TECHNICAL APPENDICES

Moving Cooler

An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions

Prepared for

***Moving Cooler* Steering Committee**

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Revised October 2009

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1.0 Introduction

1.1 Overview

Moving Cooler provides an analysis of the role that mobility-related strategies can play in helping reduce greenhouse (GHG) emissions from transportation. It identifies the effectiveness and cost effectiveness of a wide range of strategies and combinations, or "bundles," of strategies and discusses how implementation of different types of strategies work together to achieve not only GHG reductions but also other societal goals.

This equity analysis identifies the equity issues associated with implementing these different strategies as well as some of the actions needed to resolve them. The primary focus of the equity analysis is on determining the distribution of the costs and benefits of strategies and bundles among income groups. The likelihood of equity issues differs very greatly across strategies and bundles. For most strategies, equity is not a serious issue and already is being adequately addressed in the transportation planning and decision-making process.

The *Moving Cooler* study examines strategies specifically intended to reduce GHG emissions in nine major categories: pricing; land use and smart growth; non motorized transport; public transportation; regional ride sharing and car sharing and employer-based commute programs; regulatory approaches; systems operations and management; bottleneck relief and capacity expansion; and multimodal freight improvements.

Many of the strategies and bundles of strategies considered in *Moving Cooler* do not raise great equity concerns. For example, the benefits of comprehensive programs for operations, commuter ride sharing, transit investment, highway investment, and other strategies are typically spread across most or at least many groups. The equity of such investments can be determined by the mix of investments within each such category. These types of programs are not inherently equitable or inequitable. Rather, equity for all categories of strategies with the exception of pricing can be addressed by distributing the services and investments so as to impact equitably on various groups. Only for the pricing measures is equity an inherent issue which cannot be remedied as readily. Pricing has inherently different equity impacts on different groups, and equity issues arising from pricing need to be addressed through other compensatory measures outside pricing. In addition, equity for low-income groups also may involve assuring that there are alternatives to automobile travel, and thus transit investments and services will be an important contributor to equity.

The *Moving Cooler* study shows that pricing strategies, including congestion pricing, motor fuel taxes, and carbon taxes can yield substantial reductions of GHG emissions.

However, analysis of the equity of potential measures demonstrates that there are significant issues associated with these pricing strategies on low-income populations. While the quantitative equity analysis provided in this memorandum focuses on congestion pricing, motor fuel, and carbon taxes, the results are applicable to all strategies that impact upon price, including vehicle miles of travel (VMT) fees and tolls.

It also is important to note that these pricing strategies have important benefits beyond GHG reductions that can help offset equity issues. For example, the pricing strategies are able to generate substantial revenues that will help pay for the implementation of other effective strategies, such as transit and highway capital and operating investments which reduce delay. Furthermore, the improvements that then accrue to system operations as a result of the implementation of the pricing strategies and the other strategies that are now affordable also can relieve equity issues. Investments in these other strategies also can provide strong economic returns, with benefits exceeding costs by ratios of from 2-1 to 3-1. In other words, the benefits begin to multiply. The reinvestment of the revenues from pricing measures into other strategies both resolves the primary equity issues and makes further contributions to reducing GHG emissions over and above the reductions that occur as a direct result of the pricing or motor fuel tax or carbon tax measures.

Although this analysis focuses on the equity implications of the *strategies* for GHG reductions that are considered as part of the *Moving Cooler* study, the equity of GHG reductions themselves is not addressed, although it is a major concern. GHGs are assumed to impact on all parties, but their impacts may be greater upon areas that are more vulnerable to the impacts of climate change, such as low lying areas. In addition, lower-income persons are less likely to have the resources to adapt to global climate change, by moving to less vulnerable locations, for instance.

■ 1.2 Definitions of Equity in Transportation

Rosenbloom (2009) notes that "Equity… is a multidimensional concept, difficult to define, evaluate, or create." The term equity has both a descriptive (positive) and normative use. A wide range of terms and concepts are used in discussing equity, as evidenced by the list below:

- Opportunity, or process, equity – fair access to the planning and decision-making process (fairness).
- Horizontal equity – treatment of individuals within a class.
- Vertical equity – treatment of different classes.
- Spatial, or territorial, equity – benefits and costs are distributed equally over space (Viegas, 2001).

- Longitudinal, or temporal, equity – compares the past, present, and future (Viegas, 2001).
- Market equity, or the benefit principle – the benefit received is proportional to the price paid (Figure 1.1).
- Social equity – allocation is proportionate to need (Jones, 2003).
- Outcome, or result, equity – just consequences of a decision (justice).

Most equity concerns are determined by those who are a party to the action, which is how a change affects users. But many changes affect non-users. These changes are considered externalities. Levinson (2002) identifies two types of externalities in transportation:

1. Technical Externalities – the classic external costs of air pollution, noise pollution, and carbon emissions, borne by those who do not directly benefit from the travel (neither the traveler nor the road agency).
2. Mobility Externalities – transportation projects benefit some parties but worsen conditions for other travelers. Intermodal mobility externalities are illustrated by a quote from Ivan Illich: "Motorized vehicles create remoteness which they alone can shrink. They create distances for all and shrink them for only a few." (Illich, 1974). Mobility externalities can occur within a mode as well, as when a freeway interrupts a local grid of streets, or traffic calming reduces traffic on some streets to the detriment of others. Inequity is endemic in transportation, as noted in Levinson (2005), which examines the "micro-foundations of congestion and pricing" and illustrates using game theory for a very simple case that road pricing on a facility where travelers can adjust travel times (with associated schedule delay penalties) may have Nash equilibria that are inequitable. Some travel costs are borne directly by the user while different costs are borne by other users (Nash, 2001).

Ramjerdi (2006) summarizes a number of potential measures of inequality (mean, range, variance, coefficient of variation, relative mean deviation, logarithmic variance, variance of logarithms, Theil's entropy, Gini coefficient, Atkinson measure, and Kolm measure), and finds none which are both scale invariant and translationally invariant. There is no consensus measure among researchers, and each defines equity differently.

1.3 Current Practice in Equity Analysis

The current state of the art of addressing equity in transportation investments for different income groups has been primarily through analyses of the equity of transportation programs at the metropolitan level. Studies of equity have addressed overall equity and environmental justice concerns. Environmental justice specifically focuses on whether programs and investments are fairly beneficial to disadvantaged groups in relation to other groups. The analysis presented in *Moving Cooler* makes use of the findings of these metropolitan studies of equity.

The type of analysis done by metropolitan planning organizations (MPO) spans the issues which are sometimes termed "environmental justice." We are always concerned about equity when it comes to introducing changes to the existing system, because of perceptions of fairness and government's role in increasing, or at least not diminishing, social welfare. However, there also are legal considerations of equity that have collectively come to be known as the transportation-related field of Environmental Justice, defined as the following:[149]

- To avoid, minimize, or mitigate disproportionately high and adverse human health or environmental effects, including social and economic effects, on minority populations and low-income populations;
- To ensure the full and fair participation by all potentially affected communities in the transportation decision-making process; and
- To prevent the denial of, reduction in, or significant delay in the receipt of benefits by minority populations and low-income populations.

These are issues that are required to be addressed in regional and project-level plans. As articulated by a publication from the Institute for Transportation Studies at the University of California at Berkeley, equity and fairness issues most frequently arise when:[150]

- Some communities get the benefits of improved accessibility, faster trips, and congestion relief, while others experience fewer benefits;
- Some communities suffer disproportionately from transportation programs' negative impacts, like air pollution;
- Some communities have to pay higher transportation taxes or higher fares than others in relation to the services that they receive; or
- Some communities are less represented than others when policy-making bodies debate and decide what should be done with transportation resources.

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[149] Federal Highway Administration. Questions and Answers on Environmental Justice and Title VI. April 2008. Available on-line at: www.fhwa.dot.gov/environment/ejustice/facts/index.htm.

[150] Cairns, Shannon; Greig, Jessica; and Wachs, Martin. Environmental Justice and Transportation: A Citizen's Handbook, Institute of Transportation Studies, University of California at Berkeley, January 2003, http://www.its.berkeley.edu/publications/ejhandbook/ejhandbook.html, accessed October 9, 2005.

These issues are addressed now through analyses by MPOs which determine the distribution of impacts on communities and groups from both the existing transportation system and from the planned future improvements to the system. MPOs show the current levels of accessibility for various communities, as measured by jobs within a certain travel time via highway or via public transportation, utilizing their travel modeling systems, and then forecast the impacts of their long-range plan on these measures for those communities. They assess potential negative impacts on low-income groups and on communities for both services and environmental impacts.

Equity is addressed in this report primarily in relation to income groups, and also, where applicable, in terms of users of different modes or of different types of vehicles (such as personal vehicles versus freight vehicles). There are other equity issues which already are addressed regularly, although not necessarily resolved. Two of the more regularly discussed include:

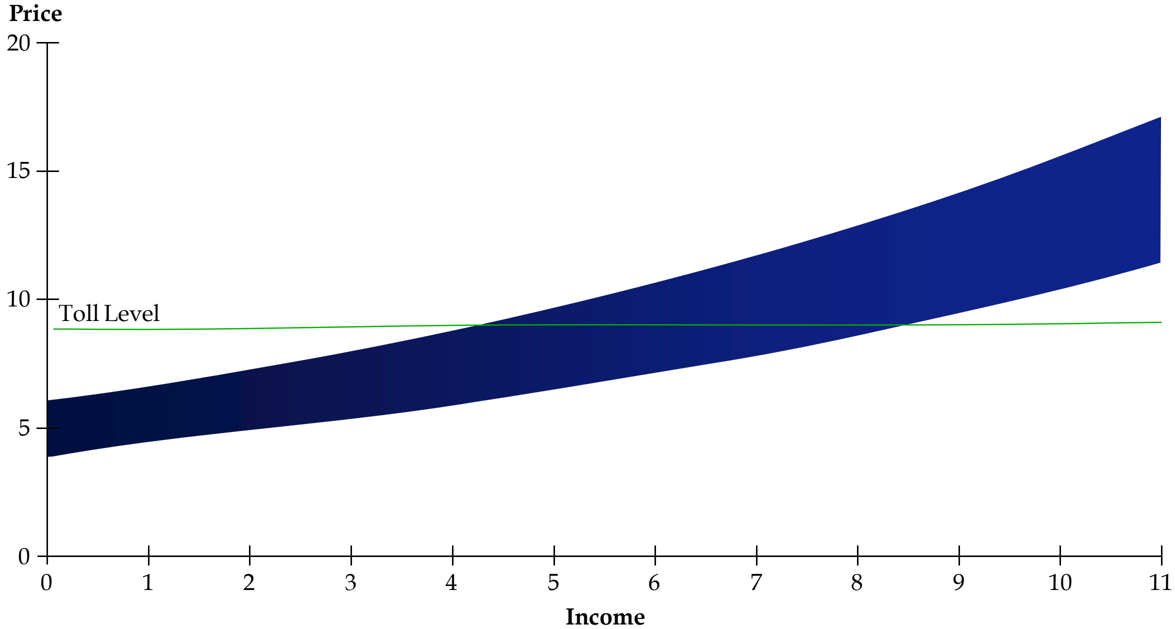
1. The equity of highway expenditures and highway fees across vehicle classes. Equity studies such as highway cost allocation studies specifically address whether road users of particular types are paying their appropriate share of road expenditures. Highway cost allocation studies generally address whether total shares of revenue payments by truckers and by auto users are relatively fair in relation to the costs each class of vehicle imposes on the highway system. Highway cost allocation studies are supported by an array of modeling procedures which are used to calculate the shares of costs and shares of revenues which are attributed to each vehicle type. Highway cost allocation is a well established mechanism to deal with the equity of expenditure programs versus revenues in relation to types of vehicles.
2. The spatial equity of transportation expenditure allocations in relation to where transportation fees and revenues that fund these allocations are generated. A great deal of attention at the Federal level also is addressed to the equity concern that the share of Federal highway expenditures allocated to each state is close to the share of Federal highway taxes calculated to be collected within each state. The Federal Highway Administration maintains models that attribute Federal highway user revenues to each state and which estimate the distribution of revenues to each state. In contrast, in distributing expenditures within a state, state legislatures have not historically pushed for returns of shares of attributed fees to those parts of the state in proportion to where the fees are generated. Virtually all states spend a much greater share of state highway user revenues on rural roads than the share that is generated by travel on those roads. They tend to do this to help ensure equity in relation to outcomes; specifically, rural road users, like their urban counterparts, should have mobility and connectivity even though user fees from the rural areas are not sufficient to fund the roads in those areas. However, some regional transit agencies allocate expenditures to services for the jurisdictions which they serve in relation to the revenues from those jurisdictions, and some do not.

1.4 Structure of this Appendix

This appendix provides a summary of the results of the *Moving Cooler* equity analysis, and documents the assumptions, data sources, and analytic approaches which have been used to assess the equity of strategies and bundles which are designed to reduce greenhouse gases (GHG) in transportation. The results of *Moving Cooler* and this supplemental equity analysis will provide critical input to national and state deliberations about the environmental and economic policies for transportation.

- Section 2.0 presents a comprehensive equity policy discussion and a review of the literature on equity, with a focus on pricing.
- Section 3.0 presents the results of the equity analysis, including a summary of equity impacts of each GHG reduction measure and a quantitative analysis of the equity of pricing strategies, including congestion pricing, motor fuel taxes, and carbon taxes. In addition, it outlines some of the options for reducing inequity by reinvesting revenues which these fees will generate.
- Section 4.0 provides a summary and conclusions.
- Section 5.0 provides a list of references cited in this appendix.

Figure 1.1 Willingness to Pay for Road Pricing by Income versus Price



Note: As income rises, willingness to pay increases, for low-income individuals, price always exceeds willingness to pay, while for very high income individuals, the opposite occurs, in the middle, travelers will sometimes pay.

2.0 Literature Review of Equity Issues in Transportation

This section provides a review of the literature on equity concerns in transportation strategies that can be used for GHG reduction. As shown in this literature review, the greatest volume of literature is to be found in investigations of the equity impacts of pricing or taxing strategies, reflecting concerns about the monetary impacts that can be imposed by these strategies on lower-income travelers.

Section 2.1 provides an in-depth treatment of pricing and taxing strategies on equity, reflecting the volume of literature on that topic, and the relative importance it is given in equity discussions in transportation. Sections 2.2 – 2.6 review the literature on equity in land use, non-motorized strategies, public transport, commuter strategies, and operations strategies.

2.1 Equity in Pricing Measures

Equity issues are of greatest importance for those *Moving Cooler* strategies that impact upon pricing, because lower-income individuals may have lesser ability to absorb the impacts of changes in pricing. This is supported by extensive equity literature examined in this section. Since income distributions determine people's ability to pay, those measures that impose higher or new prices as a means to reduce GHG emissions raise the most important equity concerns.

Additional quantitative results are found in equity studies conducted by MPOs, sometimes in conjunction with environmental justice analysis. These equity analyses look at the impacts on income groups of the investments proposed in regional transportation plans. Combining the results of these two types of quantitative studies produces a fairly exact parallel to the *Moving Cooler* bundles of interest with regard to equity. Those bundles are comprised of pricing strategies combined with the investment of the resulting revenues. As demonstrated by this equity analysis, pricing alone without consideration for how revenues are used has significant equity problems. Only reinvestment or redistribution of the pricing revenues can address the equity issues created by this category of strategies.

Pricing seeks to recover the social costs of driving not previously charged for, resulting in revenue gains to government. Until assumptions are made about what would be done with this revenue, it is difficult to determine whether individual groups, or society as a whole, would be better off. Distribution of revenue is an age-old political issue, and it would be no different with congestion pricing. For the sake of fairness and gaining political support, there would be a strong temptation to use the revenue to overcompensate the losers or to spread benefits around to all groups. In all circumstances, an underlying purpose of redistributing revenue would be to make a positive contribution to society in some way. Some approaches to achieve this include:

- Investing in transit improvements in the affected area;
- Investing in highway improvements (e.g., parallel arterials);
- Rebating pricing fees (or perhaps motor fuel taxes);
- Reducing general taxes such as income, property, or sales taxes;
- Awarding unspecified grants to the affected communities; and/or,
- Devising a system whereby users during peak times pay a price, and those who travel during off-peak get a credit. Credits might be used for travel on another day or on transit.

It is important to note, however, that these uses of revenue contrast with more traditional public ideas of how traditional toll revenues should be used. "Lessons Learned" from the FHWA's Value Pricing Pilot Program suggest that people support the use of tolls to benefit corridor-level improvements, including the transit system; or that toll revenue should only be spent for the benefit of those paying the toll, in particular, through investments in the highway being tolled. This is the traditional political justification for financing roads, bridges, and tunnels with tolls.

An interesting treatment of this topic by University of California planners King, Manville, and Shoup suggests using congestion pricing revenue to compensate communities directly.[151] Their argument is that those people perceiving themselves as losers under congestion pricing are likely to form strong political resistance to the idea. As a result, one mechanism to gain support would be to target the distribution of revenue to create more groups that perceive themselves as winners, and thus, would be more likely to be supportive. These payments could include highway, transit, or other types of investments examined in *Moving Cooler* which have added positive impacts on GHG reductions.

2.1.1 Why is Pricing Studied?

Alternatives to the gas tax to pay for roads are motivated by numerous factors:

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[151] David King, Michael Manville, Donald Shoup, *The Political Calculus of Congestion Pricing*, January 2007.

- First, there is a trend toward higher-mileage cars and ultimately away from gasoline as the fuel of choice for both environmental and economic reasons.

- Second, there is a desire to better tie road charges to road use, in particular to be specific by time of day and location to address congestion issues.

- Third, there is a need to raise additional revenues for transportation, both to maintain and replace aging infrastructure, and to expand transportation networks to serve growing demand.

- Fourth, there is an environmental interest in directly internalizing the non-congestion externalities of road use, and the fuel tax can only do so indirectly (though gasoline consumption is a good proxy for carbon emissions, it ties less perfectly with other pollutants, and more importantly is not correlated with the health damages which depend on where the fuel is burned and the rate of intake of those pollutants).

- Fifth, there is political advantage to shift the burden of payment. Levinson (2000, 2001) examined the issue of using tolls as a form of tax exporting. By placing tolls at boundaries, jurisdictions can ensure that out-of-jurisdiction (e.g., out-of-state) residents pay for their use of the road, and perhaps more than their fair share, in contrast to a system of gas taxes where out-of-jurisdiction residents may never pay their costs (if they buy gas where they live rather than where they drive) and would instead free ride on the road system.

The free rider problem identified in the last point exemplifies certain types of equity issues. The first is the spatial equity problem. Roads are provided locally, but used by both local and non local users. For large jurisdictions, this is a minor issue as most travel is local, but for small jurisdictions, the likelihood of non local travelers increases. This explains why tolls are more common on the east coast of the United States where jurisdictions are small and interstate travel is a relatively large share of all travel compared with the big states in the western United States. The second is the benefit principle, where those who benefit should pay in proportion to their benefit rather than in proportion to the cost imposed (which may be related). If non residents free-ride they violate the benefit principle. In contrast, with tolls, if non residents pay more than their use, cross-subsidizing local travelers, the benefit principle is violated in the opposite direction. King et al. (2007) extends Levinson (2001) to identify subunits of government as potential recipients of recycled revenue (as opposed to being the unit which tolls roads) to create a class of beneficiaries from road pricing, and thereby shift the political calculus.

Ramjerdi (2006) writes: "Sen (1992) states that every normative social theory that has stood the test of time demands equality along some dimension that is regarded as particularly important in that theory. Sen also suggests that demanding equality in one space implies inequality in some other space." Within road pricing there are three decisions that affect equity: allocating the burden of charges, spending the revenue, and distributing the externalities (Langmyhr, 1997), while with ramp metering there is no revenue to spend, the burden of delay is distributed to different parties. Rietveld (2003) argues equity plays two roles in transport: inequity may be a side effect of attempts to address efficiency and environmental issues, and equity may be the target of policies such as building infrastructure in undeveloped areas.

(Flynn, n.d.) Reviews the literature and identifies steps necessary to implement pricing in New York, he cites (Jones, 2002) that inequity can be mitigated through the following parameters:

- "The basis of charging (e.g., point charges, cordon or area charges, and trip length charges);
- The area covered by the charge;
- The time period covered;
- Discounts or exemptions; and
- Linkages to other transport charges, such as reduced public transit fares."

The first three items are questions of the design of the system. The latter two are questions of what to do with the revenue that is collected.

On the topic of road pricing and ramp metering, which are at the intersection of engineering and economics, equity arises as a central feature in effectiveness, acceptability, and implementability. Foster (1974, 1975) was perhaps the first to argue that road pricing discriminates against the poor. Depending on circumstances, this may be true if revenues are not recycled (i.e., used in a way that benefits the lower-income group). The marginal utility of money may be higher among the poor, leading to difficulties in analyzing the welfare effects of pricing if money is assumed equally valuable (Brekke, 1997; Brekke et al., 1996; Medin et al., 2001).

Any change will create winners and losers, and though there is always a search for Pareto Efficient solutions (at Pareto Optimality no one can gain without someone losing), in practice these solutions are hard to come by, especially if it is desired that the losers actually be compensated (Pareto Efficiency only requires that compensation could theoretically be made, not that it actually take place). The Dalton Principle says that transfer of income to a lower-income individual from a higher-income individual, so long as it keeps the rankings of individuals unchanged, improves equity (Ramjerdi, 2006; Rietveld, 2003).

The equity issues associated with road pricing has not escaped academic attention; a brief review (almost certainly incomplete) has turned up more than one-hundred papers on the topic. The findings of the important contributions are summarized below.

2.1.2 Types of Road Pricing

Figure 2.1, in the form of a three-dimensional matrix, organizes the major dimensions of road pricing: the spatial resolution (which set of links are priced), the pricing objective, and the temporal resolution of how quickly prices shift. This matrix implies 6 * 5 * 3 = 90 different types of road pricing. And while incomplete, this considers much of the literature and likely policy directions. This does not directly address a number of other parameters (e.g., ownership, regulatory regime, duration of pricing period, relationship to other road charges, differentiation between cars and trucks).

The current U.S. situation, where gas taxes applied uniformly over states, is best described as the upper left cell of the front page of the matrix: general pricing with uniform links, with average cost prices, that are coarse (unvarying over time). The theoretical ideal from an economic efficiency point-of-view is in the bottom right of the last page of the matrix, general pricing with differentiated links (not all links have the same price), using first, best marginal cost prices which vary dynamically over time.[152,153]

[152] The development of first-best pricing is generally credited to (Pigou, 1912), who argues that resources can be most efficiently allocated by setting the price equal to the social marginal cost. This argument depends on a number of assumptions, many of which either do not hold or are difficult to ensure in practice, leading to the development of second-best pricing strategies.

[153] Pigou did not deal with dynamics of charging across a period of time, which awaited the development of Vickrey's bottleneck model (Arnott et al., 2003; Vickrey, 1965). Xin and Levinson (2006) distinguishes between *omniscient pricing* (where the toll operator knows both schedule delay penalties and desired arrival times) and *observable pricing* (where the toll operator can observe only delay).

Figure 2.1 Types of Road Pricing Strategies

Dynamic	Average Cost	Profit-Maximizing	Regulated (Price-Capped) Profit Maximizing	Second-best	Marginal Cost

Time-Varying	Average Cost	Profit-Maximizing	Regulated (Price-Capped) Profit Maximizing	Second-best	Marginal Cost

Coarse (Fixed)	Average Cost	Profit-Maximizing	Regulated (Price-Capped) Profit Maximizing	Second-best	Marginal Cost
General with Uniform Links					
Facility-Specific					
HOT Lanes					
Area-Based					
Cordon					
General with Differentiated Links					

Note: Each row indicates a different spatial type, each column a different pricing objective, and each page a different temporal resolution on the pricing strategy

2.1.3 Assessing Winners and Losers from Road Pricing

Winners and losers can be identified from road pricing schemes, and the literature has identified some classes, e.g., Gomez-Ibanez (1992); Hau (2005); Kitchen (2008); Langmyhr (1997), and Lo et al. (1996) developd a taxonomy of effects by System Users (stratified by income, mode, gender, geography, trip purpose, and cause (those who cause congestion)), Transportation Service Providers, and Society. There are other groups who win or lose, most notably the agency collecting the revenue, and those who might benefit from recycled revenue.

Often categories must be considered simultaneously, e.g., the effects of income may be ambiguous depending on auto ownership. Many low-income travelers do not own a car, and thus won't pay user charges (and may benefit from revenue recycling if the money is invested in transit modes), while those low-income travelers who do use a car spend an above average share of income on travel (Metz, 2008).

2.1.4 Empirical Findings

Urban Road Pricing

Singapore had the first road pricing deployment with its Area Licensing Scheme. It was later upgraded to Electronic Road Pricing. Olszewski and Xie (2005) argues the Singapore experience is evidence that road pricing is effective in controlling congestion. Wilson (1988) found that while the Singapore Area Licensing Scheme reduced peak-hour traffic by 65 percent, and bus ridership increased from 35.9 to 43.9 percent; more travelers (44.1 percent) saw longer travel time and fewer (36.1 percent) saw a reduction as slower (and now more crowded) buses substituted for faster cars. While congestion management as in Singapore may lower welfare for some users, investing in grade-separated alternative modes (in Singapore Mass Rapid Transit (MRT) and Light Rail Transit (LRT)) can mitigate the effects of the road charge (Goh, 2002).

Norway had an early implementation of congestion pricing using toll rings, where prices varied by time of day to manage congestion. Langmyhr (1997) uses the Norwegian case to understand equity considerations, developing a thorough framework of different equity concerns. Ramjerdi (2006) argues, after testing scenarios with various types of revenue recycling for a proposed charge in Oslo, Norway, no single equity measure is appropriate to use, and different measures lead to different policy conclusions; therefore multiple measures should be considered.

Banister (2002), writing just before the opening of the London Congestion Charging Scheme, notes there is almost no empirical literature on the effect of road pricing on land use, and whether it will lead to centralization or decentralization of activities. He argues that while "the impact of road pricing on all travelers is progressive," and bus users will benefit from both the speeds and the use of road pricing revenues, "the impact on low-income car owners is regressive" (Banister, 1994). The issue of boundary effects also arises, especially important with cordon pricing schemes as the cost of driving to areas just inside a boundary will be significantly higher than staying just outside. (One might note that spillover parking issues also arise naturally in such a case, especially if parking is uncharged or undercharged. Similarly, under cordon pricing, one would expect that parking charges would drop as road pricing increased, since demand for parking is lowered and parking is fixed, thereby mitigating the effectiveness of the cordon charge on locally destined traffic). The nature of the land use effects depends on the nature of the road pricing, and whether it is limited or extensive. If the price of travel increases generally, one expects a denser urban form as people try to reduce travel costs. However if the price of travel only increases locally, there may be substitution effects as people avoid the area with higher travel costs *ceteris paribus*.

Ison (1998) discusses the issues of implementing road pricing, and presents evidence that without revenue recycling, pricing is generally considered unacceptable, and the preferred way in the UK to allocate revenues raised from pricing was to public transport locally, and to local roads secondarily.

Ison and Rye (2005) notes how equity in the London congestion charging scheme can be achieved by providing exemptions from the charge for certain groups, e.g., "alternative fuel vehicles; vehicles driven by or carrying disabled people who have registered for a 100 percent discount; emergency vehicles; vehicles with nine or more seats; motorbikes and mopeds; black cabs and London-licensed mini-cabs; and residents within the charging zone (who get a 90 percent discount)." "[T]he key in terms of acceptance is to keep the inequity to a minimum."

Eliasson and Mattsson (2006) examines the then proposed Stockholm road pricing case for equity consequences. The two key issues they argue for equity are who is affected by the charge and how the revenue is used, which are much more important than any other issues such as value of time. In the case of Stockholm, it is argued that men, the wealthy, and those living in the center city, are affected most by the charge, while the revenue spending on public transport benefits women, and those with lower incomes, thus the scheme is progressive.

U.S. High-Occupancy Toll Lane Projects

Looking at the equity concerns associated with proposed HOT lane projects, which have been derided as "Lexus Lanes," Weinstein and Sciara (2006) notes that equity may arise as an issue at any stage of project development, and is not something can simply be addressed beforehand, but instead continuous monitoring of the equity implications projects is required both before and after opening.[154] Planners would be wise to engage the issue proactively. HOT lanes are generally coupled with parallel free lanes, where the free lanes may be left for equity reasons (Verhoef et al., 1996).

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[154] The origin of the term "Lexus lane" is unclear, but a brief article on the subject can be found at Toll Road News: http://www.tollroadsnews.com/node/2143, attributing the term to Seattle-based HOV advocate Heidi Stamm.

Parkany (2005) identifies the equity issues associated with transponder ownership. Acquiring a transponder is a barrier to entry for many who wish to use roads metered by electronic tolls, and it turns out that many low-income households do not have either credit cards, or bank accounts that are often necessary prerequisites to transponder ownership. Examination of SR 91 and Pennsylvania Turnpike data shows wealthier individuals are both more likely to own transponders, and use electronic toll lanes more often given they own transponders. For routes like HOT lanes, where transponder ownership is mandatory to access the system, this may pose an additional equity issue, while when there are alternatives such as manual payment, the effect is not as severe.

A study of SR 91 by Sullivan (2000) found lower-income drivers approved of the lanes almost as much as wealthier drivers, though wealthier drivers did make more use of the facility.

Examining the I-15 HOT lanes in San Diego, Supernak et al. (2002) states "Equity issues did not emerge despite the fact that FasTrak users came from the highest-income groups." Users perceived the system as fair, as it was seen that travel-time benefits went to those who paid.

Smirti et al. (2007) summarizes literature and interviews a number of players for various congestion charging proposals in California. There was consensus that to achieve political acceptability, excess revenues should remain within the project corridor, and especially be allocated for transit.

The QuickRide system is a high-occupancy toll lane along the Katy Freeway in Houston (Burris and Appiah 2004). Burris and Hannay (2003) found that while usage among enrollees did not vary by income, the decision to enroll was correlated with income, with high-income travelers more likely to enroll in the system than those with lower incomes. Further the system is more widely used by long-distance than short-distance travelers, and by commuters more than travelers engaged in non-work trip purposes.

In Minnesota on the I-394 MnPASS lanes, while support was largely independent of income, it is clear that higher income individuals use the system more frequently, in part because of its location serving high-income communities, but even after controlling for location there is an income effect (Patterson and Levinson, n.d.). In the corridor though, income was not related to willingness to pay to save time Tilahun and Levinson (n.d.). Few individuals in the corridor cited social equity as a concern with the conversion of the carpool lanes to HOT lanes (Douma et al., n.d.).

2.1.5 Simulated Findings

There have been far more road pricing proposals than actual implementations. Thus many of the results about road pricing are based on computer simulations of the expected effects of road pricing rather than measurements of actual effects. While actual measurements are to be preferred where available, the relative dearth of road pricing implementations leads us to depend on simulations for some of our evidence. This section summarizes the results from simulations of particular proposed cases.

Urban Road Pricing

Europe and Japan

Mitchell (2005) considered the environmental justice effects of road pricing in Leeds, looking at the effects of changes on pollution by income category using a modeling approach. For the base case there is an association between economic deprivation and pollution levels. For the case with road pricing, the pollution reduction associated with pricing benefits the most deprived quartile more than the highest-income quartile. The exact changes depend on the specifics of the scenario. Further, the author argues that pricing addresses pollution inequity more effectively than Low Emission Zones (LEZ). Bonsall and Kelly (2005) also study the effects of the proposed road pricing scheme in Leeds, concluding road user charging will increase social exclusion for some drivers, especially for low-income, car-captive travelers.

Santos and Rojey (2004) shows that whether road pricing is regressive or progressive depends on circumstances, and tests via traffic simulation for proposed cordon toll scheme in three UK towns (Cambridge, Northampton, and Bedford), even before redistribution, because of the mix of incomes and mix of transit passengers, pedestrians, bicyclists, and drivers.

Raj´e et al. (2004) describes potential exemptions for the proposed Edinburgh congestion charge. It also considers the problems of boundary effects, especially the issue of spillover parking as people park on street at the edge of the congestion charge zone to avoid payment. Exemptions are a strategy to ameliorate some of the equity impacts and make projects more acceptable.

Fridström et al. (2000) tested a number of first-best and second-best pricing strategies for three scenarios: Edinburgh, Helsinki, and Oslo. Prior to revenue recycling, consumers were worse off, but there were positive welfare gains overall as the operator's gains exceeded consumers' losses. In the long-term pricing could reverse urban sprawl, and by increasing density make urban public transport more economically viable with increased economies of scale and increased ridership as travelers switch away from auto. A poll transfer of excess revenue (returning the money equally to all individuals) benefits the poor more than the wealthy, and not all money need be reimbursed in order to ensure a Pareto-improving scenario, just enough so that the poorest group is better off, leaving additional revenue which can be used in other ways. Looking at the question of spatial accessibility, pricing diminishes accessibility by car (using generalized cost, clearly if it improves travel time, time-based accessibility should increase), but increases accessibility by public transit (Fridström et al., 2000).

Teubel (2000) examines the effect of introducing road pricing on commuters in Dresden, Germany. As is commonly found, in the absence of revenue recycling "All measures indicate that the welfare is distributed more unequally after the introduction of road pricing than before. Both components of the welfare changes analyzed before contribute to this effect. The tolls itself as well as the travel time gains separately enlarge inequality." Revenue recycling can remedy the inequity provided the toll collection costs are not too high.

Maruyama and Sumalee (2007) compares cordon and area pricing schemes, (where a cordon toll requires payment each crossing, while an area-based toll requires payment once per day) testing the cases on a simulation of Utsunomiya, Japan, with a finding that while the area scheme has greater welfare than a cordon (and a higher optimal toll), it also has greater inequity. Larger coverage of either system increased welfare and greater tolls decreased equity.

United States

Anderson and Mohring (1997) finds from a transportation network model, that while a hypothetical comprehensive road pricing system in the Twin Cities would improve system efficiency, it will make most travelers worse off unless revenue is recycled. Mohring (1999) extended the analysis to consider difference by income category. Without revenue recycling under severe congestion, incomes needed to exceed $80,000 for travelers to experience welfare increases.

Johnston and Rodier (1999) running simulation experiments on the Sacramento, California region, found from a user welfare measure that pricing would have a detrimental effect on low-income households but positive for middle- and high-income categories in the absence of revenue recycling. Some strategies for investing the revenue in transit could produce positive benefits for all groups.

Testing a proposal to combine day-of-week rationing with tolls to buy out of the rationing, Nakamura and Kockelman (2002) state it will be "very difficult to provide a Pareto-improving policy for [the San Francisco-Oakland Bay Bridge] via pricing and rationing," and without revenue recycling, as had been theoretically proposed by Daganzo (1995) because the travel-time savings needed to be much greater than the simulation found. From an equity perspective, the scheme was most beneficial under pure rationing, with mixed rationing and pricing harming the lowest income group.

Road pricing of various kinds is being seriously considered in the Seattle region because the high-congestion levels due to topology and economic growth. Tolling across bridges to pay for their reconstruction, and more systematic approaches have been debated. Dill and Weinstein (2007) reports that "A poll of Washington State residents found that more people felt that tolls were fairer than increasing the gas tax if more funds were needed. Respondents who were specifically asked about fairness to lower-income groups felt even more strongly, with 52 percent indicating that tolls were fairer than increased gas taxes (27 percent) (Lawrence, 2006)."

Franklin (2006) focuses on the issue of vertical equity, distribution between groups. He simulates in a stylized way proposed charges on the Washington State Route 520 Bridge, connecting Seattle to Bellevue, assuming alternatives also are tolled, and testing the tolls for the morning peak period so that most trips are work-related, leaving mode as the primary substitution effect. The repressiveness of tolling will tend to be understated when excluding the income effect, but even without redistribution a toll may be Pareto-improving because the wealthy have a higher value of time.

Kitchen (2008) describes a pilot experiment conducted in the Puget Sound region using 400 in-vehicle, GPS-based tolling, where tolls would be assessed across the network (not on every street, but on major streets and highways). The households were all given a travel endowment, which would be drawn upon to pay tolls, and for which the remainder would remain with the household. They found value of time rose with wage rate, from about $10 per hour for the lowest-income group to $60 per hour for households making $150,000 per year or more. The study estimated the region would be able to raise about $3 billion per year, which compares with $500 million per year from gas taxes at current rates (though clearly annual administrative costs would be much higher from one percent for gas taxes, up to eight percent for network tolling, excluding initial capital expenditures). The study suggests the large revenue collected could be used to ensure fairness.

Safirova et al. (2004) considers short-run distributional effects from three pricing scenarios for Washington D.C.: HOT lanes, limited congestion pricing (on all freeway segments that have HOV lanes), and comprehensive congestion pricing (on all freeway segments) modeled in their START model. HOT lanes are most equitable, with benefits accruing to all income groups even before recycling, while achieving between 77 and 83 percent of the efficiency benefits associated with comprehensive road pricing, writing "HOV lanes, which have disappointed their many advocates, may end up being a Trojan horse for congestion tolls."

Safirova et al. (2006) considers longer term responses to policy, such as changes in land use and the location of jobs and residences. Urban economic theory assuming a mono-centric city predicts that long-run effects of comprehensive congestion pricing reduce the physical size of the city (i.e., increasing density). However more sophisticated models suggest that industry may leave the central core, and thus pricing might have a decentralizing effect. While workers may select commutes with shorter travel times in response to congestion charges, there is no guarantee that either workers or firms move toward the center. Safirova et al. (2006) models cordon tolls in Washington, D.C. extending their START model with the LUSTRE model. When considering land use effects, optimal (welfare maximizing) tolls are higher then when considering only transportation effects. However, as noted by Parry and Bento (2001), pricing without appropriate revenue recycling leads to higher wages but higher unemployment. Unlike that paper, the authors still found welfare gains even with lump-sum redistribution.

Looking a bit farther afield, some theoretical studies have examined hypothetical networks of private roads, and compared those with a scenario of publicly owned roads This is important to consider what might occur should road privatization become more widespread, as evidence suggests this is gaining additional credence with many new toll roads being privately owned and some states (e.g., Indiana) selling, or considering selling (e.g., Pennsylvania, New Jersey) their turnpike systems. Zhang and Levinson (2005*b*) find that under private autonomous links, the disparity in accessibility is much greater than under centralized control. Zhang et al. (2008) uses coupled agent-based travel demand

and link investment models to examine the effects of product differentiation in a network of private roads. Generally (and assuming no recycling as these are private roads), "users with lowest value of time harvest the least benefit (or suffer the most loss) from road pricing and investment decisions."

National Road Pricing

Steininger et al. (2007, n.d.) use a computable general equilibrium (CGE) approach to model private transportation in Austria with road pricing. Their model suggests that road pricing is in fact progressive, poorer households would bear a smaller burden than wealthier households. This is because poorer households spend less money on transportation in general, and use public transport more. It is noted that to be effective, redistribution of revenue needs to be independent of use, or it negates the benefits of road pricing.

The proposed national road user charge in England has been examined (Glaister and Graham, 2005, 2006), finding that if revenues are recycled through a reduction in the fuel tax, benefits accrue to rural more than urban residents, in contrast with the current situation in England (with its high fuel tax) where rural residents overpay compared with urban residents.

Bonsall et al. (2007) considers the proposed UK national road pricing scheme. The system is a national, largely distance-based charge. Concerns arise because of the prospective complexity of the scheme (which may raise difficulties for travelers without the ability to appropriately deal with the complexity and who find such complexity frustrating). It is especially pertinent as drivers are often unaware of the distances they travel, leading to charges perhaps being perceived as surprises. Further if charges are higher as well in certain areas (congestion charging), the exact formula may be difficult to discern.

Whitty and Imholt (2005) describes the proposed Oregon distance-based road user fee, extending some of the pioneering methods developed in Oregon from charging trucks (Oregon also was the first state to impose the gas tax). A distance-based charge is more equitable than existing gas taxes according to the benefit principle, costs are tied to benefits received, though of course as with any disruption will create winners and losers.

Forkenbrock (2005) advocates a move toward mileage-based road user charges, ultimately a national scheme for the United States. Forkenbrock, (2006) is critical of using electronic tolls on selected arterials and highways, noting the equity issue of double payment, as those tolls may be in addition to already collected motor fuel taxes. Further if tolls only collected on part of the system pay for the entire system, horizontal inequity may result.

2.1.6 Comparative Equity between Vehicle Classes

Gillen (1997) notes the inequity of the current transportation system, where all modes are subsidized to one degree or another. (If one includes local streets, the highway system is highly subsidized from general revenue (usually property taxes pay for local streets), if one includes only major roads, those direct costs are largely paid for with a gas tax, excluding external costs). He argues for a multipart tariff to pay for roads, an access charge (e.g., a motor vehicle license fee) to pay for fixed costs per user, a mileage fee for cars (perhaps as a fuel tax) to pay for infrastructure costs that are proportional to use, especially on uncongested roads, and congestion and environmental externality charges to optimize use of the system, and for trucks a weight-distance charge, as is used in Oregon, to replace the diesel fuel tax.

The 1997 Federal Highway Cost Allocation Study found that because heavy vehicles impose road damage disproportionate to their fuel taxes, they underpay compared to other classes of vehicles, and are thus cross subsidized (Forkenbrock, 2005).

Doll (n.d.) considers the issue of joint costs: infrastructure is shared between different classes of users (e.g., cars and trucks) and how much to toll each class is especially important, as many highway financing equity debates center on the problem of cost allocation. This especially became important in Germany with the implementation of TollCollect on Heavy Goods Vehicles (HGV). In the U.S. an incremental approach to costs is used, where infrastructure required by a class (and all heavier classes) (e.g., thicker pavement) is charged to those classes. In Austria, a statistical approach allocating costs is used. Each approach creates a different set of winners and losers, and thus there will be contention between the different user groups. Doll tries to find Shapley values derived from game theory for classes of users.

2.1.7 Road Pricing versus Other Revenue Mechanisms

Arnott (1994) examining the likelihood of implementing road pricing, and noting its difficulty, considers alternatives. While in favor of pricing in principle, he argues tolling only some streets (or tolling freeways while leaving streets untolled) can worsen congestion by displacing cars from facilities that are better able to tolerate congestion to those with less capacity. Parking is seen as an opportunity, as the cost of parking is higher in many urban areas than the rest of the cost of the trip. A number of second-best strategies are required in the absence of pricing.

As the gas tax continues to shrink its share of the transportation funding pie, alternatives must be considered. Road pricing and general funds are two possible sources, local option sales taxes are a third. Schweitzer and Taylor (2006) find local option sales taxes, which are popular in California as a mechanism for transportation financing to be more regressive than congestion charging. "The fuel tax is regressive with respect to income, but progressive with respect to highway use" since users of highways with more expensive (and less fuel-efficient) vehicles pay more. Sales taxes in particular penalize non-users.

2.1.8 Acceptability

Studies of acceptability have been widespread in the field of road pricing, as it is the political concerns, rather than their economic efficacy that have held back implementation

(Jaensirisak et al., 2005; Link and Polak, 2003; Marini and Marcucci, 2003; Odeck and Bråthen, 1997; Pädam and Wijkmark, n.d.; Schade and Schlag, 2003; Truelove, 1998; Whittles, 2003). Ungemah (2007) provides a practical set of questions to consider when examining the equity implications of various road pricing projects that may further acceptability. Dill and Weinstein (2007) summarizing results from a number of surveys suggest "Support for pricing options was not clearly related to income or ethnicity, as might be expected based upon the debates over equity" because the alternatives such as sales taxes are clearly less equitable. Lyons et al. (2004) survey a wide span of international evidence on the acceptability of road pricing finds acceptance rises when the "when the revenues are hypothecated to the development of transport generally."

In a survey of Sweden, Japan, and Taiwan about perceptions of pricing, perceived fairness was higher in Japan and Taiwan than Sweden, and acceptance depends on perceived fairness, which was the most important factor (Fujii et al., 2004). Different cultures respond differently to the social dilemma that congestion poses, a decision that is selfishly rational may be detrimental to society.

Rajé (2003) conducted a series of focus groups analyzing a potential road pricing scheme in Bristol, England, interviewing groups that are potentially socially excluded (ethnic minorities, non-English speakers, elderly, and young). The author concludes "[P]ublic acceptability of road user charging will be directly related to its perceived effects on local residents." Recycling the revenue to local transport initiatives would be important in addressing issues of fairness of the system to socially at-risk groups and thereby promoting social inclusion, but car-based transport will still be important for many members of these groups, and taxi and paratransit should be considered as possible recipients of recycled revenues.

2.1.9 Recycling the Revenue

Many strategies have been proposed to use the revenue raised from congestion pricing. The first cost is paying for the implementation of the system, which is much costlier than gas taxes (Levinson and Odlyzko, 2008). The remaining funds may be used for general revenue, additional road investments (either near where the tolls were collected or otherwise), or additional transit investments, to help encourage modal shift (both through the higher monetary cost of road travel and the better service provided by alternatives (which in the case of bus transport can take advantage of the faster road speeds as well), or returned to users in some other fashion.

Newbery and Santos (1999) argue in favor earmarking (hypothecating) fuel tax revenue for use in the road sector, as is done in the U.S. with the Highway Trust Fund. Currently in England, fuel taxes go into the general fund (and are high enough to account for 10 percent of total tax revenue, far exceeding the amount spent on roads). They call for a three-way allocation of road taxes: one part of road user charges dedicated to paying for roads, a second part paying for environmental damages, and a third part which revenue is raising. They write: "The political attractions of green taxes are obvious they are likely to command more support than other kinds of taxes, as they cloak the painful process of extracting revenue in a mantle of virtue and provide a salve for guilt. The main economic advantage of taxes that reflect the marginal damage is that they leave the user to decide how best to respond, rather than forcing him or her to make one particular kind of decision." Distinguishing green taxes is important, but difficult as accounting for the full costs of transportation, including determining the capital value of infrastructure (which is historically valued at less than replacement cost, potentially leading to under investment), has not generally been performed in a systematic way. Just as fuel taxes might be hypothecated to the road sector, the same argument can be made for road tolls.

Oberholzer-Gee and Weck-Hannemann (2002) address the question raised by Lave (1994) "Why is the world reluctant to do the obvious?" Arguing that "marginal cost pricing does not prevail throughout the economy, the information cost of determining Pigouvian taxes are likely to be considerable, and there is ample evidence that policy-makers do not maximize social welfare," the authors warn that prices can crowd out "intrinsic motivation" so that people who were previously doing good because they wanted to be responsible instead become selfish. Unfortunately the public tends to overestimate the effectiveness of many behaviors that result from intrinsic motivation (e.g., rewards for carpooling or using public transportation). Charges should avoid displacing people's underlying motives. The paper also argues that effective compensation should be in same dimension as the perceived losses from the charge. Thus if people lose the ability to travel in the peak, they should be compensated by easier travel at other times. Implicitly this argument is in favor of pricing credits of some kind.

2.1.10 Building Winning Coalitions

Button (2006) looks at alternative uses of the money raised by pricing with the hope of finding a winning coalition of supporters for such a change. Goodwin (1989) came up with the rule of three, allocating revenue to roads, transit, and reduced taxes, though not necessarily in equal shares, and Small (1992) makes a similar point. The question of earmarking arises as a way to help ensure support and show taxpayers that the money raised will be spent on something they desire, but which may not be economically efficient.

Small (1983) in an early simulated analysis of the effects of road pricing by income class uses a queuing model and a logit mode choice model to understand distributional effects. The highest-income group benefitted most from road pricing as while they paid more tolls, they had a higher value of time and saved more time. However once revenue was recycled, every income group benefitted, assuming congestion was sufficiently severe.

Mayeres and Proost (2002) use the idea of Pareto-frontier to tradeoff efficiency against equity in road pricing, and only consider changes to financing acceptable when they are Pareto-improving. This requires comparison of absolute utility levels across individuals, which is a theoretical difficulty. On the Pareto Equity-Efficiency Frontier, it is impossible to improve one individual's utility without worsening another's. The authors use Computable General Equilibrium (CGE) model of Belgium to argue that revenue recycling is required to achieve equity across income groups when a marginal social cost pricing regime is instituted.

2.1.11 Solving Societal Problems

To address broader social equity concerns (that is, to use transport policies to address societal inequities, not just transportation inequities or the marginal inequities associated with a change in transport policy), Nash (2003) argues for use of distributive weighting systems making use of Ramsey pricing (Ramsey, 1927) while retaining marginal social cost pricing as a starting point, following the ideas laid out in (Feldstein, 1972). This however may not fully recover costs.[155]

Parry and Bento (2001) considers the issue of how road pricing affects labor force participation. Theory suggests higher commuting costs will discourage the marginal commuter (the cost of the toll exceeds the benefit of congestion reduction for most travelers), and in most of the authors' numerical simulations, the welfare gains from road pricing (internalizing congestion costs) is less than the efficiency cost in the labor market. The authors suggest recycling the revenue to reduce labor taxes, offsetting the penalty associated with road prices, and that this is more effective than providing transit subsidies or providing a lump-sum payment to households (which does not encourage labor force participation).

Lindsey (2003), citing (Nix, 2001) notes that the Maritime provinces have resisted tolls because of spatial equity and double taxation rationales. He further identifies the issue of spillover effects on customers of firms that have located based on a particular assumption about the costs of freight, which post-tolling would see their cost structure change, citing (Lake et al., 1999).

Levine and Garb (2002) argues that traditional congestion pricing policies are mobility based, and thus may lead to spatial deconcentration as prices discourage driving to congested areas. The authors suggest tolls be redistributed to enhance accessibility (the ability to reach places) rather than mobility (the ability to move on the network).

Evans (1992) notes the redistribution aspects of road pricing may drown the efficiency gains. (This is similar to the case with ramp metering, discussed below, which serves foremost to transfer delay, and secondarily to improve system efficiency.)

Minimizing congestion and minimizing emissions can be at odds (Rilett and Benedek, 1994). First-best marginal social cost congestion pricing do not necessarily reduce emissions, but there is a toll pattern which does (Yin and Lawphongpanich, 2006).

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[155] Ramsey pricing charges users in proportion to willingness to pay, using price discrimination to differentiate customers by their elasticity of demand, constrained to recover some amount of money.

2.1.12 Summary of Issues Regarding the Tradeoff Between Efficiency and Equity

The tradeoff between efficiency and equity emerges naturally as systems mature, as users compete over the allocation of scarce resources rather than growing the resource base. Issues of both process and outcome equity arise. In order to achieve process equity, transparency in the decision-making process, in addition to allowing input from all potentially affected individuals or groups representing them, is required.

Because of past experience, citizens will remain skeptical of claims about road pricing and ramp metering projects. The Pareto maxim, that so long as the losers could theoretically be compensated by the winners, the project is worthwhile, cannot be used as a political rustication, actual compensation is required. In the absence of such compensation, political opposition will continue to rise, and new construction will continue to be more and more difficult. Viegas (2001) posits that the reluctance of politicians to adopt road pricing despite receiving ideas along these lines suggest they are "seeing dimensions of the problem that the economists are not considering."

The perception of equity is highly subjective. A project that may appear equitable to an analyst across one set of dimensions may not to individuals affected by the project. Achieving consensus on decisions (thereby ensuring people believe the decision was equitable) may involve departure from objective "engineering" rationality, moving into the realm of politics. The issue is further complicated because equity concerns may mask opposition motivated by other reasons (Giuliano, 1994).

Resolving the equity versus efficiency problem requires a recognition that in complex, politically driven, mature systems like transportation, *equity is efficiency*. Without satisfying potential constituent groups, nothing can be accomplished. Logrolling, as described by Buchanan and Tullock (1962), recognizes the political efficiency under representative democracies for satisfying multiple groups. Side payments of cash or as an in-kind subsidy, bargaining, bundling of projects, and buying-off losing groups, or in the language of road pricing, revenue recycling, may be necessary to achieve consensus about acceptability, achieving a package that is considered win/win by the relevant players.[156]

From an equity perspective, HOT lanes are the pricing strategy least likely to raise public concerns, especially if it involves conversion of underutilized HOV lanes, or construction of new lanes without taking new right-of-way. While there is a slight bias in use towards wealthier individuals, all travelers benefit from the additional usable capacity, and the revenue can be recycled to benefit transit users in the corridor. However these are not as effective as more extreme pricing that is more comprehensive at the urban or national level. More comprehensive pricing is not optional in the same way as HOT lanes with

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[156] Bundling ensures that not only is there a net benefit (when all projects are considered together), the number of winners exceeds the number of losers by a significant amount.

parallel free lanes are. Thus it raises more equity issues as to avoid the toll, drivers must switch modes, destinations, or time of day.

2.2 Land Use Strategies

More compact growth patterns have been cited as having a number of co-benefits. These include improved mobility/accessibility for populations without access to an automobile, and potentially safety benefits related to lower travel speeds and therefore less severe crashes. One study found that U.S. metropolitan areas with high levels of "sprawl" have higher traffic fatality rates than "non-sprawling" regions (Ewing, Pendall, and Chen, 2003). Another focused on Hawaii found that higher population densities were associated with lower crash rates (Kim & Yamashita, 2002). On the other hand, while overall emissions of air pollutant will decrease because of VMT reductions, concentrated land use has the effect of concentrating air and water pollutants in areas of potentially greater population exposure.

To the extent that growth management policies constrain the supply of land, consumers and businesses may experience higher land costs and therefore higher housing and floor space rents. Some have argued that growth management laws have had significant impacts on affordability. For example, Staley and Gilroy (2002) conclude that Florida's Growth Management Act (GMA) may have contributed to a 15 percent decline in affordability between 1994 and 2000, and that Washington State's GMA may have added about 0.7 percentage points to the housing inflation rate for each year the county had a comprehensive plan in place. Other studies, however, have found that growth management effects are minor after controlling for other factors. For example, an analysis of the urban growth boundary in Portland, Oregon found that the boundary has created upward pressure on housing prices, but the effect is relatively small in magnitude, contributing no more than $10,000 compared to an overall cost appreciation of $144,000 over their study period (Phillips and Goodstein 2000). A broader literature review concluded that market factors, including increased housing demand, increased employment, and rising incomes are much more significant influences; and furthermore, that policy changes to allow increased densities and smaller units have mitigated any affordability impacts by allowing housing supply to be increased within the growth boundary (Nelson et al. 2002).

A variety of both social benefits and ills have been assigned to "sprawl" versus "compact" land use patterns (Burchell et al. 1997). For example, some have argued that land use controls could reduce consumer welfare by constraining consumer choice (e.g., requiring smaller dwelling units and/or yards). To the extent that land use policy changes simply *accommodate* latent market trends for more compact development, this should not be a concern. However, more aggressive policy changes that restrict where people live could potentially lead to welfare losses. The factors that influence residential and neighborhood quality are complex and there is not a consensus on the extent to which compact land use may increase or decrease overall social welfare or benefit particular income groups.

2.3 Non-Motorized Strategies

Bicycle and pedestrian strategies can improve mobility by providing people with increased travel options, at a lower cost. Bicycle and pedestrian improvements and programs also should increase safety for non-motorized travelers, many of whom are lower income. Non motorized improvements will provide increased opportunities for, and will encourage, recreational activity as well as non-motorized transportation, thereby increasing physical activity and improving public health. The evidence from many studies on walking and bicycling demonstrate that regular participation in these activities provides a health benefit for people of all ages, genders, and races (Dunn et al., 1999).

2.4 Public Transportation Strategies

A major co-benefit associated with transit is its ability to reduce the relative degree that non-drivers are disadvantaged compared with motorists (VTPI 2008). Transit increases economic and social opportunities for people who are disadvantaged, and helps achieve equity objectives, such as helping physically and economically disadvantaged people access public services, education, and employment. The equity benefits of transit improvements will depend, to some extent, on the type of service provided, and the neighborhoods and employment opportunities served. For example, bus commuters tend to be lower income than light- and heavy-rail commuters, who similarly have lower incomes than commuter-rail users. Service improvements in low income and minority neighborhoods will have greater equity benefits than improvements serving wealthier areas. However, suburban transit service can be important for providing "reverse-commute" options for car-less central city residents to suburban jobs.

The numerical equity analysis in Section 3.2 illustrates that public transportation services may be relatively more used by lower-income groups than by all groups, and thus the benefits of public transportation investments may occur with higher proportionality towards lower-income groups. This is of course dependent on the specific services and investments.

2.5 Commuter Strategies

Like transit, commuter measures that improve the availability and quality or reduce the cost of travel for commuters, as well as those that provide information about alternatives, can improve equity by increasing mobility for lower-income commuters. Examples of strategies that may improve equity include additional transit service (e.g., shuttles), transit subsidies, and expanded ridesharing and vanpooling options. Strategies such as parking cash-out will particularly benefit lower-income commuters who may place a higher relative value on the cash benefit received (compared to higher-income commuters), if they choose not to drive. Similarly, ridesharing and vanpooling produce benefits through reduced vehicle operating costs which may be more meaningful to lower-income commuters. For example, at a round-trip length of 24 miles and a cost of $0.55 per mile per current Internal Revenue Service (IRS) guidance (as of January 2009), the typical commuter could theoretically save about $13 per day (although the actual savings may be less as this includes some fixed costs such as insurance).

Strategies that are implemented by increasing costs or providing other disincentives may have a negative equity impact. For example, increasing parking costs will represent a relatively greater hardship for lower-income commuters than for higher-income commuters. They will either need to pay a greater share of their income for parking costs, or make use of travel alternatives that may be less convenient.

Strategies that provide expanded work hour options, including telecommuting and compressed work weeks, can provide a social benefit by providing employees more flexibility in scheduling work and personal commitments. This could lead to increased job satisfaction, reduced stress, shorter commute time, and more free time during non-weekend periods for employees. Employees may use this time to become more engaged in their families and communities, leading to stronger family support and a deeper level of civic engagement. However, not all employees will prefer longer work days or working at home, or have compatible personal schedules. Therefore, if telecommuting or compressed work weeks are made mandatory, some employees are likely to be made better off while others are worse off.

2.6 Operations Strategies

On the whole, operations strategies do not have significant equity impacts. The one exception is ramp metering, which decreases travel time delays for one group of users (those starting farthest from the ramp metering zone) while increasing delays for the other users. The most significant empirical studies of ramp metering's real efficiency and equity effects were conducted in the Twin Cities during fall of 2000, when the metropolitan area's meters were turned off for eight weeks so that an assessment of their effectiveness could be made. While the primary assessment focused on the efficiency of the system, considering mobility and safety particularly (Cambridge Systematics, 2001), a transportation equity analysis of the delay distribution across space also was conducted. Levinson and Zhang (2006) fully describes the methodology. The latter paper considered equity for a number of corridors that had sufficient data. The authors found that, for instance on Route 169, a suburb-to-suburb limited access highway, connecting the North and South legs of the region's beltway, with ramp metering, the average travel speed (taking ramp delay into account) of the highway increases from 37 km/h to 62 km/h; travel delay per mile decreases from 136 seconds to 112.5 seconds, and the average travel time for one trip decreased from 610 seconds to 330 seconds. The shortest trips actually are hurt in mobility terms by ramp metering, while the longest trips, benefit the most. As is expected, metering redistributes delay. Moreover, metering makes the system less equitable overall, when considering the Gini coefficient, removing metering improved the equity of trip speed, running speed, and travel delay per km. Alternative ramp control strategies can improve equity, but the theoretically most efficient system (metering ramps closest to bottlenecks) is likely to be the least equitable (as delay is borne by a minimum number of ramps) (Kotsialos and Papageorgiou, 2004; Zhang and Levinson, 2005*a*, 2002), showing the real tradeoff between these two distinct objectives.

Unlike road pricing, there is no excess revenue to be recycled with ramp metering, so there is no direct way to compensate the losers in such a system. So long as the losses appear to be small, complaints may be minimal, but when delays get large, as was the case in the Twin Cities prior to 2000, a reaction may take place, leading to equity becoming a more significant constraint. In the Twin Cities ramp delays were capped at four minutes following the ramp meter shut down. As a consequence the efficiency of the system is degraded.

3.0 Analysis of Equity in Moving Cooler

Section 3.1 discusses the equity implications of each of the *Moving Cooler* GHG reduction strategies. Section 3.2 provides a more detailed analysis of the pricing strategies and Section 3.3 does the same for the motor fuel and carbon taxing strategies. Section 3.4 discusses some of the options for remedying the inequities generated by these strategies.

3.1 Equity Implications of Strategies in *Moving Cooler*

Travel behavior strategies may have consumer welfare, economic, and equity impacts that are either positive or negative, depending upon the specific strategy and how it is applied. Essentially, strategies that rely on measures such as improved service or financial incentives to induce voluntary behavior changes will, by definition, result in increased consumer welfare, through time savings, vehicle operating cost savings, and/or other benefits such as increased comfort and convenience. On the other hand, strategies that are implemented through disincentives (such as price increases) or requirements will make some people worse off.

Strategies that improve the availability and quality or reduce the cost of travel alternatives, as well as those that provide information about alternatives, can provide increased mobility to travelers and improve equity. The mobility benefit is particularly acute for low-income people for whom an automobile may be a financial hardship, as well as for children, seniors, and those with disabilities that make driving impossible.

Table 3.1 provides an assessment of equity impacts by strategy. The subsections below discuss each of the strategy groups shown in that table.

Pricing Strategies – Strategies in the pricing group require intensive analysis and consideration of additional measures to remedy equity concerns. This is, of course, reflects the monetary costs of driving and parking fees on low-income groups, for whom the costs may be more important than benefits (such as time savings) gained. These issues are explored in greater depth in Section 3.2, but a brief summary is provided here.

Modest to strong negative equity impacts on low-income groups are projected for the pricing strategies. For instance, congestion pricing has greater benefits for higher income than for lower income single occupant (drive alone) work trips, although both groups will see lower benefits from pricing itself than the costs of the tolls they will pay. Equity concerns with motor fuel taxes and carbon taxes are similar to those for other pricing strategies or fees, in their effect in increasing financial burdens on low-income groups. Carbon taxes, it should be noted, also will impact other fuel costs besides motor fuel costs. The one exception to these equity concerns is pay-as-you-drive insurance, which essentially turns existing fixed insurance costs into a per-mile insurance cost. Since the overall cost does not change, the equity effects are minimized. It is estimated that approximately two-thirds of drivers will experience cost savings under a fully implemented pay-as-you-drive regime, and low-income groups may benefit to the extent that they are not high-mileage drivers.[157] Pay-as-you-drive does create a difference in impacts between low-mileage and high-mileage drivers, as does any mileage-based fee. In addition, it should be noted that equity issues for lower-income groups created by congestion pricing or by higher fuel costs could be addressed through reinvestment in highways, public transportation, system operations, and commuter and ridesharing programs, as discussed in Section 3.2.

Land Use and Smart Growth Strategies – Modest to strong positive equity impacts on both low-income and inner-area (i.e., located near urban cores) groups are expected from the land-use and smart-growth strategies analyzed in *Moving Cooler*. More compact development patterns benefit these groups by bringing jobs, retail, and health care closer. This reduces travel times and costs, particularly for individuals who may not have reliable access to private automobiles. These policies also could increase housing costs, presenting an offsetting negative externality. As discussed in the literature review, however, particularly when offset by policies allowing increased densities and smaller units these effects have been shown to have a relatively small influence on overall household housing costs.

Non-Motorized Transport Strategies – Positive equity impacts also are shown for non-motorized transport, reflecting the improved mobility and access, and decreased cost of travel for low-income groups and inner-area groups. The gains may not apply equally to all within low-income and inner-area groups; those with disabilities or the infirm may not be able to take advantage of non motorized strategies as easily.

Public Transportation Improvement Strategies – Because low-income groups utilize public transportation more than average, investments in public transportation can potentially target a larger percentage of benefits to low-income groups. The fare measures, level of service improvements, and expanded route miles will all greatly benefit low-income and inner-area groups by decreasing monetary travel costs on existing routes (e.g., decreased fares), decreasing travel times, and expanding the destinations that can be reached via transit. These equity benefits are not experienced for intercity public transportation, however. The *Moving Cooler* strategy emphasizes intercity rail, which is not disproportionately used by low-income groups. High-speed rail travel in particular will likely not benefit low-income travelers due to the cost of service.

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[157] Bordoff, Jason and Pascal J. Noel. "*Pay-As-You-Drive Auto Insurance: A Simple Way to Reduce Driving-Related Harms and Increase Equity*." The Brookings Institution, Washington D.C., 2008.

Regional Ride Sharing, Car Sharing, and Commuting Strategies – Car sharing, which is most successful in denser areas, would – like transit – be a particular boon to inner area groups who may not own private vehicles, whether because of affordibility or choice. Employer commute strategies in general would have positive equity impacts on low-income groups, by increasing access to jobs (through shared ride or shuttle options). However, charging for employer parking would represent a negative equity impact for low-income groups, who would be less able to afford the fees. They also would be less likely to benefit from telework strategies, which often are not readily applied to lower-income positions.

Regulatory Measures – These strategies have mixed equity impacts. Urban non motorized zones and urban parking restrictions will have negative equity impacts on inner-area groups and to some extent on low-income groups, who are more likely to live in those areas. Speed limit reductions could have negative equity impacts on rural drivers, who are more likely to be driving longer distances on highways operating in free flow conditions (and thus be constrained by the lower speed limits). Eco-driving will not have significant equity impacts.

Operations and Intelligent Transportation System (ITS) Strategies – Almost all of the operations and ITS strategies analyzed in *Moving Cooler* do not have significant equity effects. They primarily serve to smooth traffic flows and increasing operating speeds on existing roadways throughout both urban and rural areas. The exception is ramp metering, which reduces travel times in the aggregate but also redistributes some of the delay to inner-area drivers. It favors drivers starting at the edge of urban areas – i.e., drivers who enter the highway at non metered ramps – who drivers benefit from the increased operating speeds of the roadway for the longest distances, without even experiencing the delays at metered ramps (in one direction, at least).

Bottleneck Relief and Capacity Expansion Strategies – These strategies have strong positive equity impacts. Improved highway transportation is an important source of mobility for low-income persons. Despite their proportionately larger transit ridership than other socioeconomic groups, nationally low-income groups still rely primarily on highways for their mobility. Improved mobility gives these groups better access to jobs, healthcare, and retail.

Multimodal Freight Strategies - These strategies do not have significant socioeconomic equity impacts. It is possible that implementation costs could be passed onto customers in the form of higher prices for goods (which would affect low-income groups, who spend a greater share of their income on food and other necessities than other groups), but this is not likely to be significant for the strategies analyzed, and in many cases, savings may be generated instead. However, rail and marine improvement strategies do favor those modes at the expense of trucking.

Table 3.1 Equity Impacts of Greenhouse Gas Emission Reduction Strategies

GHG Reduction Strategy	A. Expanded Best Practice	B. More Aggressive	C. Maximum Effort
Pricing Strategies			
Parking pricing (combine with land use, transit, operations, equity analysis)	Modest negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Moderate negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Strong negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.
Cordon pricing (combine with land use, transit, highway investment, operations, equity analysis)	Modest negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Moderate negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Strong negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.
Congestion pricing	Modest negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Moderate negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Strong negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.
Intercity tolls	Modest negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Moderate negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Strong negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.
Pay-as-you-drive (PAYD) insurance	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
VMT tax	Modest negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Moderate negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Strong negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.

Table 3.1 Equity Impacts of Greenhouse Gas Emission Reduction Strategies *(continued)*

GHG Reduction Strategy	A. Expanded Best Practice	B. More Aggressive	C. Maximum Effort
Pricing Strategies (continued)			
Gas tax and carbon tax	Modest negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Moderate negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.	Strong negative equity impacts on low-income groups – reduced access to jobs, health care, education, and retail.
Land Use and Smart Growth Strategies			
Combined strategies	Modest positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.
Non-Motorized Transport Strategies			
Combined strategies – pedestrian	Modest positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.
Combined strategies – bicycling	Modest positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.

Table 3.1 Equity Impacts of Greenhouse Gas Emission Reduction Strategies *(continued)*

GHG Reduction Strategy	A. Expanded Best Practice	B. More Aggressive	C. Maximum Effort
Public Transportation Improvement Strategies			
Fare measures	Modest positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.
Increased levels of service/improved travel times	Modest positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.
Expanded urbanized area public transportation	Modest positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.
Intercity Bus and Rail/High speed rail	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Regional Ride Sharing, Car-Sharing and Commuting Strategies			
HOV lanes	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Car-sharing	Modest positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs, health care, education, and retail.

Table 3.1 Equity Impacts of Greenhouse Gas Emission Reduction Strategies *(continued)*

GHG Reduction Strategy	A. Expanded Best Practice	B. More Aggressive	C. Maximum Effort
Regional Ride Sharing, Car-Sharing and Commuting Strategies (Continued)			
Employer-based telework and compressed work week programs: private sector	Modest positive equity impacts on low-income and inner area groups – increased access to jobs.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs.
Employer-based telework and compressed work week programs: public sector	Modest positive equity impacts on low-income and inner area groups – increased access to jobs.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs.	Strong positive equity impacts on low-income and inner area groups – increased access to jobs.
Employer-based TDM requirements, outreach, and support	Modest positive equity impacts on low-income and inner area groups – increased access to jobs.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs.	Moderate positive equity impacts on low-income and inner area groups – increased access to jobs, offset by parking charges.
Regulatory Measures			
Urban non-motorized zones	Modest negative equity impacts on low-income groups.	Moderate negative equity impacts on low-income groups.	Strong negative equity impacts on low-income groups.
Urban parking restrictions	Modest negative equity impacts on low-income groups.	Moderate negative equity impacts on low-income groups.	Strong negative equity impacts on low-income groups.
Speed limit reductions and/or auto governors	No significant equity impacts by-income level, but substantial negative impacts on rural mobility.	No significant equity impacts by-income level, but substantial negative impacts on rural mobility.	No significant equity impacts by-income level, but substantial negative impacts on rural mobility.
Ecodriving	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.

Table 3.1 Equity Impacts of Greenhouse Gas Emission Reduction Strategies *(continued)*

GHG Reduction Strategy	A. Expanded Best Practice	B. More Aggressive	C. Maximum Effort
Operations and Intelligent Transportation System (ITS) Strategies			
Ramp metering (centrally-controlled)	Modest negative equity impacts on inner area groups.	Moderate negative equity impacts on inner area groups.	Strong negative equity impacts on inner area groups.
Electronic roadway monitoring	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
VMS	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Active traffic management	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Integrated corridor management	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Detection algor/free cell call	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Closed circuit TV cameras	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
On-call service patrols; tmc integration/coordination	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Road weather management (snow/ice/fog; freeways)	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
TMC deployment	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Signal control level	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
VMS	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Traveler information	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Vehicle Infrastructure Integration (VII)	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.

Note: VII deployment is based on the deployment curve in Volpe VII BCA Report (Chart 3.1: Projected Phase-In of VII Equipped Vehicles in the US Fleet). The "More Aggressive" scenario uses these forecasts and they are adjusted for "Current Practice" and "Maximum Effort" scenarios

Table 3.1 Equity Impacts of Greenhouse Gas Emission Reduction Strategies *(continued)*

GHG Reduction Strategy	A. Expanded Best Practice	B. More Aggressive	C. Maximum Effort
Bottleneck Relief and Capacity Expansion Strategies			
Bottleneck relief	Modest positive equity impacts on low-income and inner-area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner-area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner-area groups – increased access to jobs, health care, education, and retail.
Capacity expansion	Modest positive equity impacts on low-income and inner-area groups – increased access to jobs, health care, education, and retail.	Moderate positive equity impacts on low-income and inner-area groups – increased access to jobs, health care, education, and retail.	Strong positive equity impacts on low-income and inner-area groups – increased access to jobs, health care, education, and retail.
Freight Strategies – Modal Diversion			
Rail capacity improvements	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Marine transportation system maintenance and improvement	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Overweight load permits for trucks carrying shipping containers	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Overweight load permits for longer combination vehicles (LCV)	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Low-speed WIM screening at weigh stations	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Truck stop electrification	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Truck-only toll lane networks	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.

Table 3.1 Equity Impacts of Greenhouse Gas Emission Reduction Strategies (continued)

GHG Reduction Strategy	A. Expanded Best Practice	B. More Aggressive	C. Maximum Effort
Freight Strategies – Mode Optimization (continued)			
Use of electronic credentialing to allow vehicles to bypass weigh stations and safety inspections	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Heating and cooling systems for sleeper cabs	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.
Freight Strategies – Logistics			
Urban consolidation centers and limitations on pickup and delivery (pud) service in dense urban areas	No significant equity impacts.	No significant equity impacts.	No significant equity impacts.

3.2 Quantitative Equity Analysis of Pricing Strategies in *Moving Cooler*

While the literature on equity in pricing is very rich, as demonstrated in Section 2.0, the quantitative analyses conducted to date of equity are very limited. It is necessary to combine the results of several prior analyses in order to develop useful numerical estimates of the equity implications of individual strategies and of packages. The concept of equity is intrinsic to the concept of bundles of strategies, because it is only through bundling of strategies that the equity issues arising from pricing can reasonably be addressed.

Equity in Pricing Itself – Differences in Impacts By Income Group

A very useful evaluation of congestion pricing by the Puget Sound Regional Council (PSRC) "Traffic Choices Study: Findings From a Road Pricing Experiment (2008)" provides evidence of the equity consequences of pricing. PSRC tested congestion pricing using a sample of households whose responses to road pricing were monitored. The PSRC study is particularly useful for quantitative equity analysis because it measures impacts on different income groups, and also because it measures whether congestion pricing produces net benefits prior to reinvestment of the revenues. The study involved charging a sample of users different fees for use of the roadways at various times of day. Because only a sample was charged congestion pricing fees, the responses were extrapolated to regional totals. However, the responses of specific different income groups, and the benefits they received from pricing, were measured by PSRC.

The PSRC study applied tolls during weekdays and measured the responses of different user groups. The toll rates per mile examined in the PSRC region are shown in Table 3.2. The toll rates are illustrative and are obviously not set for each particular roadway segment, which would presumably be done in a comprehensive application of congestion pricing. Also, although it may be the case that toll rates should be set higher on non-freeways than on freeways due to the greater impact of an additional vehicle on congestion on non freeways, the PSRC sets freeway toll rates higher than non freeway toll rates. This is a common problem with other studies of pricing. Tolls ideally should be set by segment and time of day.

Table 3.2 Weekday Toll Rates: PSRC Pricing Study

Time Period	Toll Rates Per Mile For Freeways	Toll Rates Per Mile For Non Freeways
6 a.m. to 9 a.m.	$0.40	$0.20
9 a.m. to 4 p.m.	$0.15	$0.08
4 p.m. to 7 p.m.	$0.50	$0.25
7 p.m. to 10 p.m.	$0.10	$0.05
10 p.m. to 6 a.m.	$0.00	$0.00

Table 3.3 shows PSRC's results in terms of the savings, by type, for the different classes of users. Results for work trips based on income levels were reported, providing important information for evaluating the equity of pricing applications.

PSRC's definitions of user groups and vehicle types presents results by income level for the drive alone work trips, and aggregate results for all income groups for the other user groups. It is likely that if the results also were compiled for non-work trips, the same equity results for income groups would also be demonstrated.

Of greatest interest are the comparisons among income groups, which PSRC compiled for single occupant auto work trips. For other trips with higher occupancies, the PSRC study did not report on income levels, perhaps because that is somewhat ambiguous for multi-occupant travel. Trucks show very high time savings, and very high unreliability cost savings, due to congestion pricing.

Table 3.3 PSRC Daily User Benefits From Tolling Application
(Dollars in Thousands)

User Group	Time Savings	Operating Cost Savings	Unreliability Cost Savings	Total of All Savings
Drive Alone Home Based Work				
Low-Income	(0.4)	2.9	0.0	2.5
Low-Middle-Income	48.7	12.0	(4.0)	56.7
High-Middle-Income	299.6	29.8	15.7	345.1
High-Income	865.2	46.8	68.8	980.8
Drive Alone Non Work	548.0	121.6	68.9	739.4
Carpool and Vanpool	339.4	65.7	41.6	446.7
Public Transportation	156.1	0.0	0.0	156.1
Light Truck	1,524.1	131.4	260.2	1,914.7
Medium Truck	557.6	65.0	70.5	693.1
Heavy Truck	648.4	50.2	71.5	770.1
Totals For All Groups	$4,983.7	$525.4	$593.2	$6,102.3

Table 3.4 shows total savings versus tolls paid and the ratio of savings to tolls paid for each group. The most important column is the fourth column which shows the percentage of the benefits in comparison to the tolls paid for each user group. It is very interesting that, before the use of the revenues to generate offsetting benefits, all groups are worse off, some far more than others. An important equity lesson is that pricing has disbenefits for all user groups except transit users, *until* revenues are reinvested. Transit

vehicles were exempted from tolls in the PSRC demonstration. The lowest-income users are the worst off, consistent with a wide range of similar findings reported in the Section 2.0 literature review.

As can be seen, although low-income drive alone auto users have very low benefits, also they pay a small portion of the tolls. For drive alone work trips, the share of benefits is greater than the share of tolls paid only for the high-income group. In the PSRC estimates, truck users receive higher portions of benefits than of tolls paid. This is primarily due to the estimated benefits to them from time savings and reliability savings, which make the benefits to truck users higher than the benefits to other users.

Table 3.4 PSRC Daily User Benefits Versus Tolls From Tolling Application
(Dollars in Thousands)

User Group	Total of All Savings	Tolls Paid by Group	Ratio Percent of Benefits per Dollar of Tolls	Percent of Total Tolls Paid	Percent of Total Savings (Benefits)
Drive Alone Home-Based Work					
Low-Income	$2.5	$111.5	2.24%	0.84%	0.04%
Low-Middle-Income	$56.7	$391.6	14.48%	2.97%	.93%
High-Middle-Income	$345.1	$1,054.1	32.74%	7.99%	5.66%
High-Income	$980.8	$1,745.2	56.20%	13.22%	16.07%
Drive Alone Nonwork	$739.4	$4,203.8	17.59%	31.85%	12.12%
Carpool and Vanpool	$446.7	$1,978.3	22.58%	14.99%	7.32%
Public Transportation	$156.1	$0.0	N/A	0.00%	2.56%
Light Truck	$1,914.7	$2,147.5	89.21%	16.27%	31.39%
Medium Truck	$693.1	$707.3	97.99%	5.36%	11.36%
Heavy Truck	$770.1	$861.1	89.43%	5.52%	12.62%
Totals For All Groups	$6,102.3	$13,200.3	46.23%	100.00%	100.00%

The PSRC study did not provide a basis for estimating the impacts on groups due to the reinvestment of revenues. This would have to be accomplished through parallel analyses, which has been estimated here using investment models.

To evaluate the combined impact of including the reinvestment of revenues, a Cambridge Systematics (CS) analysis of the user benefits of highway investments also has been added to the PSRC equity results for congestion pricing itself. The CS analysis was conducted as part of the recent Bottom Line technical report on National and State Investment Needs for Highways and Public Transportation, under NCHRP Project 20-24(54)G.

Combined Equity in Pricing Plus Equity in Investments

To estimate the total equity of pricing, it is necessary to estimate the equity implications of reinvestments using the revenues generated by pricing. Two methods are used to illustrate the impacts of the reinvestments of revenues on various user groups. The first is a CS analysis of the net return on investment of the added user benefits associated with increasing national highway capital investment levels by funding all projects that pass a benefit-cost criterion. The second is an analysis by the San Francisco area's Metropolitan Transportation Commission of the equity of its adopted program of future investments on low-income households.

Highway and Transit Investments – Equity and Return on Investment

The Highway Economic Requirements System (HERS) model calculates highway needs based upon the maximum economic return, which is defined as implementing projects whose benefits exceed their costs. The results of the recent NCHRP analysis of highway needs were a justified level of highway capital investment of $166 billion per year, which is $98 billion per year higher than current investment levels. This is a large increase in investments, but it will generate an even larger increase in additional net user benefits. The NCHRP analysis and a parallel Transit Cooperative Research Program (TCRP) analysis also calculated comparable public transportation capital investment needs, with a mid range of $48 billion in investment needs versus a current level of $13 billion. Thus, a comparable figure for the incremental needs for public transportation over and above current levels is about $35 billion per year.

Increasing investments in mobility without any limit is clearly not necessary or desirable. It is important to estimate what maximum level of additional transportation reinvestment would generate net benefits capable of offsetting equity issues resulting from pricing or other user fees. Considering that many *Moving Cooler* strategies are less costly to implement than highway and public transportation, a very reasonable estimate is that over $150 billion per year generated by pricing measures and then reinvested in the other *Moving Cooler* mobility measures will have very high economic returns to society, and could remedy the equity issues created by pricing while also contributing to further GHG emission reductions.

This rough estimate of a $150 billion per year of additional economically justified investment in mobility measures would be equivalent to a $1.00 per gallon of motor fuel tax, or an average of five cents per vehicle mile of travel. This figure is only cited to illustrate that desirable reinvestments with positive economic returns can be made for a very large amount of any new revenues generated by any of the pricing measures. All the equity analysis is done on a dollar-for-dollar basis, comparing payments to net benefits for each group. Thus the same conclusions are applicable across all levels of investment in these measures.

For the full economic needs scenario and the existing funding scenario in recent NCHRP research for project 20-24(49)G, a comparative calculation was performed of the net present value of the increase in user benefits from the higher investment versus the costs of the increase in capital investment itself. The higher level of economically justified investment, over the 20 years covered in the NCHRP study, would yield $2.13 trillion more in net benefits after subtracting out the higher investment costs, which were about $2 billion more investment over 20 years compared to current levels. To put another way, the failure to increase investment to an economically justified level will cost the economy $2.13 trillion dollars in losses. A rational society would not fail to make these investments.

When averaged across the years in the equity analysis for the *Moving Cooler* study, which expanded on the NCHRP work, the added user cost benefits as calculated for reinvestment in highways will be 1.95 times as great as the added costs of the higher investment in highway infrastructure.

Public transportation returns on capital investment are comparable. A previous estimate for APTA in "*Public Transportation and the Nation's Economy: A Quantitative Analysis of Public Transportation's Economic Impact*" also showed a positive yield for public transportation investments, with a return on investment of 3 to 1. This estimate was for a broader measure of benefits, and is the ratio of the net increase in business sales per dollar of increase in public transportation investments. The highway and public transportation benefits per dollar of additional investment may be fairly equal, perhaps 2 to1 when just user benefits are considered and 3 to 1 when broader benefit measures are used. Thus, reinvestment in both highway and public transportation programs can produce very large net benefits.

The benefits from reinvestment are additive to the equity results from pricing alone. To estimate the overall value of pricing plus reinvestment, the benefits of the reinvestment would be added to the impacts of pricing by user group. Each user group would have at least $1.95 in benefits from reinvestment for every dollar paid, based upon a long-term comparison of the costs of higher levels of investment to the associated higher level of benefits to the users.

Table 3.5 shows the illustrative results of the numerical equity analysis for congestion pricing, utilizing the PSRC Traffic Choices Study results for estimating the pricing responses and using the CS Bottom Line and *Moving Cooler* analysis results for estimating the benefits of the reinvestment of the pricing revenues.

Table 3.5 Equity Analysis: Return on Investment by User Group: From Pricing Alone, From Reinvestment of Revenues, and From Combined Pricing and Reinvestment

User Group	From Pricing Alone: Dollars of Benefit Per Dollars of Tolls Paid	From Reinvestment Alone: Dollars of Benefit Per Dollars Reinvested	Combined: Dollars of Benefit Per Dollars Paid and Reinvested
Low-Income SOV Work Trips	$.02	$1.95	$1.97
Low-Middle-Income SOV Work Trips	$.14	$1.95	$2.09
High-Middle-Income SOV Work Trips	$.33	$1.95	$2.28
High-Income SOV Work Trips	$.56	$1.95	$2.51
Drive Alone Nonwork	$.19	$1.95	$2.14
Carpool and Vanpool	$.23	$1.95	$2.18
Heavy Trucks	$.89	$1.95	$2.84
All Vehicle Classes Combined	$.46	$1.95	$2.41

Sources: Puget Sound Regional Council Traffic Choices Study and CS Analysis for *Moving Cooler* Report and Bottom Line Report. All returns from the reinvestment are shown as the same for each group on a per mile basis of vehicle miles of travel. Transit investments are estimated to return $3 for each dollar invested, in a CS and Economic Development Research Group study, which includes all economic benefits (user and non-user). This table includes only user benefits, and overall economic benefits are likely to be higher for each group with highways as well as with transit.

Further Addressing Low-Income Equity Issues With Public Transportation Investments

Another useful source of quantitative results is the San Francisco Metropolitan Transportation Commission's *MTC Transportation 2035 Equity Analysis Report*. The report estimates the equity impacts of the region's proposed long-range transportation plan on income groups in the Bay area. As with other equity analyses, it focuses on the equity of expenditures among the various income groups, and compares the expenditures that may benefit low-income households to the expenditures that benefit all households. This comparison of expenditures defines the current state of the art in equity analysis for regional plans. Other measures considered include whether accessibility increases more for target groups than for all groups.

The ultimate impact on different income groups, however, is heavily influenced by how the revenue from congestion pricing or any other revenue is spent. Revenue reinvestment is widely acknowledged by economists and policy-makers to be a solution to inequitable-income effects, by redistributing benefits to specifically targeted recipients, through tax policy changes, or to the public in general, through infrastructure and transit investments.

Table 3.6 shows the San Francisco area's calculation of expenditures per household for low-income households versus all households.[158] The MTC concluded that their planned investments were equitable to low-income groups based on the average expenditure they calculated for low-income households versus other households.

Table 3.6 Quantitative Equity of San Francisco Long-Range Plan (T2035) Expenditures

	All Households	Low-Income Households	All Other Households
Share of Transit Usage	100.0%	26.7%	73.3%
Share of Roadway Usage	100.0%	2.4%	97.6%
T2035 Transit Expenditures (Dollars in Billions)	$148.9	$ 39.7	$109.1
T2035 Highway Expenditures (Dollars in Billions)	$76.4	$ 1.8	$ 74.6
Total Expenditures	$225.3	$ 41.6	$183.7
Households (in 2006)	2,468,024	436,554	2,031,470
Expenditures Per Household (Dollars in Thousands	$91.3	$95.2	$90.4

The MTC long-range plan has very high investments in public transportation relative to investments in highways. Because low-income groups receive 27 percent of the benefits from public transportation versus 2 percent of the benefits from highways, the MTC's investment mix, which is oriented to transit, will tend to provide very strong returns for low-income households. The MTC example shows that adding significant public transportation investments into the reinvestment mix could potentially strengthen the already good returns on investment that would occur for lower-income groups from only highway reinvestments.

[158] The study includes detailed tables for transit operations, transit capital, highway operations, highway capital, etc. However, since all the expenditures were assigned by percentage of users, these tables do not provide more information about the equity of specific categories of expenditures.

Regardless, the primary lesson is very positive: either highway or public transportation investments or a mix can provide solutions to the equity issues of pricing impacts on low-income groups. In addition, the *Moving Cooler* effectiveness analysis shows that these reinvestments contribute to further reductions in GHG emissions. This conclusion can be extended to other strategies that are less capital intensive than reinvestment. Operations improvements, for example, have very high user benefits per dollar invested, also while contributing to reductions in GHG emissions.

3.3 Equity Analysis of Motor Fuel Taxes and Carbon Taxes

Table 3.7 shows the Consumer Expenditure Survey information on incomes, transportation expenditures, motor fuel expenditures, and percentages of income paid by income quintile for 2007. Each income quintile represents the average of one-fifth of the households in the U.S., ranked by income from the lowest one-fifth of households to the highest one-fifth of households. This information is commonly used to track expenditures by income group, and the distribution and magnitude of consumer expenditures by income group.

Table 3.7 Equity Analysis by Quintile of Income: Motor Fuel Expenses

Parameters	Lowest One-Fifth	Second One-Fifth	Middle One-Fifth	Fourth One-Fifth	Highest One-Fifth	Average
Income After Tax	$10,534	$27,419	$45,179	$70,050	$150,927	$60,858
Transportation Expenditures	$3,242	$5,717	$7,926	$11,058	$15,831	$8,758
Air and Public Transportation	$171	$242	$362	$506	$1,406	$538
Private Transportation	$3,071	$5,475	$7,564	$10,552	$14,425	$8,220
Percent on Private Transportation	29.2%	20.0%	16.7%	15.1%	9.6%	13.5%
Gas and Oil Expenditures	$1,046	$1,768	$2,418	$2,988	$3,696	$2,384
Percent on Gas and Oil	9.9%	6.5%	5.4%	4.3%	2.5%	3.9%

The last row of Table 3.7 shows how much each income group now spends on motor fuel and oil in comparison to its income. Virtually all these expenditures are on motor fuel itself. The lowest-income group spent nearly 10 percent of after tax income on motor fuel in 2007, which compares to about one-fourth the percentage of income which the highest income group spent on motor fuel. Although fuel was at a historically high price in 2007, the price in 2007 was less than the even higher average price in 2008. Since the end of 2008, motor fuel prices have declined.

The equity implications of increases in fuel user fees are parallel to those of congestion pricing fees. Comparable impacts on different user groups from incremental motor fuel fees have not been estimated in the same manner as was done by PSRC for pricing fees.

The analysis for the Bottom Line report utilized the HERS model system with its "self financing feature," e.g., the user fees in the analysis were set equal to the levels of investment which were generated in the analysis. Therefore, all the impacts of the higher fuel prices needed to fund the investments and generate the benefits shown in Table 3.8 below, already are considered in the parameters that are used in forecasting vehicle miles of travel and other parameters. This means that the results of the HERS already runs include the motor fuel taxes and the expenditures together. What they may be missing are additional fees necessary to fund the motor fuel tax portion of higher transit investments. Table 3.8 shows the motor fuel tax return on investment by income group.

Table 3.8 Equity Analysis: Return On Investment By User Group: From Fuel Taxes and Reinvestment of Revenues

User Group	Dollars of Benefits Per Dollar Reinvested
Low-Income SOV Work Trips	$1.95
Low-Middle-Income SOV Work Trips	$1.95
High-Middle-Income SOV Work Trips	$1.95
High-Income	$1.95
Drive Alone Non Work	$1.95
Carpool and Vanpool	$1.95
Heavy Trucks	$1.95
All Vehicle Classes Combined	$1.95

Although lower-income groups and all groups would receive net benefits, the incidence of added motor fuel user fees on the household budgets of lower-income groups is still of concern. As with the congestion fees, the types of additional equity repayments suggested by other researchers for lower-income groups include potential reductions in income taxes, payroll tax rebates, increased earned income tax payments, increases in social security and supplemental security income benefits, increases to food stamp benefits, and others.

A very useful quantitative analysis of equity is included in a study by the MIT Joint Program on the Science and Policy of Global Climate Change "Analysis of U.S.

Greenhouse Gas Tax Proposals" Report No. 160, April 2008. MIT uses its Emissions Prediction and Policy Analysis (EPPA) Model to evaluate the economic consequences of GHG and energy tax proposals. The model includes an evaluation of the welfare consequences (gain or loss of effective income) for various income groups under different GHG tax and rebate proposals. The model predicts the impacts on fuel prices and welfare for the alternative legislative proposals, and relates the CO_2 prices to anticipated prices of fuel. For example, they estimate that a $27 per ton CO_2 price would cause a $0.26 increase in the price of regular gasoline, as well as changes in price for other energy sources. The model forecasts potential revenues for alternative legislative proposals through 2050. Tax revenue for three selected proposals ranges from $69 billion to $126 billion per year in 2015, growing to a range of $141 billion to $1,031 billion per year by 2050. For comparison purposes, also they estimate the percentage of CO_2 revenues to overall Federal revenues. These range from 4 percent to 7 percent of Federal revenues in 2015 to from 3 percent to 21 percent of Federal revenues in 2050. These are very substantial revenue streams.

The model utilizes an input/output model and consumer expenditure survey data from 2003 (similar data to table 3.8) to estimate the increase in costs by household. An example analysis for a $15 per ton CO_2 equivalent tax estimated price increases for various energy sources and other purchased products. The carbon tax calculated as a percentage of income, which constitutes an income loss, ranged from 3.7 percent of income for the lowest 10 percent to only 0.8 percent of income for the highest income 10 percent of the population. Their analysis also estimated the impacts of a "lump sum" rebate of all carbon revenues to all households, as the means to address equity issues. Rebating all revenues as a common lump sum would result in a 5.6 percent income gain for the lowest 10 percent of households to a 0.6 percent gain for the highest 10 percent of households. The results are shown in Table 3.9.

Table 3.9 Distributional Impacts of Carbon Tax and Lump Sum Rebate

Income Decile	Carbon Tax as Percent of Income (Income Loss)	Lump Sum Rebate as Percent of Income (Income Gain)	Net Impact
1	-3.7	5.6	1.9
2	-3.0	4.0	1.0
3	-2.3	3.1	0.8
4	-2.0	2.4	0.4
5	-1.7	2.1	0.4
6	-1.5	1.6	0.1
7	-1.3	1.3	0.0
8	-1.2	1.2	0.0
9	-1.0	0.9	-0.1
10	-0.8	0.6	-0.2

Thus, a full rebate in equal amounts to all households, of the proceeds of carbon taxes can eliminate the equity impacts on the lowest-income groups. However, the rebate of all these fees misses the net additional benefits that can be achieved for all groups from reinvesting some portion of these revenues in transportation GHG reduction measures. Perhaps a mix of uses of carbon taxes, with some portiongoing to transportation programs, could both remedy the equity issues of the taxes and contribute further to reducing GHG emissions.

3.4 Addressing Equity with Revenue Distribution

The analysis presented in *Moving Cooler* showed that economy-wide pricing strategies have the potential to generate reductions in GHG emissions greater than those of many other individual strategies. By the same token, pricing strategies also present the most significant equity issues for lower-income groups and rural residents. According to the U.S. Bureau of Labor Statistics data, the lowest-income group spends four times the percentage of their income on motor fuel, when compared to the highest-income group. Given this fact, any strategy that increases the price of travel will have a disproportionate effect on lower-income populations.

Table 3.10 shows the incomes, transportation expenditures, motor fuel expenditures, and the percentages of income paid by income quintiles for 2007. Each income quintile represents the average of one-fifth of the households in the U.S., ranked by income level from the lowest one-fifth of households to the highest one-fifth of households.

The last row of the table shows how much each income group now spends on motor fuel and oil, in comparison to its income. Virtually all these expenditures are on motor fuel itself. While the lowest-income group spent nearly 10 percent of its after-tax income on motor fuel in 2007, the highest-income quintile spent about 2.5 percent of income.

Approaches for addressing potential equity effects of higher prices need to first identify how those prices affect different populations. Planning organizations are increasingly analyzing overall equity effects as part of their planning processes. For example, the analyses performed by such MPOs as the San Francisco Metropolitan Transportation Commission explicitly estimate how planned transportation expenditures are allocated to lower-income households, as compared to all other households. This type of analysis will be central to first understanding and then mitigating equity effects of pricing strategies to reduce GHGs

The revenues generated by the pricing strategies can be a significant part of the response to mitigate inequities through the reinvestment of those revenues in other transportation services. There can be three basic ways of mitigating equity effects with these revenues. First, revenues created by the pricing strategies could be transferred to affected groups. Second, these revenues could be reinvested in the transportation system to benefit all groups. Third, transportation investments could be further focused on those portions of the transportation system, such as public transportation, that are used more extensively by lower-income populations.

Table 3.10 Equity Analysis by Quintile of Income: Motor Fuel Expenses as a Percent of Income of U.S. Households
2007

Parameters	Lowest One-Fifth	Second One-Fifth	Middle One-Fifth	Fourth One-Fifth	Highest One-Fifth	Average
Income After Tax	$10,534	$27,419	$45,179	$70,050	$150,927	$60,858
Transportation Expenditures	$3,242	$5,717	$7,926	$11,058	$15,831	$8,758
Air and Public Transportation	$171	$242	$362	$506	$1,406	$538
Private Transportation	$3,071	$5,475	$7,564	$10,552	$14,425	$8,220
Percent Spent on Private Transportation	29.2%	20.0%	16.7%	15.1%	9.6%	13.5%
Gas and Oil Expenditures	$1,046	$1,768	$2,418	$2,988	$3,696	$2,384
Percent Spent on Gas and Oil	9.9%	6.5%	5.4%	4.3%	2.5%	3.9%

Source: 2007 United States Bureau of Labor Statistics Consumer Expenditure Survey.

Addressing Equity Through Rebates

As one example of how revenue transfers might be used to address inequities, an MIT study evaluated the economic consequences - that is the gain or loss of income - of GHG and energy tax proposals. In its examination of a carbon tax equivalent to a $27 per ton CO_2 price or a $0.26 increase in the price of regular gasoline, MIT estimated that the revenues generated would total from 3 to 21 percent of Federal revenues in 2050. The carbon pricing revenues evaluated by MIT would apply to all sectors of the economy, not just to transportation. MIT also estimated that the monetary impacts of a carbon tax on households - constituting an income loss - ranged from 3.7 percent of the income for the lowest 10 percent to only 0.8 percent of the income for the highest 10 percent of households. To address this inequitable effect, MIT estimated the effects of a "lump sum" rebate of all carbon revenues to all households. Rebating all revenues as a common lump sum would result in a 5.6 percent income gain for the lowest 10 percent of households to a 0.6 percent gain for the highest 10 percent of households. The net equity results generated by MIT are shown in Table 3.11. It is conceivable that rebates of general carbon taxes might use just a portion of the total revenues generated, rather than reimburse households the full amounts that are generated. This allocation would allow some proceeds to be used for transportation investments that could provide benefits to all income groups.

Table 3.11 Distributional Impacts of Carbon Tax and Lump Sum Rebate

Income Decile	Carbon Tax as Percent of Income (Income Loss) (pPercent)	Lump Sum Rebate as Percent of Income (Income Gain) (percent)	Net Impact (percent)
1 (lowest)	-3.7	5.6	1.9
2	-3.0	4.0	1.0
3	-2.3	3.1	0.8
4	-2.0	2.4	0.4
5	-1.7	2.1	0.4
6	-1.5	1.6	0.1
7	-1.3	1.3	0.0
8	-1.2	1.2	0.0
9	-1.0	0.9	-0.1
10	-0.8	0.6	-0.2

Source: Analysis *of U.S. Greenhouse Gas Tax Proposals,* Report No.160, (Boston: MIT Joint Program on the Science and Policy of Global Climate Change, Massachusetts Institute of Technology, April 2008).

Addressing Equity Through Highway Reinvestment

Revenue reinvestment is widely acknowledged by economists and policy-makers to be an effective response to inequitable income effects of user fees, by redistributing benefits through transit, highway, or other investments. Using pricing revenues to reinvest in the transportation system is therefore another way to address potential inequities. A highway investment analysis conducted for AASHTO's Bottom Line report estimated the net user cost savings of higher levels of investment that would be economically justified, compared to current investment levels.[159] The analysis showed that the increased user benefits were two times greater than the increased investments needed. All of the projects implemented

[159] American Association of State Highway and Transportation Officials, *Transportation: Are We There Yet?: Bottom Line* Report, (Washington, D.C.: AASHTO, 2009).

in this analysis return benefits that are greater than their costs. These net benefits are proportional for each income group's use of the roads, as are the motor fuel taxes paid by each group. Given this positive return, investments will provide a benefit to all groups, which will help offset the higher price of travel. Operations improvements have been shown to have even higher net returns on investments than the average for other types of highway investments.

Addressing Equity Through Targeted Public Transportation Investments

Focusing reinvestment of the pricing revenues on public transportation improvements is another way to address equity. Also, like the highway investment above, it also returns significant economic benefits. Because public transportation is used disproportionately by lower-income users, by other disadvantaged groups such as the disabled, and by those too young or too old to drive, providing more services would benefit those groups and offset the effect of higher prices of travel by automobile.

A Cambridge Systematics report for APTA, "*Public Transportation and the Economy*" (2000, and 2009 Update),[160] found returns on investment of 3-1 or more for public transportation capital improvements. The average returns for the largest urban areas are 6-1. These returns on investment were calculated using a much broader measure of benefits than in the highway benefit calculations, so the results of these studies do not directly compare the return on investment for public transportation and for highway investments.

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[160] American Public Transportation Association, "*Public Transportation and the Economy*" (Washington, D.C.: APTA, 2000, and updated 2009).

4.0 Moving Cooler Final Report Summary of Equity Issues

The potential equity issues that might occur with the implementation of differing types of *Moving Cooler* strategies and opportunities to address them are summarized below.

- **Pricing strategies.** All pricing strategies (including carbon taxes or the effects of cap-and-trade on the prices of fuels), unless mitigated, would adversely impact lower-income groups more than those with higher incomes. The poorest users get fewer benefits from congestion pricing, VMT fees, or other fees, because they spend a higher proportion of their income on transportation, are less able to afford to pay higher fees, and may be priced off these services altogether. Lower-income groups pay four times as high a percentage of their income for motor fuels as the highest-income groups, and would receive even more inequitable effects from pricing strategies that increase their traveling costs. Rural or exurban users, because of lower incomes and fewer transit and carpool options, will also have equity issues from pricing that may be even harder to remedy. To mitigate these adverse equity effects, the revenues generated by the pricing strategies could be used to invest in other transportation services, or to fund income transfers among those affected by the strategies.
- **Land Use and Smart Growth.** Land use and smart growth can improve accessibility and mobility for those without access to autos, and enable individuals in all income groups to avoid the increased costs of travel that would occur with other GHG reduction strategies, thereby providing an option to mitigate the adverse effects of those strategies. While there are potential concerns with the effects on property values, these may be offset by decreased transportation costs. Gains and losses to property owners in more or less centrally located areas from the changes in land use regulation are a secondary concern, but should be noted.
- **Nonmotorized.** Investment in nonmotorized modes can have substantial positive equity effects by increasing mobility for lower-income groups and all those without significant access to vehicles (youth, the elderly, disabled persons, or others unwilling or unable to obtain a driver's permit).[161] These

[161] According to U.S. Census 2007 estimates, 15 percent of the age-eligible U.S. population does not hold a driver's licenses. When accounting for the elderly, those unable to afford a car, and multi-

(Footnote continued on next page...)

new modes would enhance their access to jobs, medical care, education, retail services, and other needed services.

- **Public Transportation.** Public transportation services provide access to employment opportunities, health care, education, retail services, and other services. Because lower-income people rely more on public transportation than other groups, public transportation improvements can potentially channel higher percentages of benefits to lower-income people and those without other mode choices, such as people who reside in rural areas. As with nonmotorized transportation, these benefits also should apply to many in the driving-age population without daily access to an automobile. Public transportation improvements can thus remedy part of any mobility loss due to pricing measures. Reduced fares also can make transit more affordable for lower-income groups.
- **Commuter, HOV, Carpool, and Vanpool.** Commuter, HOV, carpool, and vanpool measures can improve equity by providing low-cost mobility and access to jobs, medical care, education, retail, and other needed services for lower-income, disabled, and other users who are most in need of sharing the costs or tasks of travel. These strategies, along with investments in public transportation services, may be particularly helpful in rural settings to mitigate other inequities. These equity benefits would also apply to many others who are unable to drive a vehicle.
- **Regulatory.** Lower speed limits will impose significant travel time penalties on all groups, and perhaps more on rural users. Lower speeds improve safety, reducing fatalities and injury incidents.
- **System Operations and Management.** System operations measures have no significant equity issues, except for ramp metering, which may have negative effects on drivers who must access the metered roadway from locations closer to urban centers than other drivers.
- **Capacity Expansion and Bottleneck Relief.** Highway improvements provide significant mobility and accessibility benefits to all highway users. Economy-wide pricing, by providing a source of funding to make investments in capacity expansion and bottleneck relief, can mitigate the equity issues caused by higher per mile costs from the pricing measures. These strategies can thus provide improved access to employment opportunities, health care, education, retail services, and other services for highway users.
- **Multimodal Freight Strategies.** Freight strategies, while potentially having some redistributive effects across freight modes, should have no negative equity implications for other users and may decrease congestion. They can

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driver and single-vehicle (or similar) households, a significantly larger portion of the U.S. population does not have daily access to a personal vehicle.

enhance delivery of various goods and services to businesses and consumers.

All of these factors will influence the design of national and local strategies to reduce GHGs from transportation. There are significant opportunities to build win-win solutions through integrated approaches that improve the nation's transportation network and enhance mobility, in addition to creating the benefits of the reductions in GHG emissions. However, the investment costs of some of these strategies are considerable and the potential for negative equity effects from some of the pricing strategies are high, absent strong policy intervention.

Many negative effects - mobility losses and the potential burdens placed on lower-income and rural travelers - could be addressed by using the revenues from fees and taxes to provide substantial benefits, for example, through highway, ride-share, transit, or other improvements or through financial reimbursements to lower-income and other low-mobility groups. These reinvestment strategies could help ensure that lower-income and other low-mobility groups do not have their travel restricted as a result of increased costs because of pricing or other measures. Morever, equity-based reinvestment is economically justified. Analyses of highway and public transportation strategies in *Moving Cooler* and the results of the cost-benefit studies cited above conclude that these investments provide economic returns on these investments ranging from 2-1 or 3-1 or more, in terms of their benefits in relation to costs. However, equitable reinvestment is a key policy decision and will not happen automatically.

- Carbon taxes on all fuels or the effects of cap-and-trade on the prices of all fuels also will increase other non-transportation fuel costs for lower-income groups.

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