis. For toll roads in the United States these rates have been seen to vary anywhere from $0.05 per mile to $0.50 per mile, with many being around $0.10 per mile. The second approach is a per-trip pricing mechanism. This form of pricing is seen more often with toll bridges where the trip distance is already set. As is clear, the choice between these options is largely dependent on the design of the roadway section that will implement CBVP. When there are multiple access and/or egress points to be considered over a given roadway section, then one can set credits charged to be a function of the distance traveled. This way, the number of credits deducted and trip costs vary based on distance.

Alternatively, one can ignore distance and charge just for using the road space. This is tantamount to charging on a per-trip basis. From an administrative standpoint, the per-trip prices are much more cost-effective to administer. Distance charges require independent distance traveled readings combined with a system that is capable of data collection. Both per-trip and distance charges have been implemented in toll pricing applications. For instance, SR 91 Express Lanes (10 miles long) and I-15 HOT lane (8 miles) applications in California charge only on a per-trip basis. Currently, both these applications require access and egress at specified locations with little to no alternatives to traveling the entire length of the facility. Both of these applications have variable trip rates over the peak, as shown in Figures 5 and 6. The HOT lanes on I-10 and US 290 in Houston also have a per-trip rate ($2), which is flat over the peak and drops to $0 in the off-peak. However, each HOT lane has several entry and exit points. Highway 407 in Canada previously utilized a variable rate distance-based pricing. Tolls were $0.10 (Canadian) per kilometer during weekday peaks, $0.08 per kilometer during weekends and off-peak, and $0.04 per kilometer at night.

The steps in a variable rate credit structure can be distributed symmetrically or asymmetrically around a peak time. The I-15 example shows a scenario where the three steps are symmetrically distributed around the peak hour of 7:00 a.m. – 8:00 a.m. In the SR 91 application, the number

of steps is distributed asymmetrically around the peak hour of 7:00 a.m. – 8:00 a.m. Research has also demonstrated that as the number of steps increase, so do the efficiency gains. This correlation exists because as the number of steps increase, the rate structure slowly approaches a continuous structure as shown in Figure 7.

While the technology exists to implement continuously varying time-dependent or congestion-dependent schedules, implementing too many steps poses problems for deciding total allocations and for public acceptability. Completely dynamic schedules (or step schedules that are not fixed over the peak) like that implemented on I-15 present problems for CBVP applications with trading because of the interaction between credit schedules and the fluctuating price of credits. So, variable schedules with a limited number of steps symmetrically distributed around the peak hour are valid candidates for a CBVP congestion-relief application. Two to three steps are typical in variable pricing applications. This step structure is essential to provide some representation of the concentration of preferred arrival times at destinations.

Length of the Peak Hour and Days

The length of the peak period should be determined by traffic analysis for the candidate facilities to determine the number of steps in the variable rate credit structure. Most pricing experiments have weekday and weekend schedules as well. It is recommended that the weekend rates, as with off-peak rates, be set to a low level for CBVP.

Value of Increments between Steps

The value of increments to trip costs should be easily understood by the user. Therefore, as much as possible, the price of travel, in credits, should be a round number of credits. For example, the credit schedule shown in Figure 9 for a given facility would be relatively easy for users to follow and understand. However, if this facility could be entered and exited at multiple points, then the number of credits required for a short trip might be just a fraction of what is shown in Figure 9. In that way an off-peak transit trip might end up requiring less than a full credit. This kind of situation would not be an issue as the database and user account could readily handle fractions of credits.

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Credits Required for Travel—Eastbound

Time of Day	Automobile	Transit
Midnight to 7 a.m.	3	1
7 a.m. to 9 a.m.	8	2
9 a.m. to Noon	5	1
Noon to Midnight	4	1

Credit Pricing:
  Last Sale: 15 credits at $0.57
  Highest Bid: 10 credits at $0.54
  Lowest Offer: 20 credits at $0.61

Figure 9. Sample Variable Weekday Credit Schedule.

Also shown in Figure 9 is an indication of how buying and selling of credits might operate. In this example the last sale, and therefore the current market price, occurred at $0.57. Also shown is the highest bid, or the maximum someone is willing to spend to purchase credits at this moment, which is $0.54 per credit, and that person is willing to purchase 10 credits. The lowest anyone is willing to sell a credit for is $0.61. Therefore, no trading is occurring at this moment. For a trade to occur the highest bid must be at least as high as the lowest offer (similar to a stock exchange).

Treatment of Mode

This report focuses on the automobile mode given that current modal splits are largely skewed in favor of automobile travel, with approximately 78 to 80 percent SOVs, approximately 15 percent HOVs, and only 2 to 4 percent using transit in most metro areas in Texas. The remaining percentage of trips are walking, biking, and other modes that comprise a very small percentage of trips. Based on existing modal splits, even very small shifts in the percentage of people using the automobile mode can have a large impact on transit ridership. However, existing studies indicate very low cross price elasticities, indicating that even large increases in automobile costs result in small modal shifts to transit. For example, Hensher cites cross price elasticities ranging from 0.003 to 0.06 *(68)*.

 In order to make transit options more attractive, the transit user credit rates should be kept positive but low throughout the peak period (see Figure 9). From an administration point of view, this will require some coordination and integration between transit agencies and operators of CBVP roadway sections. Joint setting of credit schedules by agencies and operators can assist

in ensuring that the goals of congestion relief are met and the environmental benefits are maximized.

The lower transit credit rates would be an incentive for some automobile drivers to switch some or all of their trips to transit. Since frequent transit users would have surplus credits at the end of a period, these credits can be sold for a profit. Alternatively, the cost of travel, in credits, may be set such that users receive an allotment of credits that is sufficient for most of their peak-period travel by automobile, but some trips would need to be made by transit in order not to have to buy additional credits on the market. In that way some automobile drivers will choose to take a few trips on transit, and some will choose to spend money to buy the additional credits necessary for automobile travel for all of their trips. These incentives are likely to vary in direct proportion to the effort/costs of obtaining extra credits. So, the free trade scenarios are likely to produce superior results as opposed to trade with the agency. Free trade would likely induce economically efficient mode shifts, as the users choose the price at which they will be willing to shift modes.

Congestion Relief: Rate Levels Basis for Derivation of Rates

Cost-Based Pricing

Considerable literature is devoted to the analysis of the optimal price of travel to induce the optimal flow of vehicles and optimize the use of the transportation facility (*4, 7, 8, 10, 12, 18*). The results of this research show that the optimal price is the marginal social cost (MSC) of the trip. This marginal social cost is basically the cost of the trip to the person making it plus the added cost of everyone else's trip due to that person traveling.

Distance-based prices or per-trip prices need to be based on the costs of travel, and more specifically, they should be linked to the marginal social cost of travel. In this case, MSC pricing should be implemented to enable maximum self-selection opportunities for individuals. In other words, pricing is based on behavioral parameters to ensure that the optimal behavioral (modal, trip timing, and trip abandonment) shifts will occur. Based on the economic theory cited above,

this pricing scheme will maximize the net societal benefits of travel and provide more optimal driving conditions for the users.

MSC pricing should be based on those cost concepts that are most pertinent for making travel decisions at the time of making the trip. Some of the most significant relevant cost categories are delay costs. Specifically, it is the delay imposed by the additional road user on all other users. Researchers are increasingly examining other costs incurred by users that are representative of constraints and barriers that force them to travel at certain times of day. In this regard, there are several research articles that demonstrate how socially optimal and/or cost-minimizing, time-dependent tolls or trip prices (and therefore credits) can be derived *(69, 70, 71, 72, 73)*. In essence, all of these researchers develop triangular tolls, or tolls that peak at the center of the peak hours. Sometimes they are based only on time delay costs, which are a function of value of time (VOT). In other cases, the tolls are a function of internal valuation parameters, such as the penalty (or disutility) of early or late arrival at their destination. The latter present a challenge to implement because little is known about the distribution of internal disutility valuation parameters. However, it is important to note that a toll with enough steps can mimic (but not replicate the effects completely) a totally time-dependent toll. However, with the addition of a free market where the price of credits is allowed to fluctuate based on demand (as in this research), the total cost of travel, including the credit cost, should theoretically approximate the MSC of travel.

Thresholds for Rate Derivation

Once the appropriate user costs are identified, appropriate cut-off thresholds also need to be defined for credit rate setting. The most accurate method involves the use of vehicle flow/travel speed thresholds. This method is often completed by examining travel speeds and vehicle flows on the facility. With that information specific credit charging rates can be set that attempt to keep speeds close to free flow conditions. This option will ensure societal benefit by providing optimal driving conditions.

In the next section of this report a simple theoretical model has been developed for a sample peak period to set credit rates. The rates were based on a flow cut-off threshold defined using optimality principles and based on congestion externalities as defined by MSC pricing, assumptions on demand of traveler groups, and their demand parameters. It also relies on the difference between the marginal and average social costs at the flow threshold to develop rates. In essence this is a marginal cost pricing application to assess the cost of travel in credits.

Summary of Suggested CBVP Economic Structure

The previous section of this report documented many of the economic issues associated with the development of CBVP. Using economic theory and the literature on other value pricing projects as a guide, the researchers make the following suggestions for a CBVP scenario for congestion relief:

- Credits should be distributed free of charge.
- Initial distribution of credits should be based on grandfathering of existing facility users on a staggered schedule.
- There should be free trade (buying and selling) of credits among users.
- There should not be banking or borrowing of credits from one period to another. All credits should only be valid for the period in which they were issued.
- Periods should be one month in length.
- The cost of travel, in credits (the credit schedule) should be set in advance with:
  - two to three steps in the peak period and
  - a low number of credits required for off-peak, weekend, and transit use. Therefore interagency coordination with transit agencies is necessary.

Future Work/Research

To fully develop the economic principals behind CBVP, a great deal of future research is required. Some of the most critical aspects include:

- Develop tools to assess the temporal and modal shifts that will occur as a consequence of credits charged. A simple peak-period model was developed (in the following section) to assess the number of credit exchanges that would be offered for sale at any given credit price. This measure is critical when studying the behavioral impact occurring via shifts or abstinence. At this time, the model is not able to distinguish between mode and departure time shifts. This measure is envisioned as the first step in the development of tools that can assist in CBVP strategy development.
- Assess alternate ways of utilizing flow thresholds.
- Use alternate flow rate thresholds and study their impact.

DERIVATION OF CUT-OFF FLOW THRESHOLDS, IMPACTS, AND TRADING EQUILIBRIUM

A "representative peak" period approach is developed to study the effect of thresholds on both the utilization of credits and credit exchanges in a market where trade is allowed. In this simplified example, trading could be with either the agency or the market. A representative peak period is any single peak period, and since all peak periods are assumed to be the same, it is enough to look at one peak and aggregate over the entire credit issue period. The standard congestion pricing model is used in this part of the analysis. It is essentially a static analysis in that it examines the entire peak period as a whole. The following terms will be used in the analysis:

Equilibrium: Given by q^*, it represents the socially optimal or desirable level of flows for given costs and demand conditions. It will vary across roadways.

Threshold demand: It is defined to be the maximum demand and is $= \theta$. It is a demand parameter.

Demand elasticity: It is given by (c/μ), where c is costs (measured in dollars) and μ is net user benefit (measured in dollars per vehicle per hour).

α = Value of travel time. It is a cost side parameter.

Cut-off flow threshold (K): Given by K, it can be set equal to q^*. It therefore is a function of demand and cost parameters. K can be converted to maximum permits to be issued.

Group allocation (K_i^g): K can be divided into an allocation for every group i.

Group utilization (K_i): Part of the group allocation for user group (i) that is actually utilized by group i.

Demand groups: Three demand groups are assumed. They do not represent any particular group in this exercise. However, demand groups can be developed to correspond to categories and trip-purposes represented in the traditional travel demand model.

Demand Side Specification

Since travel demand is unknown, a specification of the demand side is required for an illustration of the way the market works. It is necessary to specify demand in such a way that it is representative of a wide variety of trips at different valuations of time, a key variable impacting cost perceptions and demand for travel. The exponential demand function is a particularly attractive form because of its general conformity to observed behavior. Therefore, the amount of traffic per hour using the roadway *(Eq. 1)* is defined by the function:

$$q = \theta e^{\left(-\frac{c}{\mu}\right)}$$
(Eq. 1)

θ is the threshold demand that will occur when the costs are perceived as zero. As is frequently done in the literature, demand and supply are assumed to be represented by traffic flow. Then, q (traffic flow) can be represented as quantity demanded per hour. The generalized cost of travel is represented by c. μ is directly related to the demand elasticity, which is given by (c/μ) at any given level of costs. A higher value of μ indicates the user has less sensitivity of demand to changes in cost. Hence, c/μ is demand responsiveness which is unitless and measures propensity to change behavior. Both these parameters can be subjected to a sensitivity analysis to assess the impact of those variables under different demand scenarios. This particular form of the demand curve has a very appealing property and is widely used in economic analysis. This functional form is also consistent with a skewed value of time distribution for road use.

In the scenarios presented below, the threshold demand (θ) is assumed to be 4000 vph and is therefore less than the design capacity (s) of approximately 6000 vph in the peak direction of a three-lane interstate facility.

Supply Side Representation

Supply conditions require a description of costs facing the users *(Eq. 2, Eq. 3, Eq. 4)*. Following Walters' key contribution and many other articles in the congestion pricing that followed, the congestion represented by speed-flow curves can form the basis for the development of a trip cost curve of the generic form *(74)*:

$$C(q) = c_0 + \alpha \, L/v(q) \qquad \qquad \text{(Eq. 2)}$$

where L is the distance traveled, v is the speed expressed in terms of the flow, c_0 represents travel costs other than those associated with travel time, and α is the unit cost of travel time. In this case, we define costs as follows:

$$C(q) = \tau + d \, (q/s), \qquad \qquad \text{(Eq. 3)}$$

where
s = capacity (assumed equal to = 6000 vph),
τ = trip costs, and
$d \, (q/s)$ = delay costs.

C(q) is defined as the average cost to the traveler of making a trip including time costs (external costs) and actual money costs. If congestion is the only other external cost that is included, then C(q) also represents the average social cost of making a trip. The marginal social cost is then also the marginal cost (MC) of making a trip (a key function in pricing studies) and is:

$$MC = C(q) + q(\partial C(q)/\partial q). \qquad \qquad \text{(Eq. 4)}$$

τ is related to non-travel time costs associated with making a trip, for example, tolls or the dollar value of credits. The other costs, which are congestion related, were assumed to be due to travel time costs only. In reality this assumption is reasonable since other congestion-related costs, such as increased emissions, are generally much smaller than the cost of additional travel time. In addition, this model also captures the schedule disutility costs of late arrival or early departure. Drivers automatically, and possibly subconsciously, already weigh and pay those schedule disutility costs. For example, by choosing to drive during the peak traffic congestion period drivers are willing to spend extra time in traffic to arrive at their destination at a specific time. If there were no schedule disutility costs, drivers would simply make their trip during uncongested periods.

Under these assumptions, time or delay costs are a function of the relationship between flow of vehicles and the corresponding vehicle speeds. For simplicity, a linear speed flow relation is assumed. However, this relation can also be subjected to sensitivity analysis. Also, the analysis is based on a 1-mile section (L=1) of roadway. This analysis can readily be expanded by multiplying the results by the actual length of the facility. Therefore, vehicle speed can be expressed as proportional to $(1 - (q/s))$. Time is the reciprocal of speed and is therefore equal to $1/(1 - q/s)$. The average delay costs $d(q/s)$ can be calculated as the difference between the value of time spent traveling when the flow is greater than zero and when the flow is zero *(Eq. 5)*. This difference is found using the following equation:

$$d(q/s) = \alpha \left(\frac{1}{1 - \frac{q}{s}} \right) - \alpha \qquad \text{(Eq. 5)}$$

and therefore the MSC *(Eq. 6)* is:

$$MC = MSC = \alpha \left(\frac{1}{1 - \frac{q}{s}} \right) - \alpha + \alpha \left(\frac{q}{s} \right) \left(\frac{1}{\left(1 - \frac{q}{s}\right)^2} \right) \qquad \text{(Eq. 6)}$$

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These demand and supply functions can now be used in the derivation of flow threshold cut-offs using equilibrium principles. Given the marginal trip cost curve (*Eq. 6*) and demand, an economic equilibrium (also known as the socially optimum usage) is established by the intersection of the two curves.

Cut-Off Flow Thresholds and Maximum Number of Credits to Be Allocated

There are several ways of deriving the maximum number of credits to be issued. The easiest method is to use a fraction of the total number of existing trips as the desired flow threshold basis for conversion. However, this approach is ad hoc. This section presents an alternative way of computing the cut-off flow threshold (K) and then uses it to derive the maximum number of credits based on assumptions with respect to modal split.

Given the demand and supply equations derived above, the standard congestion pricing framework is used to illustrate its application for CBVP scenarios via the derivation of maximum number of credits to be issued based on an economic threshold. For any set of demand and cost parameters, equilibrium principles dictate the intersection of the MC curve and demand (see Figure 10). Given an observed use pattern, an optimum flow cut-off (K) can be established based on optimality principles at (q^*). K is therefore assumed to be the maximum allowable flow measured in vehicles per hour and can be set equal to the socially optimal usage (q^*) derived from economic principles of optimality. This cut-off flow threshold in turn forms the basis for deriving the maximum number of credits to be allocated for a given roadway section. Therefore, the total number of initial permits is a function of q^*. The difference between the observed usage pattern (q^0) and (q^*) represents the desired reduction in number of peak-period trips to achieve the optimal flow. This flow cut-off threshold and desired reduction rely on external cost estimates and optimality principles. Since flow units are used for demand and cost representation, the flow threshold cut-off value will also be in the same units (vph) for 1 mile (since L=1, in our example). Figure 10 shows these values.
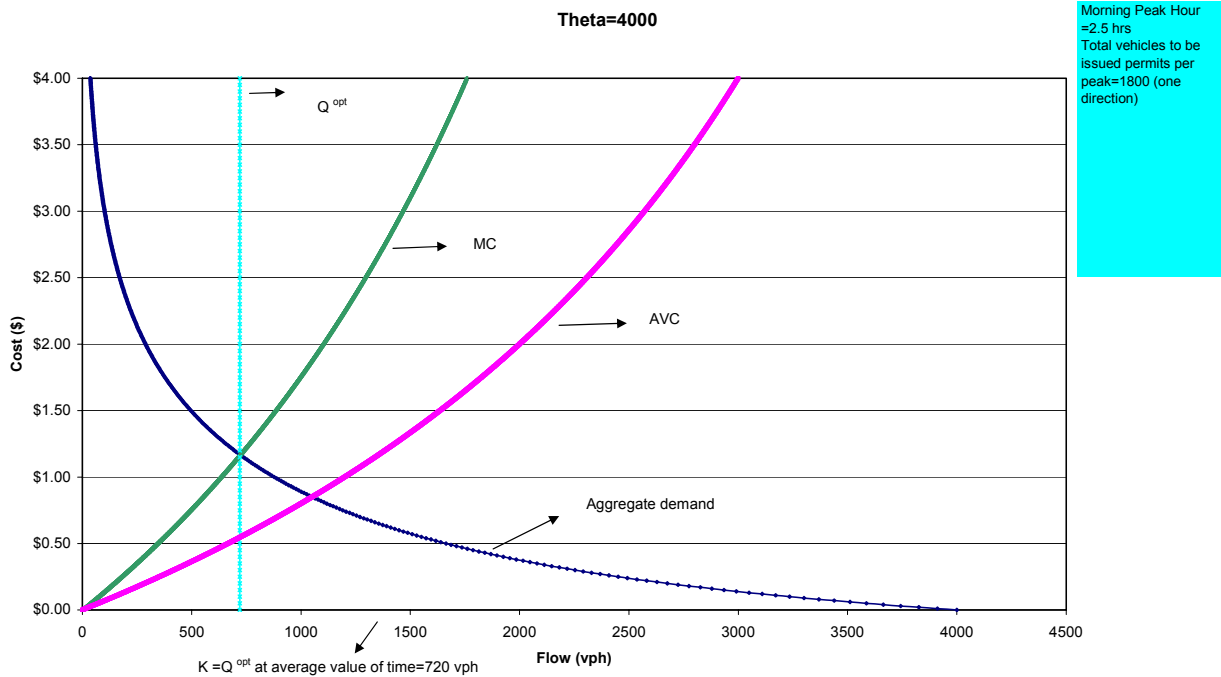
Figure 10. Determination of the Flow Threshold.

Assumptions Used in Derivation of Flow Thresholds

Several assumptions were made in order to present a model of the use of CBVP, including:

- Capacity (s) = 6000 vph on the three lanes in the peak direction.
- There are three demand groups D1, D2, and D3 whose demand is aggregated to define the aggregate demand of each group. Each of the groups is differentiated in terms of their demand responsiveness to prices. With the general demand function described here, the μ parameters are allowed to vary to account for differences in behavioral responses to pricing. μ is indirectly proportional to demand responsiveness, and a higher value implies a more inelastic response. The following values are assumed for the three demand groups $\mu_1 = 1$ for D1, $\mu_2 = 0.5$ for D2, and $\mu_3 = 0.2$ for D3. Each demand group is assumed to have its own threshold use (D1 = 2000, D2 = 1000, D3 = 1000 for $\theta = 4000$). The aggregate demand formed by the combination of D1, D2, and D3 was used as the basis for derivation.
- Typical values of time were used in computations. Average travel time values of $10 in congested conditions are found in the literature. However, these values were scaled down

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by a factor of 2.5 to arrive at the uncongested valuation of time of $4. These values are on the low end of those reported in the literature and are reasonable for uncongested conditions *(75)*. (Note that the use of congested time values led to extremely low usage and high optimal prices for L = 1, well over $1 per mile.)

The results are reported for a flow threshold of $\theta = 4000$. However, the analysis was also conducted with other threshold demands for road use including $\theta = 5900$ and $\theta = 3000$. It was found that as θ, the base demand for road use, increases (given all other parameters), the optimum flow threshold also increases. Therefore, the agency can set θ to optimize its desired use of the facility and the optimum flow threshold.

Conversion of Cut-Off Flow Thresholds to Maximum Permits

The following additional assumptions have been made to convert the cut-off flow threshold (K) to a quantity constraint of a maximum number of permits for one peak period:

- Peak hour length is 2.5 hours.
- Average vehicle occupancy by mode is 1.2 for auto users and 14 for transit users.
- There are only two competing modes, auto and transit.
- Modal splits between auto and transit modes are assumed to be 96 percent and 4 percent, respectively. This number conforms to estimates reported in Census Transportation Planning Package (CTPP), which shows existing modal splits extremely skewed in favor of the auto mode. As such, this number can be considered a sensitivity parameter, and credits required for travel for either mode can be modified to encourage the use of either mode.
- All user groups (D1, D2, and D3) are charged the same number of credits for the same travel behavior.

Using these assumptions, the cut-off flow threshold of 720 vph derived for $\theta = 4000$ converts to 1800 vehicles (= 720 * 2.5). These permits should be distributed to grandfathered user (D1, D2, and D3) groups. We have assumed that they will be equally distributed. This distribution can be

done by converting the overall flow limit to group limits or group allocation, $K_i^g = 240$ vph for group i.

To obtain the number to be issued for the entire period, the length of the period has to be assumed. One month has been recommended in this report. In this case, (L = 1) values have been derived for 1 mile. This methodology is appropriate to assess the impact of a flat credit schedule on the number of permits. With appropriate adjustments for distances greater than 1 mile, the model can also assess the impact of a distance-based pricing strategy.

Optimal Charge for One Credit Using Cut-Off Flow Thresholds

The dollar value or the base value of one credit can be developed just as in the case of tolls since one credit must have a dollar value associated with it, and it is necessary to determine the maximum number of credits that will be charged for a trip of any given length *(Eq. 7)*. This price is also the socially optimal value of the credit. With distance-based pricing, the total number of credits will then vary with distance. With a flat pricing structure, the denomination is not critical; one trip can just cost one credit. Since L = 1 mile, we can obtain optimal credit prices for 1 mile using traditional toll measurement approaches. Given MSC and average costs, the optimal dollar value of the credit is exactly equal to the difference between MSC and average costs evaluated at q^*.

$$P^* = (base\ value\ of\ credit) = MSC(q^*) - AC(q^*) = q^* \frac{\partial C(q^*)}{\partial q} \qquad \text{(Eq. 7)}$$

In principle, if estimates of delay costs (and other costs, if included in the analysis) are developed as functions of flow, permit prices can be developed simply by using the difference at a certain desired threshold. These results are standard from congestion pricing, but they can be applied in this context as well. The results can be examined with varying speed-flow scenarios. With $\theta = 4000$, the optimal credit price is equal to $0.58 for 1 mile (since L = 1 in this example). However, buyers and sellers may buy and sell credits at considerably different prices based on their own perceived benefit of travel.

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Behavioral Shifts Due to Pricing

The imposition of credit-based pricing is hypothesized to cause behavioral shifts because of the utilization of both price and quantity constraints to target peak-period road use. The equilibrium use patterns are given by the q_0^i, which is a function of the delay costs and the optimal credit price *(Eq. 8)*.

$$q_0^i = \theta e \left[-\frac{\alpha}{\mu} \left(\frac{1}{\left(1 - \left(\frac{q_i}{c}\right)^2\right)} - 1 \right) \right] \qquad \text{(Eq. 8)}$$

for i = 1,2,3. This relation provides the behavioral response of traffic to the imposition of a price (in this case the price of credits required for travel) for road use. In the case of $\theta = 4000$, the equilibrium road use declines for:

- D1 group: 964 to approximately 695 vph at a trip price for 1 mile = $0.58; 455 vph over D1 group threshold cut-off.
- D2 group: 519 to approximately 245 vphpl: 5 over cut-off.
- D3 group: 340 to approximately 54 vph: 175 below cut-off.

These values will not add up to the flow constraint (K) because of two reasons: (1) the possibility of obtaining credits exists via trade (in the free market), and (2) each individual user group optimizes based on their own market perceptions of costs while flow thresholds (K) are based on aggregate flows. These flows are diverted from roadway either to off-peak or to modes that require no credits. At present this model does not have the capability to assess how these shifts occur.

The "over" threshold implies that demand exists for some trips by some groups (D1 and D2); however, there is an undersupply of permits which acts as a deterrent to further trips at the price

of $0.58. These extra trips (indicated by additional flows) will be made if the possibility of obtaining extra permits exists via trade either from the agency or via free trade. Therefore, the free market price may exceed $0.58 (the optimal credit price).

In an implementation study, data can be collected to assess just these effects and assess the demand sensitivity of different groups to determine behavioral shifts. However, the design of such experiments should be carefully conducted to reflect the quantity constraints of the roadway, nature of initial allocations (paid/free), and ability to capture different kinds of behavioral shifts.

Credits directly impact behavioral decisions because they both cost money (if paid) and impose a quantity constraint by limiting the number of credits issued. Issuing a certain maximum number of permits alters individual budget constraints by making some number of trips unavailable, so these can force or induce behavioral change especially if the ratio of number issued to number required is set low.

Trading Equilibrium: Excess Demand/Supply of Permits

Proposition 1: Given an allocation of credits, demand and supply of permits/credits (k) is dependent on q_i^0 (the equilibrium use) at any given τ (non-zero credit price). This q_i^0 also translates to a group utilization of credits K_i, at any credit price. The difference between group allocation K_i^g and K_i at any τ (free trade market credit price) provides the basis for obtaining the excess demand/supply of credits.

If $K_i^g - K_i < 0$, it represents a demand condition for permits.
If $K_i^g - K_i > 0$, it represents a supply condition.

For $\theta = 4000$, equilibrium use was obtained for different prices ranging from $0.05 to $1.10 per credit. These prices were used as examples. In practice the users would derive the actual price in a free market system. In each case, the equilibrium was compared to group allocation excess

demand/supply conditions in the trade market as shown in Tables 10 to 12. The actual demand functions and supply functions for all three groups, as well as the aggregate demand/supply functions, are demonstrated in Figure 11. Permits relating to approximately 300 vph will be traded in at an optimal price of about $0.90, which implies that the existing optimal price is currently undervalued by about $0.30. These permit acquirers are those belonging to D1, the least demand-responsive group. In principle, this group could include all those for whom it is most difficult to travel at any time other than the peak. These demand and supply functions are important for monitoring and attaining behavioral outcomes.

Table 10. Obtaining Excess Demand/Supply for Permits from Use Patterns and Allocations—Group D1.

Tau (τ, credit price)	Q_i^0	K_i^G	$K_i^G-Q_i^0$	D1, 2000 Excess Demand	S1, 2000 Excess Supply
$0.05	932	240	−692	692	0
$0.10	909	240	−669	669	0
$0.15	896	240	−656	656	0
$0.20	862	240	−622	622	0
$0.25	838	240	−598	598	0
$0.30	818	240	−578	578	0
$0.35	792	240	−552	552	0
$0.40	767	240	−527	527	0
$0.50	727	240	−487	487	0
$0.60	678	240	−438	438	0
$0.70	640	240	−400	400	0
$0.80	603	240	−363	363	0
$0.90	557	240	−317	317	0
$1.00	525	240	−285	285	0
$1.10	499	240	−259	259	0

Table 11. Obtaining Excess Demand/Supply for Permits from Use Patterns and Allocations—Group D2.

Tau (τ, credit price)	Q_i^0	K_i^G	$K_i^G-Q_i^0$	D2, 1000 Excess Demand	S2, 1000 Excess Supply
$0.05	478	240	−238	238	0
$0.10	455	240	−215	215	0
$0.15	429	240	−189	189	0
$0.20	398	240	−158	158	0
$0.25	385	240	−145	145	0
$0.30	359	240	−119	119	0
$0.35	328	240	−88	88	0
$0.40	321	240	−81	81	0
$0.50	277	240	−37	37	0
$0.60	232	240	8	0	8
$0.70	200	240	40	0	40
$0.80	168	240	72	0	72
$0.90	149	240	91	0	91
$1.00	130	240	110	0	110
$1.10	111	240	129	0	129

Table 12. Obtaining Excess Demand/Supply for Permits from Use Patterns and Allocations—Group D3.

Tau (τ, credit price)	Q_i^0	K_i^G	K_i^G-Q_i^0	D3, 1000 Excess Demand	S3, 1000 Excess Supply
$0.05	308	240	−68	68	0
$0.10	275	240	−35	35	0
$0.15	238	240	2	0	2
$0.20	200	240	40	0	40
$0.25	168	240	72	0	72
$0.30	149	240	91	0	91
$0.35	143	240	97	0	97
$0.40	120	240	120	0	120
$0.50	98	240	142	0	142
$0.60	60	240	180	0	180
$0.70	47	240	193	0	193
$0.80	41	240	199	0	199
$0.90	35	240	205	0	205
$1.00	30	240	210	0	210
$1.10	25	240	215	0	215

Figure 11 shows excess demand/supply curves for permits for each user group as well as the aggregate demand/supply curves. It shows that approximately 300 vph will trade at a free market price per credit of $0.90, $0.30 over agency-determined socially optimal price per credit. This excess demand is largely driven by group D1. Shifters will be from D2 and D3 groups.

Trading Based Excess Demand and Supply - Avg. VOT

Legend:
- D1,2000
- S1,2000
- D2,1000
- S2,1000
- D3,1000
- s3,1000
- Aggregate Demand
- Aggregate Supply

Y-axis: Credit Price
X-axis: Excess Demand/Supply for Permits Based on Road Use
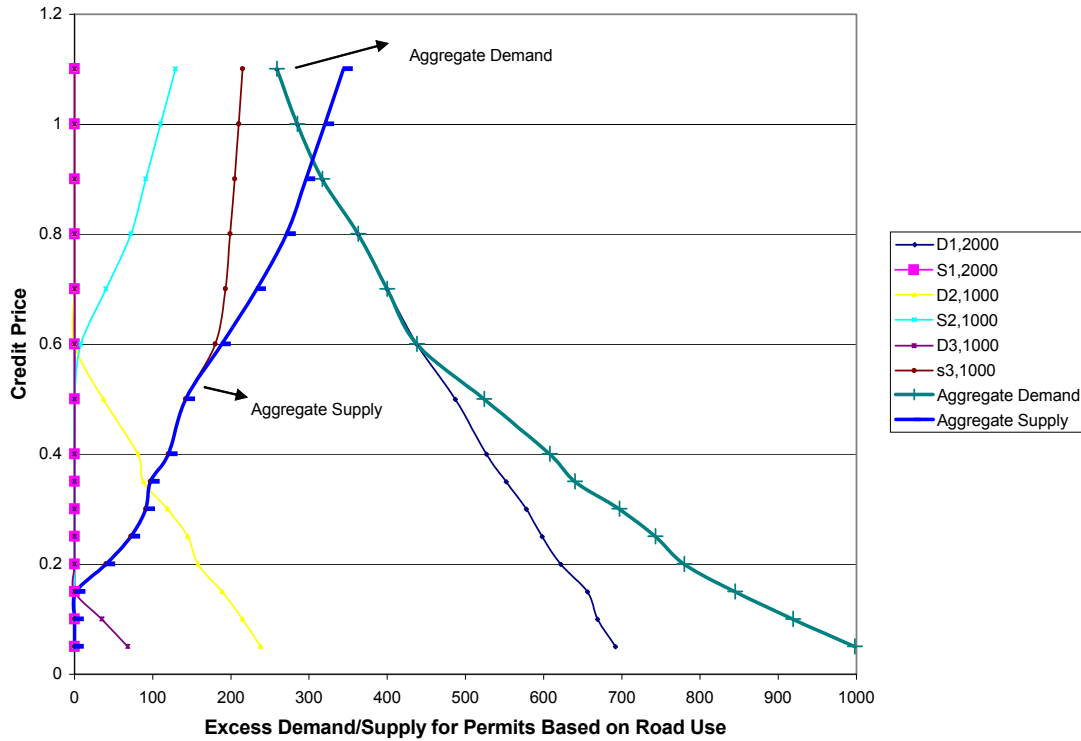
Figure 11. Number of Permits Exchanged as a Result of Maximum Permits Issued.

Summary

This theoretical illustration shows behavior shifts and demand and supply for permits issued on the basis of flow cut-off thresholds regardless of implementation scenario (trade with agency or free trade). This framework can be used to study the effect of imposing upfront flow threshold cut-offs on peak-period usage and permit trade. The flow threshold translates to a quantity constraint on existing users. It can also be used to study (1) the reverse effect of imposing maximum limits (quantity constraints) on permits issued and (2) the effect of level of service thresholds. In each case, the impact can be assessed by converting the imposed limit to an equivalent flow threshold.

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The flow threshold is derived using traditional optimality principles and is linked to congestion externalities (in this case, congestion or time costs). The model suggests that the level of the cut-off threshold is critical in obtaining desired goals. If goals are not met, then updating the initial allocation limit can achieve the desired effect.

The model demonstrates the number of peak trips that will be shifted off and where the shifting comes from (i.e., which demand groups). The trips are just model-derived shifts. In practice, the actual shifts will have to be assessed. The following comments are in order:

- All demand groups reduce their trips from pre-implementation to post-implementation because of the flow threshold restriction.
- The aggregate permit supply function is indicative of the quantity constraint and indicates the number of unused credits that will come up for trade. Similarly, the aggregate permit demand function shows that there are users with credits who are currently underserved and require more credits. These are important for tracking behavior effects and for updating permit allocations.
- Demand activity for permits is directly linked to μ parameters (and therefore indirectly proportional to group elasticity). At the optimal base price for a credit, all demand groups will be impacted, but there is still a balance excess demand that persists because the D1 group is underserved and demands additional trips. This explains why permits may sell for a higher price in the open market (there is at least one or more user group who is willing to pay higher). In reality, hundreds of such user groups will form, with as few as one person per group, with their own internal μ valuations. The key in deriving actual behavioral shifts is therefore strongly linked to ability to segment the market into well-defined user groups.
- With "free" allocations, there are no upfront costs associated with travel, so only the quantity constraint operates. The effects may therefore be lower than this analysis indicates. What it does indicate is that with "free allocations" quantity constraints have to be judiciously set to achieve desired outcomes or flows, and trip rates can be set to attain maximum behavior shifts. Note that the credit pricing strategy section recommends variable per-trip rates, peaking during the peak traffic period.

- The framework can be used to analyze the overall impact of a flat (and with modifications for distances greater than 1 mile distance-based) pricing strategy for credits as well.
- A specific scenario is examined. Traffic is assumed mixed (i.e., it varied in behavioral parameters); i.e., only μ varies. Other scenarios can be examined.

The assumptions imposed are not to be considered limitations. All these parameters can be subjected to sensitivity analysis. Other scenarios can be examined as well.

TECHNOLOGY ISSUES

Implementation of this type of system will require technology to perform three primary functions: determination of the number of credits to be charged for road use, collection of credits, and violation enforcement. Two primary technologies, AVI and GPS, are available for credit collection. The use of AVI requires that every vehicle that uses the facility be equipped with a transponder. Readers/antennas also must be installed to identify vehicles. The best method would be to install readers/antennas at all entry and exit points. This method ensures that every vehicle using the facility is identified.

With an AVI system, the determination of credits to be charged is relatively simple and can be done with a host computer. Raising the number of credits charged during the peak hour would be done by linking the computer to a clock (to charge by time of day) or calculating travel speeds from the AVI reads of vehicles between stations (to charge based on congestion). This research recommends charging based on time of day according to a set schedule.

Although not recommended, it would be technically possible to charge based on congestion using the AVI system. The readers/antennas installed at every entry and exit point would enable the computer to determine the exact traffic density of the facility at any time. The number of credits charged could be based on the current traffic density of the facility by developing a pricing scale. With the number of credits required for travel changing frequently throughout the day, as on I-15, variable message signs would be necessary to display the current number of credits being charged so drivers can make their decision on whether or not to use the facility (see

Figure 8). The current number of credits being charged could also be on the radio or shown on the Internet.

AVI also allows for vehicles to be charged by the number of miles traveled. The computer can use the distance between a vehicle's entry and exit points to determine the appropriate number of credits to charge.

A GPS-based system has slightly different technological requirements than AVI. GPS-based systems transmit a signal and do not rely on local readers/antennas. Facility use can be monitored from a central location using a receiver. However, although no readers/antennas are necessary, the cost of installing of a GPS unit in a vehicle is considerably higher than that of an AVI transponder. The total cost will be dependent on both the size of the facility and the number of users. Collection of credits using GPS is done by simply monitoring a vehicle's use of the facility and charging the user's credit account accordingly. Determination of the number of credits to be charged is done in the same manner as it would be using an AVI system. The only difference is the method by which users are identified. Violation enforcement is also similar. If a vehicle is detected by the presence detector but a GPS signal is not being received from that location, a photograph of the driver's license plate can be taken.

Either an AVI or a GPS-based system would be satisfactory for this type of application. The primary factor to determine which to use will likely be cost. GPS units are more expensive to install than AVI transponders. However, a GPS system does not require any readers/antennas to be installed. Another factor that may influence the decision is the technology itself. AVI systems have been implemented quite successfully all over the world. GPS-based systems, although proven successful, have never been used for this type of application. Currently, AVI would likely be cheaper for a single facility application. However, as of 2003, 11 percent of vehicles (over 2 million) sold in the United States have GPS, and this number is increasing rapidly to a projected 70 percent by 2010 *(76)*. Therefore, with time, it would not be surprising if a GPS system would be more economical for CBVP. Therefore, the decision between AVI and GPS would have to be made at the time of project implementation.

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POLITICAL ISSUES

Public and Political Response to Past and Present Road Pricing Schemes

The economic rationale for road pricing is well understood by the economists who support it. However, attempts to persuade politicians and planners of the merits of this approach have often been met with resistance. Viegas points out that "this probably means they are seeing dimensions of the problem that the economists are not seeing" *(11)*. Viegas and others have described several factors that have influenced past road pricing schemes, both positively and negatively.

Road pricing has been embraced in several British cities recently. In London, the new mayor included the issue in his election agenda, and several other cities are preparing to go this route as well. According to Viegas, "in all these cases, the major factor in favor of road pricing seems to be that citizens are no longer willing to face recurrent heavy congestion and believe that all other sensible approaches have been tried without success. So, it comes as a solution of last resort, but without strong support" *(11)*.

In the United States, the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (known as ISTEA) opened the door for creative road pricing projects by requiring demonstration projects in congestion pricing. The encouragement to implement congestion pricing, however, was not well received by all. For example, the Illinois Transportation Secretary was quoted as saying, "what the nation needs now is a Marshall Plan to rebuild its interstates, not arcane experiments in fancy finance." Others have argued that the new financial tools are too complicated and expensive *(56)*.

Studies indicate that commuters will respond to options that result in time savings, and that value pricing can alleviate congestion from adjacent roads as well *(56)*. One such program that has been heavily studied in the United States is the I-15 congestion pricing pilot program in the San Diego region of California. During the proposal phase of the program, the San Diego Association of Governments studied the preferences of the transportation users in the region. They concluded that "congestion pricing programs will be more readily accepted if consumers

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are offered an opportunity to purchase a product or service that is more desirable or productive [than the product or service currently being used]. This approach is preferable to one that requires consumers to pay a fee to keep a product or service they previously enjoyed for no charge or that would force them to accept a less desirable product or service because of added costs" *(77)*. Once the I-15 project was proposed, elected officials not only supported it, but many included their support as part of their election campaigns by touting the benefits it would bring to their constituents. In fact, the candidates who vocally supported the proposal in districts most affected by congestion each won reelection by a substantial margin *(77)*.

A case study of the San Francisco Bay Bridge tolling project by Dittmar et al. highlighted the public and political challenges for implementing congestion pricing *(78)*. Dittmar enumerates the themes that were most often debated during public discussion:

1. Roads should be free.
2. Voters, not elected officials, should decide on fee or tax increases.
3. Pricing proposals disproportionately benefit the wealthy at the expense of the poor or middle class.
4. Squabbles over revenues can block any proposal, especially if there is no clear link between the use of the proposal and those paying.
5. There is a clear perception that adequate alternatives to single-occupant vehicles are not available.
6. In the Bay Area there is tension among central city, inner suburbs, and outer suburbs that must be resolved *(78)*.

Dittmar suggests that "any congestion pricing proposal must respond to each of the foregoing themes with tangible demonstrations either that the implied condition has been met or that the perception is false" *(78)*. The failed Bay Area demonstration pricing program illustrated that good data, analysis, and a sophisticated political approach were essential. Even with this focus on those equity issues, it was equity which stopped the project from full implementation. One conclusion was that "each region will have to be responsive to the same sets of pressures and barriers" although they may manifest themselves differently.

CBVP FOCUS GROUPS

While much has been researched and written regarding the public perception and acceptability of value pricing, the feasibility of a credit-based system has not been explored in terms of the public response to it. The viability of the program may not hinge on the administrative, technological, and economic feasibility, but in large part on the merits as perceived by the public. Beyond public support, the support or opposition of policy makers and/or politicians can mean life or death for the program. To investigate its palatability, the Texas Transportation Institute (TTI) conducted two focus groups and seven interviews with policy makers. The individual and group discussions were limited to Houston and Dallas area participants as individuals in these cities face considerable traffic congestion.

Background

Prior to conducting the two groups of interest, a pilot group was conducted in College Station. This group enabled the study team to test the discussion questions and explanations, to time the discussion, to practice fielding questions, and to discover what additional information was warranted to describe the concept.

The two urban groups in Dallas and Houston were recruited from office buildings in the vicinity of TTI's offices in these cities. The groups were conducted in the evening immediately following the workday in the conference rooms of the TTI buildings. Participants were compensated $20 for their participation.

Group Composition

The Houston group was composed of three females and six males, ranging in age from 26 to 51. The Dallas group was composed of four males and four females who ranged in age from early twenties to late forties. The groups were balanced with regard to occupational representation, with a balanced mixture of white collar, technical, and service occupations. All of the participants were familiar with commuter-related congestion, either from direct everyday

experience or from past experience from which they had escaped (either by moving or by changing jobs).

Discussion Format

The moderator began the discussion by asking participants to describe their experience with congestion, their attitudes toward it, and the significance of traffic congestion in their life. The opening discussion was intended to break the ice and to put the focus on problems related to driving during peak hours. After approximately 10 minutes during which everyone was given an opportunity to comment, the subject was turned toward value pricing. Examples were given of value pricing in other venues, such as hotels and entertainment. Then the example was applied to freeways in terms of variable tolls. Participants were asked to give their reactions to this financing mechanism. After considerable time for discussion on variable pricing, the moderator introduced the concept of credit-based value pricing. Two types of plans were explained, one in which all lanes on a facility would be subject to credits and one in which a single lane would be dedicated for use only by those with credits. The moderator described various scenarios as to how the system could be implemented, but was careful not to present the ideas in such a way as to appear to be "selling" the concept. Participants were asked to share their opinions of the idea, to discuss the positive and negative aspects of the idea as they saw them, and to speak on behalf of the general public as to the feasibility of credit-based value pricing.

Results

In general, the focus group participants expressed a commitment to their personal vehicles and to driving on freeways during peak travel periods. Very few individuals were willing to consider alternative forms or times of transportation under current conditions, citing inflexible work schedules and personal convenience as reasons against a change in their travel behavior. The discussion indicated that these urban commuters view congestion as an external circumstance that is despised by them but considered a natural consequence of living "in the big city."

When the subject of CBVP was introduced, participants in both focus groups reacted negatively. Immediate reactions had to do with the perception of increased bureaucracy, the complicated

nature of the credit system, and the difficulties associated with enforcement. Furthermore, no one in the groups believed that congestion would be reduced with this method. Participants in both groups brought up the point that traffic would not decrease but would shift away from freeways during peak travel periods, thus introducing other quality of life issues.

Each group fully explored what they raised as problems with CBVP, including enforcement issues, administrative issues, privacy issues, economic issues, and psychological issues. Enforcement issues centered on the cost and the level required. One person admitted he would risk a citation or other consequences by driving without credits. Others felt that many people would violate the restrictions and heavy enforcement would be required. Others mentioned the need for transponders that could easily be stolen.

Administrative issues were raised regarding how to handle out of town traffic, the type of bureaucracy that would be created to administer the program, and how drivers keep up with their credit balance. The notion of "big brother" was mentioned several times as a reaction to the CBVP concept.

In both groups skepticism was evidenced toward the revenue-generating potential of a credit-based program. The participants generally believed that the public would circumvent the system or that other means of generating revenue would be more feasible. The other means suggested were raising fuel taxes, taxing larger vehicles, and tolling more roads. Additionally, other economic effects were raised including that travel decreases on a facility-wide system would hurt local businesses. On a more macro level, some feared that tourism would be adversely affected.

The CBVP concept seemed to introduce a significant amount of stress to the commuters in the focus groups. The benefits of tradable credits were far outweighed by the additional workload perceived to be involved. Participants voiced a preference for cash transactions over credits. They did not want to "have to keep up with it" or "worry about it" in addition to the stress of dealing with traffic. Again, they did not perceive a significant enough time savings to make the complicated system worth the fear of being out of credits.

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Of the 17 focus group participants, two or three had some positive things to say about some features of the credit-based value pricing idea. One participant was intrigued with the concept of banking and profiting from reserve credits. One participant thought there was potential for reducing congestion with the plan. One participant admitted that the plan might be feasible in the future but seemed ahead of its time currently. One participant agreed with the concept as an emissions reduction measure more so than a congestion management technique. None of the focus group participants thought that the general public would comprehend or support CBVP any more than they did.

POLICY-MAKER INTERVIEWS

In lieu of assembling policy makers and elected officials in two different cities, each one was contacted individually. Targeted decision makers were first contacted by mail, followed by a telephone interview. All were from the greater Dallas and greater Houston areas.

Interviews were conducted with decision makers in positions of mayor, county commissioner, council of government official, toll authority official, mobility council official, transit authority executive, and congressional public affairs expert.

Elected officials candidly revealed that the concept did not seem to be one that they thought the public would endorse. Therefore, they did not view CBVP as an idea they would support, primarily on that basis. Other officials gave their opinion and generally agreed that this is not an appealing option. A sampling of their comments illustrates the flavor of their responses:

"It's a least attractive option. Our basic theory is that the way to address capacity is with more funding (from Austin). Tolling of any sort is a small level solution. The only real solution is additional capacity."

"Theoretically the idea is sound but you will have a very difficult time selling it to the public, making it very difficult to sell to policy makers. I don't think the public will buy into the idea."

"Implementation seems incredibly difficult. Policy makers will want to know how much implementation will cost. What is the fiscal impact of the program? How do people know when they've used all the credits? Doesn't seem very user friendly."

"Seems to be a backward way to deal with equity. It would be better to offer toll rebates. This plan is putting the onus on the low-income people rather than making things easier for them."

"There is a fatal flaw in the idea. Basically, why create another bureaucracy? I think it's a completely hair-brained idea and has no merit whatsoever."

"I think it would be difficult to sell in my district. I would not support it without a basis of support."

"There are certain things, when they get to be too complicated that aren't workable. The credits and all that, they are a little too complicated such that the public would not be supportive. New ideas are open to critics for mis-interpretation, and transportation has both its supporters and its critics. When there is an idea that is a community favorite, it is easy to rally around it and support it. We need to always be looking for a better or a simpler way. This doesn't achieve that."

Conclusion and Recommendations

Focus groups revealed that the benefits of CBVP are not readily apparent to motorists in Texas. The benefits are not recognizable primarily because of the doubt that CBVP will actually decrease congestion. The perceived cost to individuals, not only monetary, but more predominantly in the loss of autonomy and schedule flexibility was far greater than the perceived minimal benefit. Further, the equity benefits of credit-based value pricing in terms of tradable credits were basically obscured by the anticipated increased workload of managing personal accounts. Political reaction was negative in general and based almost entirely on the perceived complexity of the concept.

Tolling a single lane had much greater appeal than applying the concept system wide. One recommendation from the focus group research is to consider only the single lane option initially if a credit-based pricing project is promoted. Any advancement of the project should be accompanied by concentrated efforts to educate the affected public (and their political stakeholders) on the anticipated congestion-reducing benefits and on the mechanisms for trading credits.

CHAPTER 5. CONSTRUCTION/EXPANSION CBVP SCENARIO

A traveler credit system could also be used to charge users who would benefit the most from the construction of a new road or expansion of a current one. The system-wide application was deemed inappropriate as this scenario is, by definition, focused on a single facility.

Also, note that the administrative, technical, and political aspects of this CBVP scenario are very similar to the ones encountered in the congestion-reduction scenario. Therefore, only the differences between the scenarios will be examined.

ADMINISTRATIVE ISSUES

The construction or expansion scenario is designed to generate revenue to fund either expansion of an existing roadway or to finance the construction of a new roadway. Extreme political opposition is likely to occur in a construction plan due to the difficulty in determining which motorist to charge credits in addition to identifying all of the potential benefactors of new construction (see Chapter 3). Therefore, the administrative assessment focuses on using credits for expansion of an existing facility.

Administrative Issues for Motorists

The same operating procedures as the CBVP for congestion reduction would apply in the CBVP for expansion. The difference is that this scenario requires that credits be purchased for travel on the facility. The monies generated from the purchase of credits would be used to finance the expansion facility that will benefit these motorists. It would be unlikely that the charge for credits would be sufficient to finance the entire expansion; therefore, the charge for credits would most likely remain after the construction is complete to continue financing the facility. Since the focus is on expansion of the facility due to congestion, credit charges would be higher during congested periods and very low in uncongested periods. A set number of credits would be available for purchase at a set price by the agency responsible for the distribution. After this, the market would determine the price for additional credits bought and sold by the facility users.

Transit administration would be identical to the congestion-reduction scenario. Credits charged during congested periods would be very low to encourage transit use since they do not contribute in a meaningful way to congestion, thus mitigating the need for expansion. Carpool and vanpool operations include the same provisions as in the congestion-reduction scenario.

ECONOMIC ISSUES

Many of the issues examined here are the same as those for the congestion-reduction scenario. Only significant differences are addressed in depth. The largest difference would be that credits have to be purchased since revenues are to help finance the improvements and indirectly go back to users. Anyone who wanted to use the facility to be expanded, or was deemed to be a potential beneficiary of the facility to be constructed, would have to purchase credits prior to travel. In this way credit purchase may be unrestricted, or if necessary, the right to purchase credits may be limited to current users. In this manner current users are offered the right to purchase credits but do not need to if they intend to avoid the priced facility. Unused credits can be sold in the market, and required additional credits can be purchased on the market as well, just as in the congestion-reduction scenario.

Similar principles used in the congestion-reduction scenario can be used to decide initial number of credits sold by the agency to users. There would be no banking or borrowing allowed, and the credits would again last for a one-month period. The use of credits on the facility may last until the cost of construction is recovered or may last indefinitely to cover maintenance and resurfacing costs.

All the issues raised in the discussion of rate structure/levels and criteria as discussed in the congestion-relief section apply in this case as well. Credit rate schedules would be very similar to those in the congestion-relief scenario—with peak-period credit requirements exceeding off-peak and transit rates in a set schedule. A logical initial sale price of the credits by the agency would be so that the cost of the credits brought the cost of travel in the peak period close to MSC.

TECHNOLOGY ISSUES

Technologies for use in CBVP and their potential application to each of these scenarios were discussed in Chapters 2 and 3. This section of the report summarizes those findings.

Construction Scenario

The CBVP system can be used to charge users for construction of new roads. Drivers traveling from point A to point B would be charged credits to fund the construction of a new, direct road between A and B. This scenario would require all travel between the two points to be monitored. The simplest way to monitor drivers would be with the use of video cameras. By mounting video cameras along the routes between the two points, license plate numbers could be used to determine which drivers would benefit from the new road.

This determination could also be accomplished with AVI or GPS, but the cost would be significant. In order to determine who should be charged, every vehicle would need a transponder or GPS unit. While GPS and AVI could both feasibly be used for the scenarios, GPS is much better suited for the task. Because vehicle trips need to be monitored, not just entrances and exits, a very large number of readers/antennas would be needed for an AVI system. GPS systems are better equipped to monitor trips, but the difficulty arises in equipping all vehicles that may use any number of roads to travel from point A to B with GPS receivers. Therefore, video is the recommended option for this scenario. From a practicality standpoint, trying to charge travelers in this manner would be difficult and politically impossible. Therefore, the focus of this report is on the technologies to enable CBVP for roadway expansion and not construction of a new facility.

Expansion

CBVP could also be used to charge the cost of expanding a road to those drivers who would most benefit from it (in this case, drivers during the peak period). Charging for expansion of an existing road is much easier technologically than charging for construction of a new one. Video cameras could be used in this case as well, but the task would be easier with AVI or GPS. In order to use AVI or GPS, every driver using the road would be required to have an ETC transponder or GPS unit. A variable charge would then be implemented during the peak periods. Implementation would be achieved in the same manner as the congestion-relief scenario, by linking the host computer to a clock and deducting credits during the designated peak times. While AVI is inefficient for the construction scenario, it is likely the best choice for expansion. Traffic only needs to be monitored on one road, making the use of AVI much more attractive. For a small-scale application, AVI is a more cost-efficient system than GPS. Transponders are much less expensive than GPS units, which are only feasible for very large-scale scenarios. GPS will accomplish the goal of expansion, but because the application is on a single road, the additional costs are not justified.

POLITICAL ISSUES

Conducting the focus groups and personal interviews was described earlier in this report (see Chapter 4). During the focus groups, the scenario of using a tradable credits system as a means of financing new construction was described. The ensuing discussion was relatively brief, primarily because the participants were entirely too skeptical that the program would generate sufficient revenue to warrant consideration. The result was that most alternative solutions were posited from the group participants. For example, some suggested that money would be better spent on a viable mass transportation system.

Others agreed that motorists will pay if they have to in order to drive on the freeway. But, mention was made of resentment toward "dangling the carrot" of paying a toll to finance a new road, but "then it never gets paid for." "Basically, they promise you that they will keep the toll on it long enough to pay it off, but every time it gets to the point that it's paid off—well, let's

expand." One person thought using CBVP was a better idea to help build a new road than to convert an existing facility to a tolled facility or lane.

With regard to policy makers, again there was a reluctance to support the scenario due to the complicated nature of it and the perception that it would be negatively perceived by the public. In addition, and simply put, other means of financing were seen as politically more feasible.

CHAPTER 6. INTEGRITY OF THE PROGRAM

ENFORCEMENT

Much like value pricing programs where motorists pay for a premium service, for a CBVP system to work users must be assured of its integrity. The trading of credits must also be functional. Facility integrity is accomplished through effective enforcement and stringent safeguards on the account management computer systems.

The video enforcement procedure involves installing video or camera equipment with the reader. As the vehicle passes by the reader, a photo of the license plate is taken. If the transaction is found to be invalid, the license plate number will be matched to the vehicle's owner, and the owner will be mailed a violation notice. These are the same enforcement activities that are employed on toll roads. Both the North Texas Toll Authority and the Harris County Toll Authority use an automated enforcement system to enhance enforcement on their respective toll lanes. For maximum enforcement, a police officer is stationed at various enforcement areas and as the vehicle passes the reader, a valid/not valid signal is indicated to the officer. If necessary, this officer can then pursue the violator and issue a citation. Video enforcement is a less costly method of enforcement due to reduced personnel costs.

As noted earlier, vehicle occupancy technology is still in its infancy. However, if the project goals include providing increased benefits to carpoolers and vanpools, separate bypass lanes can accommodate occupancy enforcement (see Figures 3 and 4). In this instance, a police officer may be stationed to check occupancy or a video license plate capture system may be used.

VIOLATIONS

Two types of violations are possible. One type is violators who are enrolled in the CBVP program but do not have sufficient credits in their account. In this instance, the license plate recognition system matches a photo of the license plate to the account holder. The necessary credits are then automatically purchased by the account on the open market. The cost of the

credits is then charged to the account holder's monetary account that was set up when the account was initiated. If the account is linked to a credit or debit card, the account is automatically replenished when the balance drops below a minimum. If the account was opened with cash or check, a notice is sent to the account holder requesting the account be replenished and a fee is assessed for the notice and for the market value of the credits.

The other type of violation occurs when a motorist travels on the facility without a valid transponder or account. Again, the license plate recognition system captures an image of the license plate. A search of the motor vehicle registration database would determine the owner of the vehicle. A notice is sent to the owner requesting payment and a servicing fee of, for example, $20 for the violation. The program administrator may need to execute interagency agreements with other parties such as rental car companies or other vehicle registration agencies to ensure prosecution of the majority of violators.

Depending on the agency that administers the program and the legislative authority of the agency, habitual violators will be prosecuted and charged appropriate fines and court fees. Toll authorities commonly do this. While violations on a typical toll facility constitute a theft of service, the theft of service in this instance is especially egregious under the congestion-reduction scenario due to the fact that the credits are initially issued to travelers free of charge but can be sold for profit.

VIDEO ENFORCEMENT VERSUS LAW ENFORCEMENT PERSONNEL

The favored approach to apprehending violators is to record the license number of any vehicle passing a reader with an inadequate credit account balance. In such cases, the reader would send a signal to a camera, which would record an image of the vehicle's license plate. The image can be acquired using either a video camera, a standard still camera, or an electronic (i.e., filmless) still camera. This method has proven to be very accurate and is used extensively in ETC applications. Then a bill for the market price of the required credits at the time of violation plus an administrative fee would be automatically deducted from the account (if it was a CBVP participant) or issued to the registered vehicle owner by mail.

Camera enforcement is not foolproof. A thick coating of dirt or ice can prevent a reading, and scofflaws have evaded detection on the E-470 toll road in Denver by speeding through the read zones or by driving past on the shoulder, out of the field of vision of the cameras. Traditional enforcement by highway patrol officers and the threat of severe fines will deter most potential violators *(79)*.

The Oklahoma Turnpike Authority uses such a combination of methods on its ETC-equipped system. A light visible to state troopers (but not to motorists) parked near a toll plaza alerts them that a violation has occurred; if an officer stops a violator, there is a minimum $87 fine for failure to pay a toll. If the video enforcement system identifies a violator (e.g., a suspended tag or one with insufficient toll), the authority cross-checks the make and model against the registration; if there are no discrepancies, they send a letter to the registered owner, requesting a flat $10 fee ($15 for trucks) which covers the toll and administrative costs. An average of 0.3 percent of those using the ETC lanes on the Oklahoma Turnpike are in violation *(80)*.

SYSTEM INTEGRITY

In addition to enforcement on the roadway, safeguards are necessary to ensure the integrity of the computer system. The database system and access to it must be designed to prevent any unauthorized transactions. Consumers have become more accustomed to, and accepting of, "cashless" transactions associated with commercial banking and retail industries, partly because these industries have assured the consumers a certain level of security and privacy *(39)*. This assurance will also be required for CBVP. The CBVP system will be able to build on the advances made in the transit and toll industry.

MONITORING AND ENFORCEMENT FOR TRADING

Tradable permit schemes raise special monitoring and enforcement issues. Because a tradable permit scheme for travelers can enhance the opportunity sets available, this same aspect is problematic because it can create perverse incentives. In the absence of an effective monitoring and enforcement mechanism, higher welfare with trade can promote activities like hoarding.

Data should be collected on transfers across users in a tradable permit system so that monitoring and analysis of the market can take place. If the goal is congestion relief in the corridor, then the following types of data are key in any monitoring program:

- periodic data on congestion conditions and traffic conditions in the corridor at varying frequencies over the duration of the credit issue,
- data on transponder use via credit/debits, and
- data on credit transfer via credit trades (buying and selling).

All of this data would have to be analyzed by making the data anonymous (such as replacing the names on the accounts with a number that could not be linked back to the specific account) or in an aggregate data block so that individual records would not be examined.

Smooth implementation of a tradable permit program requires that all data be input into an integrated computer system/database that is accessible by eligible users on a real-time basis. There will be costs associated with the maintenance and setting up of such a system. The key is that this system should be available to both users and the agency responsible for issue, monitoring and enforcement and should provide up to date information on permit use. In the sulphur dioxide program, technology has played a major role *(81)*. Collection and information dissemination in this particular system occurs via the Internet. Special software programs have been developed to access this information and provide information necessary to users (stakeholder groups) and for monitoring and enforcement agency activities.

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CHAPTER 7. COSTS

The cost to implement a congestion-reduction or an expansion CBVP program would most likely be similar to that of electronic toll collection. Depending on how the program is implemented, costs will vary accordingly. If implemented on a lane or lanes of an existing facility the costs for equipment would be less than if implemented on an entire facility. Likewise, if the program is implemented on a facility that already has some hardware in place such as cameras for traffic management, some of these costs will not be incurred. The most variable and significant costs in administering a CBVP program relate to choices concerning operations. These activities are often referred to as "back-office" activities. The Harris County Tollroad Authority spends approximately $5.1 million annually on administrative costs.

REAL-TIME VERSUS BATCH PROCESSING

Current technology between readers and the central processing center allows for real-time processing of transactions. Otherwise, information from the readers is downloaded to the central processing center in batches. Downloading may be done in any time frame, but is often performed twice daily. This information is important for violation processing since the violator is required to pay the current market value of the credit at the time of the violation. Real-time processing is more expensive than batch processing because an agency is typically charged for each transaction that is charged on a credit card. Therefore, accounts that are linked to credit or debit cards incur this charge at each transaction. However, if batch processing is used, the credit card vendor considers this event as a single transaction. Therefore, violations must be processed in real time where all other transactions can be batch processed.

CUSTOMER SERVICE

How an agency chooses to provide service to the customer is an important component in the costs of the program. These costs will vary depending on the number of service centers, the number of automated machines available to customers, the number of program participants, and the traffic volume on the roadway.

The Harris County Metropolitan Transportation Authority (METRO), the agency that administers the value pricing program, QuickRide, in Houston, estimates that the agency spends approximately $12,000 per month on program administration, management, the associated overhead, and consultant expenses. This amount does not include the initial hardware and software costs but does cover all the labor necessary to administer the program, which has over 2000 registered users and typical use of approximately 200 trips per day.

Many toll agencies make great efforts to ensure account application and setup is as easy and convenient as possible for potential customers. This setup may be facilitated via customer service centers, websites, on-line processing, or interactive maps. The NTTA also allows for on-line payment of violations.

HARDWARE AND SOFTWARE

The costs indicated below are a rough estimate to implement a completely electronic system with no automatic coin machines or attended toll booths. An average of $140,000 per lane is spent entirely on structures and infrastructure needed to implement an electronic toll collection system. This average includes conduit for communications, buildings to house equipment, and structures for mounting readers and cameras (see Figure 3). Cameras installed for video enforcement are $80,000, and AVI toll collection equipment, i.e., readers, are $30,000.

The costs above do not include back-room processing costs. This is typically identified as a cost per transaction. The industry target is between $0.08 and $0.15 per transaction. The costs are more for manual transactions than electronic transactions. Since the CBVP programs would be all electronic costs, it would be expected to be at the lower end of the cost per transaction range. These costs include the functions of transaction processing, image processing, and violation enforcement.

The costs presented above are indicative of costs typically incurred by toll agencies utilizing electronic toll collection technology. However, costs may vary widely depending on factors such as the number of lanes equipped, the number of transactions processed, real-time versus batch processing, the number of violations, and the traffic volume of the facility.

As an example, suppose CBVP is initiated on a facility that is two lanes in each direction, is approximately 10 miles in length, and has no intermediate access. The SR 91 Express lanes are configured much the same way. Electronic toll collection technology would be used to start the program. Readers and video enforcement would be needed for each lane. If the lanes are already monitored as part of a traffic management system, it may be assumed that communications and mounting infrastructure are already in place. Table 13 illustrates the hardware costs of implementing CBVP on this hypothetical facility.

Table 13. Hardware Costs for CBVP Example.

Hardware	Units	Unit Costs	Total Costs
AVI for each lane	4 (AVI each direction)	$10,000	$40,000
Video enforcement for 2 lanes	2 (VES each direction)	$100,000	$200,00

A facility, such as the SR 91 Express Lanes, may have an average daily volume of 24,000 vehicles. The average cost for back-office operations is between $0.08 and $0.15 per transaction. In this example we will assume a cost of $0.15 per transaction for a total of $3,600. Therefore, an entity can reasonably expect to expend approximately $240,000 for hardware on a two-lane, bi-directional facility and $3,600 daily to process the transactions that occur on the facility. Not included in this illustration are the costs for transponders, which an agency typically pays upfront and then is reimbursed as customers open accounts. Transponders are roughly $25 each, and an agency may have demand for several hundred thousand transponders.

In the congestion-reduction scenario these costs would be paid by the agency without compensation. In the construction/expansion scenario the agency would recover those costs through the initial sale of credits each period.

SUMMARY

The information presented above provides a likely starting point for the administration of a credit-based value pricing program. As noted, many issues would need to be resolved.

However, many of these issues will be addressed once the business operating rules for the program are established.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

Researchers found that the use of CBVP to reduce congestion or expand/construct a highway facility is technically and administratively feasible with technologies already in place at many toll facilities. From an economic standpoint the use of CBVP can improve, and potentially optimize, next societal benefits of road use. However, even the least controversial CBVP scenarios examined here are politically infeasible and extremely unpopular with the public.

The primary objection from the public was due to the complexity of CBVP, particularly the buying and selling of credits among users. Ironically, it is this complexity that optimizes road use and benefits since travelers would need to optimize their travel behaviors based on their internal price points for credits. A less complex scenario, for example, the purchase of credits from the agency at a set price, may prove more acceptable to the public. Even then, it is unlikely it would be embraced by the public, and it could not maximize benefits the way the market pricing of credits could. There is even extra effort required from the user over more traditional forms of value pricing, making CBVP a very difficult to implement form of value pricing.

Therefore, this research does not recommend the implementation of CBVP as outlined here. Transportation agencies are encouraged to continue examining value pricing alternatives that are more politically and publicly acceptable. For example, HOT lanes and variable tolls have successfully improved the utilization of highway facilities and generated additional revenues. After the public has become accustomed to these forms of road pricing, and if there is a need, maybe then CBVP could find a role in transportation planning.

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