TRANSPORTATION & REGIONAL GROWTH

a study of the relationship between transportation and regional growth

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The Distribution of Transportation Costs in the Twin Cities Region

Report #15 in the Series:
Transportation and Regional Growth Study

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The purpose of this report is to determine who bears the costs of transportation in the Twin Cities Region for 1998 and 2020. In a previous report, *The Full Cost of Transportation in the Twin Cities Region*, we determined the total social costs of transportation in the region. In this study we determine who bears the governmental, internal and external costs of transportation (i.e., who pays for or experiences these costs). We also determine who imposes or causes the marginal external costs of transportation. Most of the costs are caused and borne by residents of the region, but some are caused or borne by people who live outside the region. We analyze cost incidence for 78 sub-regions and for nine income/vehicle ownership groups.

This report contains three appendices. The first appendix describes other studies of cost incidence. The second appendix defines the regions that we examine. The third appendix examines the efficiency and equity of a hypothetical improvement in express bus service. The purpose of the third appendix is to demonstrate ways that information on transportation costs can be used to help evaluate policy alternatives. It is not intended to reflect on the desirability of any actual projects.

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Contents

List of Tables

List of Figures

Preface

The Transportation and Regional Growth Study is a research and educational effort designed to aid the Twin Cities region in understanding the relationship of transportation and land use. Many regions of the country are experiencing rapid commercial and residential development, often accompanied by population growth and growth in the total area of land developed. This has caused a range of concerns, including the direct costs of the infrastructure needed to support development and the social and environmental side effects of development patterns.

This study is an effort to better understand the linkages between land use, community development, and transportation in the Twin Cities metropolitan area. It is designed to investigate how transportation-related alternatives might be used in the Twin Cities region to accommodate growth and the demand for travel while holding down the costs of transportation and maximizing the benefits. The costs of transportation are construed broadly and include the costs of public sector infrastructure, environmental costs, and those costs paid directly by individuals and firms. Benefits are also broadly construed. They include the gains consumers accrue from travel, the contribution of transportation and development to the economic vitality of the state, and the amenities associated with stable neighborhoods and communities.

The University of Minnesota's Center for Transportation Studies is coordinating the Transportation and Regional Growth Study at the request of the Minnesota Department of Transportation and the Metropolitan Council. The project has two components. The first is a research component designed to identify transportation system management and investment alternatives consistent with the region's growth plans. It has six parts:

- Twin Cities Regional Dynamics
- Passenger and Freight Travel Demand Patterns
- Full Transportation Costs and Cost Incidence
- Transportation Financing Alternatives
- Transportation and Urban Design
- Institutional and Leadership Alternatives

The first three research areas are designed to gather facts about the transportation system and its relationship to land use in the Twin Cities metropolitan area. The other three research areas will use these facts to investigate alternatives in financing, design, and decision making that could have an impact on this relationship. Results of this research is and will be available in a series of reports published for the Transportation and Regional Growth Study.

The study's second component is a coordinated education and public involvement effort designed to promote opportunities to discuss the relationship between transportation and growth based on the research results. It is believed that this dialogue will help increase knowledge and raise the level of awareness about these issues among the study's many audiences including decision makers who make policy, agency professionals who implement policy, stakeholder groups who try to influence policy, and members of the general public who experience the consequences of those policies.

Acknowledgements

This study was funded by the Minnesota Department of Transportation, the University of Minnesota's Center for Transportation Studies, and the Metropolitan Council of the Twin Cities as part of a long-term research project on the interaction of transportation and land use in the state of Minnesota.

Members of our Technical Advisory Panel were particularly helpful to us when we were conducting this research. Scott Peterson, Bruce Breise, Mark Filipi, Norman Foster, Scheffer Lang, David Levinson, Perry Plank, Steve Ruegg, Charles Sanft, and Rabinder Bains have all made specific suggestions that have improved this work.

Other researchers working on the Transportation and Regional Growth Study have also aided us. The work done by Gary Barnes, Barry Ryan, and Thomas Stinson has been particularly useful in this study. In addition, Tursynbek Nurmagambetov helped us in analyzing the literature on cost incidence.

Gary Barnes made substantial changes to the final draft of this report. These were mostly cosmetic, but included minor modifications to some methodologies that were made to help clarify some of the results. Because of this, he must take joint responsibility, along with the primary authors, for any errors contained in this report. The conclusions expressed in this report are solely those of the authors.

Executive Summary

The purpose of this report is to describe how the costs of transportation in the Twin Cities region are divided among its residents. We divide the people of the region in two ways: by geographic location (of the home), and by income and car ownership. We are interested here in questions of equity. If the costs of existing transportation, or of proposed policy changes, fall on the population in an unequal or unfair way, it may be desirable to think about how to mitigate these inequities.

This report addresses only the question of how the total costs of transportation are shared among the region's residents. Estimates of the size of the total costs, and the different categories that they fall into, were developed in an earlier report in the Transportation and Regional Growth series (Anderson and McCullough, *The Full Cost of Transportation in the Twin Cities Region*). Readers who are interested in the size of the total costs or in how they are placed into categories, as opposed to their allocation among residents, should refer to this earlier report.

There are three major types of costs. Internal costs occur when a person knowingly incurs a transportation-related expense, such as buying a car or spending time driving it. Some of these costs are monetary, such as buying gas, and some are non-monetary, such as the value of the time spent traveling. Non-monetary costs are converted to monetary values using standard methodologies. Government costs are purchases by various governments for transportation, such as roads and transit. External costs are when a person creates a cost that is suffered by someone else, such as air pollution. These are generally non-monetary costs.

We examine the distribution of transportation costs for both 1998 and 2020. However, the distribution in 2020 is different only because of changing settlement patterns and incomes, not because there are substantive changes in how costs will be allocated. Thus the 2020 costs have little interest from a policy perspective, and we focus in this report mostly on 1998 costs.

Divisions by Geography and Income

The distribution of transportation costs was calculated for 78 geographic sub-regions and for nine income groups.

The geographic sub-regions were chosen to coincide with political boundaries and to have generally similar populations (except for a few regions of unusual land use, such as airports). Very large municipalities were divided into two or more regions. The sub-regions consist of 66 regions within the seven-county Twin Cities Metropolitan Area (TCMA) and 12 outlying counties. Within the TCMA, 20 of the sub-regions are in the central cities of Minneapolis and St. Paul, 38 are suburban, and 8 are mostly rural.

Most costs of transportation do not vary by geographic location except incidentally, in that costs vary by income and income varies by geography. For example, people in Eden Prairie spend more on gas than people in Minneapolis, but this is mostly because residents of Eden Prairie have higher incomes and choose to drive more, not because gas costs more there.

The one significant exception to this general rule is air pollution. Residents who live closer to the center of the region suffer more air pollution, because driving is relatively concentrated there. While there is obviously also a great deal of driving in the suburbs, it is spread out over a much larger land area, so the concentration of pollutants is not as high.

We also analyzed the distribution of costs by household income and auto ownership. Most transportation costs vary significantly by income, because higher income people make different transportation choices than those with lower incomes. There are two ways of thinking about this. The first is simply how total costs change with income; the second is how costs change as a percentage of income. For example, high-income people spend more in total on their vehicles, but they spend less as a fraction of their income.

The area in which this distinction is of particular interest is in government costs. Many people feel that people with higher incomes should pay proportionately more of their income to support government, because they can afford it better. For example, the income tax rate starts at zero and goes up as income rises, so that a high income person will not only pay more tax, but will pay a higher percentage of income as tax. A point of interest for transportation financing is the degree to which it is progressive like this.

Types of Costs

Full costs are divided into three types — internal, governmental, and external costs. We estimate that in the region in 1998, transportation resulted in per capita internal costs of $7500, per capita governmental costs of $800, and per capita external costs of $600.

Internal costs are those borne directly by the person who causes them. There are several major components of this. Fixed vehicle costs, such as purchases, finance charges, and insurance, are the same regardless of how much a person drives. Variable vehicle costs, such as gasoline and repairs, vary with the amount driven. Parking is a major cost which is often incurred in a lump sum, as in the cost of a driveway or garage, or when businesses build parking lots. Finally, travel time is the single biggest component of internal costs. This is obviously an implicit, non-monetary cost.

While internal costs are by far the biggest part of total transportation costs, they are the least interesting from a cost incidence standpoint. This is because people can control these costs directly or indirectly through the decisions that they make, in terms of where to live, where to work, and what kind of car (and how many) to own. Thus there is no possibility of inequity in the sense of some people incurring more costs than they “should,” as could be the case with government or external costs.

A potentially interesting question that we do not address here is whether there is any intrinsic geographic element in internal costs; in particular, whether low-density land uses "force" people to spend more money on cars, driveways, etc., than they would in a higher density environment. The data that we used were not broken down in this way. There is also a difficult conceptual question of how to distinguish voluntary choices from what is "forced" by the nature of development. To address this question in a serious way would probably require a major survey; this is beyond the scope of this project.

Governmental costs are those borne by any level of government. The primary component of this is streets and highways; other major parts are law enforcement, transit, and publicly provided parking. The major questions here are who pays for these things, through what mechanisms, and whether different income levels pay a fair share. These costs vary primarily by income and choices regarding car ownership and driving habits, and only indirectly by geography. The only (relatively minor) geographical variation is that cities and towns might devote different levels of local tax revenues to transportation; however, we do not delve into this level of detail. Thus our primary concern is to understand how these costs are allocated among people of different income levels.

As with internal costs, there is an interesting question of whether some styles of land development lead to higher than necessary government costs. Again, the available data sources do not allow us to address this issue; to do so would be a significant research project in its own right. In this report we study only where tax revenue is generated, not where it is spent. This also means that we do not address issues of geographical equity, that is, whether the geographic distribution of spending matches that of revenue generation. The sole issue that we address in looking at government costs is how the tax burden falls across income groups and, indirectly, geographic areas.

External costs are costs that are not borne by the person who causes them. The major parts of this are congestion (free flow travel time is a voluntary, hence internal cost; time in excess of this is caused by others and is thus an external cost) and air pollution. Thus our main concern here is whether people in some parts of the region are imposing excess costs on people in other places, and the extent to which land use or transportation policy changes might be able to alleviate such problems.

Results: Incidence of Costs by Geographic Region

Table 1 shows the incidence of per capita internal and government costs for three large areas—the cities of Minneapolis and Saint Paul, other parts of the TCMA, and 12 outlying counties. Differences across the areas in internal and governmental costs are driven almost entirely by differences in per capita income. However, people in the lower-income outlying counties bear higher internal costs than central city residents because they drive more on average. Internal costs are broken out into monetary and non-monetary (e.g. travel time), so that the comparison to income includes only actual monetary expenses.

Table 1: The Annual Per Capita Cost of Transportation (Internal and Government) in 1998 (1998 Dollars)						
Region	Population	Average Income	Internal Monetary	Govt.	Time (non-mon.)	Total Monetary % of Income
Minneapolis & St. Paul	656,000	26,850	3,633	710	2,864	16.2%
Other TCMA	1,854,000	35,150	5,020	940	3,069	16.9%
Outlying Counties	516,000	21,750	3,722	680	3,273	20.2%
Average	3,027,000	31,050	4,497	840	3,059	17.3%

Table 2 shows external costs divided into the same three areas. Central city residents face lower congestion costs on average because there is lower auto ownership; hence many people incur no congestion costs at all. Even auto owners in the central cities are more likely to use transit to access congested destinations such as the downtowns; this further reduces the average congestion level.

As expected, central city residents bear the highest costs of air pollution, because concentrations are highest there. However, perhaps surprisingly, they also impose the highest costs, even though they drive the least of all the areas. This happens because much of the driving by central city residents is in the central cities, where large numbers of people are exposed to the pollution that is generated. A mile of central city driving may not generate more pollution than a mile in the country, but it does generate more costs.

Table 2: The Annual Per Capita Cost of Transportation (External) in 1998 (1998 Dollars)					
Region	Congestion	Pollution Borne	Pollution Imposed	Other	Imposed outside region
Minneapolis & St. Paul	136	571	511	91	100
Other TCMA	123	264	261	78	161
Outlying Counties	82	12	98	91	157
Average	118	288	288	83	147

Results: Incidence of Costs by Income Group

While higher income people spend substantially more on transportation, they spend less as a share of their income. (Of course, this is true for many types of costs, not just transportation.) Taxes paid to the government for transportation-related goods and services are relatively stable across income levels, as a percent of income. While the overall burden is relatively low compared to the private costs of car ownership, it is still true that low-income car owners pay a higher fraction of their income in transportation-related taxes than do high-income people. Thus the current system of transportation finance could be considered to be a regressive tax system. Table 3 shows monetary costs.

Table 3: Monetary Transportation Costs in 1998 Expressed as a Percent of Income

Group	Internal	Governmental
Less than $15,000, no vehicle	4.8	1.35
Less than $15,000, vehicle	40.9	2.89
$15,000 to $25,000, no vehicle	4.8	1.39
$15,000 to $25,000, vehicle	29.7	2.57
$25,000 to $35,000	23.9	2.42
$35,000 to $45,000	22.6	2.27
$45,000 to $55,000	21.2	2.23
$55,000 to $75,000	18.5	2.06
More than $75,000	15.9	1.85
Average	19.8	2.48

It is also worth noting in the context of private costs that while people that don't own cars pay a substantially lower fraction of their incomes for transportation, they are still incurring a major cost in the sense that they have considerably reduced access to the destinations they might want to reach, such as work and shopping opportunities. This analysis of transportation costs does not address the issue of accessibility (or lack thereof) as an element of transportation costs.

For external costs of transportation, the general trends are that congestion costs rise with income and pollution costs fall. The higher pollution costs for low income people are a reflection of the fact that they are disproportionately likely to live in the central cities. The presence of higher congestion costs for higher income people probably happens both because they drive more, and because the generally suburban nature of their home and work locations usually precludes the use of transit or other non-auto modes.

1 Introduction

This report describes who bears the costs of transportation in the Twin Cities Region and who is responsible for producing the costs. Information on cost incidence is important because it is helpful in evaluating how well transportation serves different groups of people and different parts of the region. This information provides a baseline that can help when analyzing the distributional impacts of potential transportation policies.

This study relies heavily on a previous report, *The Full Cost of Transportation in the Twin Cities Region*.[1] The purpose of that report was to identify and quantify all of the costs imposed by transportation in the Twin Cities. This present report explains how these costs are paid for, experienced, and caused by people in the region. This report does not discuss how the full cost was calculated, except when this is necessary to explain how the distribution was done. Readers wondering how full costs were derived should refer to the other report.

In this report we determine, for various groups of people, the costs they pay or experience and the costs they impose. The costs they pay include user fees and general taxes to support government-provided transportation services. Costs paid, or borne, also include the internal costs the group pays (both monetary costs such as vehicle purchases and non-monetary costs such as most travel time). Finally, they include the external costs that the group experiences—the congestion, air pollution, noise, etc. Most of these costs are borne by people within the region, but some are borne by people outside the region.

We examine the distribution of transportation costs for both 1998 and 2020. However, the distribution in 2020 is different only because of changing settlement patterns and incomes, not because there are substantive changes in how costs will be allocated. Thus the 2020 costs have little interest from a policy perspective, and we focus in this report mostly on 1998 costs. Full tables of cost allocation results for both 1998 and 2020 are shown in Appendix B.

The body of the report is divided into five parts, including this introduction. Sections 2, 3, and 4 present data on who bears the governmental, internal, and external costs of transportation, respectively. Section 4 also presents data on who imposes external costs. Section 5 summarizes our findings. The first two appendices contain a review of related studies, and maps and data describing the sub-regions and showing results broken out by sub-region.

In the final appendix, we examine two alternatives—an improvement in express transit service between Stillwater and Downtown Saint Paul and a status quo alternative. The analysis is conducted so that we can show how our cost data can be used to evaluate transportation alternatives. We take travel behavior as given, and analyze how changes in travel behavior affect costs and benefits.

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[1] Anderson and McCullough (2000).

1.1 Types of Costs

We attempt to account for the full social costs of transportation. Full social costs include both monetary and non-monetary costs, and include costs paid for by individuals or businesses or units of government. Monetary costs are those that are paid for with money. Examples include everything from vehicles and fuel, to insurance payments and government spending on roadway maintenance. Non-monetary costs are those costs that are not paid for with money. They include travel time (except when people are paid for their time) and the pain and suffering that results from crashes.

This report examines the costs of surface transportation in a 19-county area surrounding the Twin Cities Metropolitan area. We include the costs of truck transportation, but not the costs of freight railroads. We also include the costs of transit. The primary modes examined are auto, truck, and bus. Pedestrian and bicycle traffic is not examined here because, except for their value of travel time, their costs are generally quite small.[2] More information on the costs described in this section can be found in Sections 2 and 3 of Anderson and McCullough (2000).

We divide costs into three categories: governmental, internal, and external. Governmental costs are costs paid for by any level of government. Internal costs are those borne entirely by the individual who causes them, not including fees or taxes used to pay for government-provided goods and services. External costs are those costs that are not borne by the person who causes them.

Internal costs are those borne directly by the person who causes them. There are several major components of this. Fixed vehicle costs, such as purchases, finance charges, and insurance, are the same regardless of how much a person drives. Variable vehicle costs, such as gasoline and repairs, vary with the amount driven. Parking is a major cost which is often incurred in a lump sum, as in the cost of a driveway or garage, or when businesses build parking lots. Finally, travel time is the single biggest component of internal costs. This is obviously an implicit, non-monetary cost.

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A potentially interesting question that we do not address here is whether there is any intrinsic geographic element in internal costs; in particular, whether low-density land uses "force" people to spend more money on cars, driveways, etc., than they would in a higher density environment. The data that we used were not

[2] This does not mean that these modes are unimportant from a policy perspective. In fact, precisely because of their low external and governmental costs, they can be attractive policy options. From an incidence perspective, however, they are not very interesting.

broken down in this way. There is also a difficult conceptual question of how to distinguish voluntary choices from what is "forced" by the nature of development. To address this question in a serious way would probably require a major survey; this is beyond the scope of this project.

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1.2 Divisions by Geography and Income

We examine the costs of transportation in a 19-county area. The area consists of the 7-county Twin Cities Metropolitan Area (TCMA) and a ring of adjoining counties. These adjoining 12 counties have much smaller populations and are much more rural that the seven core counties, but (i) a significant portion of the people in these counties commute to the TCMA and (ii) there is the potential for significant growth in these counties by 2020. The area of the TCMA is approximately 3,000 square miles and the area of the entire region is approximately 10,000 square miles.

The region contained approximately 3.04 million people in 1998 and we project that it will contain 3.70 million people in 2020. Approximately 80 percent of the population lives in the TCMA. More information on the region and travel in the region is contained in Anderson and McCullough (2000).[3]

We analyze the costs for 78 geographic sub-regions within the study area. We also analyze costs for nine income/vehicle ownership groups. These divisions are driven by the data that are available from the 1990 Travel Behavior Inventory (TBI).[4] The TBI was a constructed from a one-percent sample of TCMA households. Because it was a relatively small sample, we combine the small geographic sub-regions that TBI used into larger areas. We also construct nine income/vehicle ownership groups from TBI data.

These 78 sub-regions provide us with geographic detail and help us to avoid some of the inaccuracies that would occur if we used smaller areas. In addition, the number of sub-regions is small enough that we can present information on them in tables. The geographic detail of this study is discussed more in Section 1.2.1.

The income groups are also based on the data available in the TBI. The income data from the TBI is supplemented with data from the Census Bureau. We start with seven income groups of roughly equal size, and then divide the two lowest income groups based on whether or not the household owns a vehicle. These groups are defined in Section 1.2.2.

In addition to location and income/vehicle-ownership, there are many other ways that we could analyze incidence. Examples include age, gender, race, and impairment to mobility.[5] Although important transportation-related differences surely exist for many such groups, we do not propose studying these differences here. There are a number of reasons. One is that, because of the scope of this study, we cannot analyze all of the groups we would like to. A second is that most existing research on cost incidence focuses on geography and income. A third is that there is no obvious reason why most the incidence of most costs would be affected directly by these other factors. For example, while there are surely differences by race in how some costs are incurred, for the most part these differences arise indirectly because of racial differences in home location or income, rather than because race itself impacts how costs are incurred.[6] While our work is focused on geography and income, we will be helpful to others who wish to examine different aspects of cost incidence.

Figure B.1 in Appendix B is a reference map of the Twin Cities area. Figure B.2 shows the 78 sub-regions we examine. Table B.2 lists the sub-regions and some

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[3] See especially Tables 3.4, 3.5, and 3.8.

[4] For more information on the TBI, see Metropolitan Council (1994a).

[5] On differences in travel by race and gender, see Pisarski (1999). Pucher (1982) discusses the relationship between race, transit use, and governmental expenditures on transit.

[6] There are exceptions to this generalization. There are significant racial differences in auto ownership, for example, even among people of the same income level and home location. While other such differences likely exist, we feel that their analysis is more suited to a study that focuses particularly on these few key points of difference, rather than the more general approach we take here.

of their characteristics. The definition of each of the sub-regions in terms of the TAZs it contains is in Table B.1.

1.2.1 Geographic Divisions

We feel that it is important that this study determines cost incidence by location. Costs do not necessarily vary in a uniform way, so it is helpful to do more than just divide the Twin Cities region into a central area and two or three rings. Geographic detail is also useful because cities and townships are important political units. It may be helpful to know how policies would affect people in cities and townships to understand some of the practical political consequences of a policy. A final reason to examine the geography in some detail is that other demographic characteristics, such as income and race, are to some extent location-dependent.

There are a number of potential ways to divide the study area. Three possibilities are:

- County. There are 19 counties in the region.
- Minor Civil Division (city or township). There are 197 minor civil divisions in the TCMA alone.
- Traffic Analysis Zone (zones assigned by the Metropolitan Council for transportation planning). The TCMA is divided into almost 1,200 traffic analysis zones.

Counties do not seem detailed enough for examining regional growth. The distinction, for example, between Minneapolis and the rest of Hennepin County, would seem to be crucial for identifying the effects of many types of transportation policies.

Minor Civil Divisions (MCDs) or Traffic Analysis Zones (TAZs) seem too detailed, however. Using either presents significant data problems. We rely heavily on the Metropolitan Council's Travel Behavior Inventory (TBI) as a source of data. The TBI surveyed approximately 10,000 households in the TCMA. This means that the average number of people surveyed in each TAZ was less than ten. Some MCDs are also small, in terms of population. If we used either MCDs or TAZs, we would be examining some areas on which we have little data. This might lead to quite inaccurate estimates of travel behavior and travel costs.

We propose getting around the problem of the large number of MCDs by dividing the TCMA into 66 roughly equal sub-regions. Four of the largest MCDs are divided into sub-regions—Minneapolis is divided into twelve sub-regions, Saint Paul into seven sub-regions, and Bloomington and Brooklyn Park are each divided into two sub-regions. The average population of each sub-region is 35,000 and, on average, the TBI sampled 150 households from each. All of the sub-regions have over 10,000 residents, except for the Saint Paul downtown and the sub-region containing the Minneapolis-Saint Paul International Airport. Within the TCMA, 20 of the sub-regions are in the central cities of Minneapolis and St. Paul, 38 are suburban, and 8 are mostly rural.

Outside of the TCMA, we divide the study area into the 12 counties. While the counties are large compared to the sub-regions inside the TCMA, each county has approximately the same population as each of the other 66 sub-regions. In addition, we do not have TBI data for the 12 outlying counties, so dividing them further would be difficult.

In the text, we usually summarize geographic costs by dividing the region into three rings: central cities, the rest of the TCMA, and the outlying counties. The full results for all the zones are listed in tables in Appendix B. We do this to help clarify broad differences across the region, and to prevent the large tables of results from interfering with the flow of the text. We also do this because for most costs, as discussed below, there is no intrinsic geographic variation. For those costs, such as air pollution, where there is an essential geographic element, we show results for all 78 regions in a map in the text, as well as in a table in Appendix B.

Most costs of transportation do not vary by geographic location except incidentally, in that costs vary by income and income varies by geography. For example, people in Eden Prairie spend more on gas than people in Minneapolis, but this is mostly because residents of Eden Prairie have higher incomes and choose to drive more, not because gas costs more there.

The one significant exception to this general rule is air pollution. Residents who live closer to the center of the region suffer more air pollution, because driving is relatively concentrated there. While there is obviously also a great deal of driving in the suburbs, it is spread out over a much larger land area, so the concentration of pollutants is not as high.

1.2.2 Income/Vehicle Ownership Groups

Examining costs by income is important in a study of cost incidence. While transportation policy has only limited ability to enhance social equity, knowing the effects of policy on equity is still useful.[7] Policies that are socially beneficial, but have negative impacts on equity might be implemented with other policies that have better effects on equity. In some cases, enhancing equity is seen as a justification for certain types of transportation policies.[8]

There are additional reasons for examining the incidence of costs by income. One is that, along with location, income may be correlated with other demographic factors such as household size, number of adults in the household, gender, or race. Another is that there are significant differences across income for different types of costs—differences in internal costs (of which personal expenditures are an important component) and differences in taxes paid. There are also efficiency reasons to examine income. Different income groups may

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[7] Another problem is that using transportation policy to promote social equity would probably involve significant efficiency losses.

[8] Enhancing equity is especially seen as a justification for certain transit policies. See Pucher (1982).

respond differently to policies, and these differences have consequences for the design of both equitable and efficient policies.[9]

The 1990 Travel Behavior Inventory (TBI) and the 1990 Census are our primary sources of data on household income. The TBI divides people into eight income groups and the census into twenty-five. Because we rely heavily on the TBI, and because the two groups with the lowest incomes have relatively few people in them, we combine the two lowest TBI income groups.

An additional consideration is that transportation costs vary greatly depending on vehicle ownership. The number of vehicles a household owns has important and predictable effects on both travel behavior and on travel costs. Because the vast majority of households with moderate or high incomes have access to vehicles, we divide only the lowest two income groups (below $15,000 and between $15,000 and $25,000) based on vehicle ownership. Including vehicle ownership in our analysis will make it much easier for us to predict user fees, internal costs, and transit use. The income/vehicle ownership groups are listed in Table 1.1.

Table 1.1: Income and Vehicle Ownership Groups

	Description
1	Income less than $15,000 and no vehicle
2	Income less than $15,000 and one or more vehicles
3	$15,000 to $25,000 and no vehicle
4	$15,000 to $25,000 and one or more vehicles
5	$25,000 to $35,000
6	$35,000 to $45,000
7	$45,000 to $55,000
8	$55,000 to $75,000
9	Income more than $75,000

Most transportation costs vary significantly by income, because higher income people make different transportation choices than those with lower incomes. There are two ways of thinking about this. The first is simply how total costs change with income; the second is how costs change as a percentage of income. For example, high-income people spend more in total on their vehicles, but they spend less as a fraction of their income.

The area in which this distinction is of particular interest is in government costs. Many people feel that people with higher incomes should pay proportionately more of their income to support government, because they can afford it better. For example, the income tax rate starts at zero and goes up as income rises, so that a high income person will not only pay more tax, but will pay a higher

[9] Anderson and Mohring (1996), for example, calculate efficient congestion tolls, but these tolls depend on the number of drivers in different income groups.

percentage of income as tax. A point of interest for transportation financing is the degree to which it is progressive like this.

2 Who Pays Governmental Costs?

The governmental costs of transportation are paid for through a number of user fees and general taxes that are difficult to disentangle. Determining who pays these costs is difficult because of the complexity of tax laws and because the area we are examining contains many overlapping levels of government. Expenditures for transportation are made by the federal government, the states of Minnesota and Wisconsin, 19 counties, and many more municipalities. The costs paid by a particular household will vary depending on travel behavior (through user fees) and on income and location (mostly through general tax mechanisms).

We determine who bears governmental costs in two steps. First, we determine who pays the most important transportation user fees—fuel taxes and vehicle registration fees. Second, we determine where the funds for transportation expenditures not paid for by user fees come from.

We do not attempt to determine who imposes governmental costs, only who pays these costs. This is because most governmental costs are fixed in the short run. Driving a few extra miles imposes almost no extra governmental costs in the short run.[10] In the long run, travelers are responsible for the costs of transportation, but there is no generally accepted method for apportioning fixed costs to user groups.[11] Even many costs that are not fixed, such as expenditures on Highway Patrol, can be difficult to apportion.[12]

We also do not attempt to determine the sub-regions in which government spending on transportation occurs. Such spending often varies greatly from year to year. One large road-building project, for example, could make it appear that a sub-region was receiving a disproportionate share of government funding. Even if we knew where spending occurred, however, benefits are not necessarily tied to the location of spending. A freeway expansion in Minneapolis, for example, might be opposed by neighbors and most residents of the city, and might primarily benefit people who live in other parts of the region.

The results in this section rely heavily on previous work, especially Anderson and McCullough (2000) and the work that has been done by Barry Ryan and Thomas Stinson for Part IV of the Transportation and Regional Growth Study.

The total governmental costs of transportation are summarized in Table 2.1. The table shows the midrange estimate of the annualized costs of each item in the

[10] An exception is the case of heavy commercial vehicles. They can damage roads, thus imposing costs that vary with road use in the short run. Newbery (1988) examines these costs.
[11] The Federal Highway Cost Allocation Study, FHWA (1997), presents one approach to this problem, but there are also other potential methods of assigning cost responsibility.
[12] Highway patrol expenditures appear to be subject to increasing returns. This means that that an increase in vehicle travel requires a less than proportionate increase in expenditures on highway patrol. Fixed costs are a special case of increasing returns and, the presence of increasing returns leads to allocation problems that are similar to the problems associated with fixed costs.

19-county region. It is taken from Table 4.6 of Anderson and McCullough (2000). The largest share of these costs is for streets and highways, but significant spending also occurs on transit, law enforcement and safety, environmental cleanup, energy security, and parking and drives.

Table 2.1: Annual Governmental Costs of Transportation

Cost Items	Total Spending (Millions of 1998 Dollars) 1998	2020
Streets and Highways	1,535	2,195
Transit	260	415
Law enforcement and safety	315	565
Environmental cleanup	105	165
Energy security	69	115
Parking and drives	270	415
Costs to other agencies	3	4
Total Costs	2,560	3,870

2.1 Who Provides the User Fees to Pay Governmental Costs?

The two most important types of transportation user fees in Minnesota are the vehicle registration fees and fuel taxes. The charge for registering a new vehicle in Minnesota in 1998 was $10 plus 1.25 percent of the vehicle's suggested retail price. The charge for registering a vehicle that is not new declines as the vehicle ages, and is fixed at $35 for vehicles ten or more years old.

We estimate that $238 million in vehicle registration fees were collected in the region in 1998. This estimate was produced using county-level data from the Minnesota Department of Revenue and includes the revenue collected from passenger cars and pick-up trucks, but not from commercial trucks. We assume that the fees levied on commercial trucks are passed on to consumers, but not necessarily by county of origin.[13] The $238 million also includes approximately $4 million in registration fees paid to the State of Wisconsin (Wisconsin levies a flat $45 vehicle registration fee). Within the TCMA, payments of vehicle registration fees were calculated for smaller sub-regions based on the level of auto ownership (Table 2.4), adjusted so that county totals come out correctly.

Fuel taxes are calculated by assuming that (i) the only type of fuel consumed by private passenger vehicles is gasoline, (ii) fuel consumption is proportional to vehicle hours of travel, and (iii) people buy fuel in their state of residence. The excise tax on gasoline in 1998 was $0.383 in Minnesota (of which $0.20 is levied by the state) and $0.447 in Wisconsin (of which $0.264 was levied by the

[13] For simplicity, the costs to households of business taxes are included with sales and income taxes.

state). We estimate that the residents of the region paid $610 million in fuel taxes in 1998.

We project revenues in 2020 by assuming that fees will grow at the same rate as regional income. This assumption is made because other types of government fees have grown with personal income.[14] Vehicle registration fees in Minnesota, however, were restructured in 2000, so we adjust these fees to reflect the approximately 25 percent reduction in total revenues that these changes have caused. We project that revenue from vehicle registration fees will rise to only $262 million in 2020, and that revenue from fuel taxes will rise to $1,052 million in 2020.

We do not consider vehicle sales taxes to be transportation user fees. In Minnesota, part of the sales taxes raised on motor vehicles is dedicated to transportation projects. We consider the vehicle sales tax to be a source of general revenue, however, because vehicle sales are taxed by the state at the same 6.5 percent rate as most other goods and services.

2.2 Who Provides the General Revenues Used to Pay Governmental Costs?

A great deal of general revenue is used to pay the governmental costs of transportation. Comparing the totals collected from the user fees above to the total governmental costs of transportation, one finds that user fees only pay approximately one-third of total costs. We feel that the difference between user fees and governmental costs may be somewhat exaggerated, however. There are three reasons for this. First, some user fees are not included above. Especially important are the fees paid by commercial vehicles. In addition, there are also some smaller sources of revenue such as driver's license fees. Second, some local roads are paid for with property taxes and there may be good to have property owners pay at least some of the costs of local road through property taxes.[15] Third, we take a very broad view of the governmental costs of transportation, and the connection between certain types of general revenues and the broad range of governmental costs we examine has not been well studied.

While we may underestimate the share of governmental costs of transportation that are paid for with user fees, we do not attempt to make a more accurate estimate of the share of costs paid for by user fees. The reason is that our primary purpose is to calculate the distribution of governmental costs across sub-regions and income groups, and not to determine the absolute size of these costs.

We used the *1999 Minnesota Tax Incidence Study* (Department of Revenue, 1999) to estimate who pays the general (not transportation-based) revenues that are used for transportation. We ignore the portion of general revenues used for transportation that are collected by the State of Wisconsin and the federal

[14] See Section 4.1 of Anderson and McCullough (2000).

[15] It might make sense to charge property owners for some of the costs of local roads because (i) all owners need some access to their property, (ii) it might be difficult technologically to develop a good system for collecting user fees, and (iii) it might be difficult politically to develop a good system for distributing user fee revenues.

government.[16] We also ignore differences in property taxes and assessments set by local governments. There are many local governments in our region. Short of examining the budget of each in detail, there is no way to determine the portion of their revenues that each pays for the wide range of transportation-related goods and services that we examine. We use work by Barry Ryan and Thomas Stinson to estimate the total amount of property tax that is spent on transportation. We assume any remaining shortfall is covered by revenue from state income and sales taxes. Payments are estimated for each sub-region by using Department of Revenue data on the incidence of each tax. Overall, payments of income and sales taxes vary in important ways with income (income taxes are fairly progressive and sales taxes are somewhat regressive). Because of this, we assume that payments of these taxes by people in different sub-regions vary depending on income.

2.3 The Incidence of Governmental Costs by Income Group

We determined the incidence of governmental costs by income group by (i) comparing average income in each sub-region to payments of vehicle registration fees and fuel excise taxes and (ii) using data from the Minnesota Department of Revenue to determine the incidence of property, income, and sales taxes. We had limited data for our calculations of the incidence of user fee payments by the highest two income groups. Because of this, we estimated the incidence for these groups by interpolating from the payments of the other groups.

The incidence of governmental costs for each income/vehicle ownership group is shown in Table 2.2. Overall, payments appear to be somewhat regressive. In particular, the fuel tax is fairly regressive, and it is large enough that it outweighs the progressive effects of the income tax.

[16] Only three of the 78 sub-regions we examine are in Wisconsin. Federal spending on transportation is, for the most part, paid for with revenues from fuel taxes. Some general revenues from the federal government probably are used for transportation, but (i) the amount of these revenues used for transportation is fairly small and (ii) at times fuel taxes have been used to supplement general revenues.

Table 2.2: Percentage of Income Paid to Cover the Governmental Costs of Transportation					
Group	Veh. Reg.	Fuel Tax	Property	Income/Sales	Total
Less than $15,000, no vehicle	0.00	0.00	0.38	0.97	1.35
Less than $15,000, vehicle	0.59	0.95	0.38	0.97	2.89
$15,000 to $25,000, no vehicle	0.00	0.00	0.29	1.11	1.39
$15,000 to $25,000, vehicle	0.36	0.82	0.29	1.11	2.57
$25,000 to $35,000	0.23	0.69	0.31	1.19	2.42
$35,000 to $45,000	0.22	0.53	0.31	1.22	2.27
$45,000 to $55,000	0.18	0.51	0.29	1.27	2.23
$55,000 to $75,000	0.12	0.32	0.28	1.33	2.06
More than $75,000	0.06	0.15	0.25	1.39	1.85
Average	0.26	0.66	0.28	1.28	2.48

2.4 The Incidence of Governmental Costs by Geographic Sub-region

Table 2.3 summarizes the average total per capita payments of government costs by three major geographic areas in 1998. In general, geographic variations in these costs occur only as a side effect of geographic variations in income levels.

Table 2.3: Per Capita Annual Governmental Costs of Transportation by Major Geographic Areas				
Group	Veh. Reg.	Fuel Tax	Other	Total
Central Cities	74	136	487	709
Other TCMA	86	219	638	940
Outlying Counties	66	222	395	683
Average	79	201	564	844

In this table property taxes and income/sales taxes are not broken out separately. While it is possible to ascertain totals for these taxes, and assign them to income levels with reasonable assumptions, it is not possible to assign them to specific geographic locations without knowing the property tax levels of every municipality. We did not examine government costs at this level of detail.

As expected, the suburban counties have the highest per capita governmental costs because they have the highest incomes and hence own the most vehicles, buy the most fuel, and pay the highest taxes in general. However, there is a surprise in that the central cities pay higher governmental costs per capita than do the outlying counties, despite their relatively low rates of auto ownership. Part of this has to do with higher property taxes, and with higher income and sales taxes as the average income is slightly higher in the central cities. This explains the difference in the “Other” column. For fuel tax payments the cities come out much lower, as expected. There is, however, a mystery in why the cities have higher auto registration costs.

Our best guess on the cause of this unexpected result is that the registration costs for the central cities probably include significant costs incurred by corporate and rental fleets. The information used in generating these numbers was total vehicle registration payments by county; there was no way of knowing whether these registrations were initiated by individuals or companies. Since car ownership per capita is known to be lower in the central cities, the only explanation we can think of for why total registrations would be high is corporate and rental fleets.

Table B.4 in Appendix B shows total per capita governmental costs broken down by the 78 sub-regions for 1998 and 2020. There is significant variability in some of these costs, but the variability does not seem unreasonably large given the differences in income and driving habits of the people in the different sub-regions. Some of the variability is probably accounted for by limitations in our data, however.

3 Who Pays Internal Costs?

The internal costs of transportation are those borne by the people who cause them. This means that the internal costs that one pays for (or experiences) are equal to the internal costs that one produces by definition. Because of this, internal costs do not usually generate significant equity or efficiency concerns. This does not mean that internal costs should be neglected, however. One reason is that governmental policies may lead to changes in internal costs that should be considered in decision-making. Because internal costs are so large, these changes may be more important than changes in governmental or external costs. A second reason for examining internal costs is to help inform individuals of the full costs they actually pay. It is possible that many people do not realize how much transportation costs them, and would make better decisions if they had better information. A third reason for calculating internal costs is that people are likely to respond to policies differently depending on the size of the internal costs that they pay.

Table 3.1 summarizes the total internal costs of transportation in the region. It is taken from Table 5.7 in Anderson and McCullough (2000). Fixed vehicle costs, those costs of vehicle ownership that do not vary with travel, are particularly large. Time costs are also very large. The other major categories of costs are variable vehicle costs, the costs of crashes, and the costs of parking and driveways and private roads.

Table 3.1: Annual Internal Costs of Transportation

	Total Costs (Millions of 1998 Dollars)	
Cost Items	1998	2020
Fixed Vehicle	6,450	9,000
Variable Vehicle	2,700	4,600
Transit Fares	55	80
Parking and Driveways	2,040	3,165
Total Monetary	11,245	16,845
Transit Time	165	285
Travel Time	8,910	14,440
Other Time	1,240	1,480
Crashes	1,365	2,005
Total Non-monetary	11,680	18,210
Total	22,925	35,055

We will not attempt to determine the short run marginal internal costs of transportation. This information is useful for predicting how people might respond to policy changes; however, it is not very useful for examining transportation equity. When short run marginal cost information is needed, it seldom is useful to aggregate it by sub-region or income group.

We also do not address the question of whether particular forms of land development lead to variations in internal costs. Some believe that low-density development forces households to own more cars, and to drive them more. While this possibility cannot be discounted, there are no data available that could make it possible to answer this question. There are also very difficult conceptual issues of what expenses are "necessary" and what are voluntary. To study this issue adequately would be a significant research project in its own right.

3.1 Fixed Vehicle Costs

The Census Bureau's Consumer Expenditure Survey contains information on transportation expenditures for people in different income groups. The results of the 1998 Consumer Expenditure Survey for the United States as a whole are shown in Table 3.2. The table shows total expenditures on various transportation services, as well as the percent of income spend on categories of fixed and variable vehicle costs.

We allocate all fixed vehicle costs based on how they vary with income in Table 3.2. The table shows that these costs fall fairly rapidly as a share of income as income rises. Note that costs are adjusted for the effects of vehicle ownership, so that those households without vehicles do not bear any fixed vehicle costs. When projecting costs in 2020, we assume, as was done in Anderson and McCullough (2000), that income will rise at the same rate in all sub-regions from 1998 and 2020. We assume that vehicle ownership rates will change over time based as shown in Table B.2 in Appendix B.[17]

For the purpose of allocating fixed vehicle costs in the region, we divide fixed vehicle costs into two types: those incurred by individuals and those incurred by businesses. The way we apportion costs borne by businesses is discussed in Section 3.4. Individuals in the region incurred costs of $4.95 billion in 1998 and are projected to incur costs of $6.85 billion in 2020. We also add in the costs of residential parking and driveways to apportion them to individuals based on region.[18] These costs were $350 million and $585 million in 1998 and 2020, respectively. We allocate all of these costs based on the relative income of households with vehicles.

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[17] The table was constructed by assuming that vehicle ownership rates would stay the same over time for households with the same income, and that ownership rates will rise as the general level os income rises.

[18] Apportioning based on vehicle ownership and income seems a plausible method of assigning these costs, but ideally one would account for differences in property values between different parts of the region. Unfortunately, not much information on the property value of garages and driveways is available.

Table 3.2: Annual Transportation Expenditures in 1998 by Household Income Quintile (United States Averages)						
	Lowest 20	20 to 40	40 to 60	60 to 80	Top 20	All
Average Before Tax Income	7,264	18,033	31,876	52,331	110,105	43,951
Vehicle purchases	1,218	2,277	2,899	4,346	6,287	3,305
Gasoline and motor oil	505	759	1,079	1,350	1,661	1,055
Vehicle finance charges	88	166	319	490	583	320
Maintenance and repairs	350	515	659	838	1,190	664
Vehicle insurance	323	552	757	964	1,308	756
Vehicle rental, leases, other	143	227	384	606	1,210	513
Public transportation	164	255	286	403	931	397
Total Transport Expenses	2,791	4,751	6,383	8,997	13,170	7,010
	Percent of Income for Fixed Costs					
Vehicle purchases	16.77	12.63	9.09	8.30	5.71	7.52
Vehicle finance charges	1.21	0.92	1.00	0.94	0.53	0.73
Vehicle insurance	4.45	3.06	2.37	1.84	1.19	1.72
Vehicle rental, leases, other	1.97	1.26	1.20	1.16	1.10	1.17
Total Fixed Vehicle Costs	24.39	17.87	13.67	12.24	8.53	11.14
	Percent of Income for Variable Costs					
Gasoline and motor oil	6.95	4.21	3.38	2.58	1.51	2.40
Maintenance and repairs	4.82	2.86	2.07	1.60	1.08	1.51
Total Variable Vehicle Costs	11.77	7.06	5.45	4.18	2.59	3.91

3.2 Fuel, Oil, and Maintenance Costs

The costs of fuel, oil, and maintenance accounted for $3.15 billion in 1998 and $4.35 billion in 2020. It was estimated that ten percent of these costs were incurred by businesses, and these will be allocated with other costs to businesses discussed below.

We assign the costs that individuals incur for fuel, oil, and maintenance based on vehicle hours of travel. It also would be reasonable to assign these costs based on vehicle miles of travel, but we feel that using vehicle hours of travel provides a better overall proxy for fuel use. In particular, vehicle hours of travel help us to account for the higher maintenance costs and lower fuel consumption on city streets. Table B.3 in Appendix B shows estimated and projected annual vehicle hours, personal hours, and vehicle miles of travel for 1998 and 2020 by sub-region. These estimates are based on the 1990 Travel Behavior inventory. Projections were made by assuming that travel will increase by the same aggregate rate in all parts of the region.[19]

[19] For more information on how these assumptions about aggregate travel behavior were made, see Section 3.3.4 of Anderson and McCullough (2000).

One additional, rather small monetary cost that varies with travel is the cost of parking. We estimate that this cost amounted to $90 million in the region in 1998 and will rise to $150 million in 2020. Most of these fees are incurred in the central business districts. We apportion them based on the share of trips taken to the central cities.

Like fixed vehicle costs, it appears that variable vehicle costs fall significantly as a share of income as income rises. We base our estimates for expenditures across income groups on the 1998 Consumer Expenditure Survey. When making projections for 2020, we assume that expenditures will remain constant for any given real income level. As general income levels rise, therefore, overall expenditures will fall slightly as a share of income, since expenditure shares are lower at higher income levels.

3.3 Other Internal Costs Not Borne by Businesses

The internal costs of time account for a large share of the total costs of travel. We apportion these based on hours of travel, for which data are available in the 1990 TBI and in Anderson and McCullough (2000). While apportioning time costs based on average income is a standard economic practice; we do not do this here. We assign the same value of time to all residents regardless of income. The reason is that we are trying to understand how these costs vary across different groups. If we allowed time costs to vary not just by the amount of time spent traveling, but also by assigning different values to different people, it would be impossible to tell "true" variations in time from "artificial" variations in value. We take the same approach for other non-monetary costs as well; for example, we assume all people place the same value on avoiding a particular type of crash or a particular amount of noise.

One implication of this assumption is that time costs do not vary by income level. Time spent traveling per day is nearly constant across many population groups.[20] While there are variations from the average, especially in the lowest income levels, these variations are small enough that we ignore them here.

The internal costs of transit account for a relatively small share of total internal costs. They equal $220 million in 1998 and $365 million in 2020, which is slightly more than one percent of the total internal cost of travel. Because they are so small, we simply assign them based on population. Note that the 1998 Consumer Expenditure Survey suggests that transit costs are approximately proportional to income. However, most of the transit costs for higher-income people are probably for air travel (which we do not examine in this study) and not for bus transit.

Crashes account for a significant share of the internal costs of transportation. We apportion all of the costs of pedestrian and cyclist crashes to individuals. For other crashes we assume that 90 percent of costs accrue to individuals and ten

[20] Barnes and Davis (2001).

percent to firms.[21] We use 1996 data on the costs of crashes by county to estimate the share of all internal crash costs that occur in each county. For TCMA counties, we allocate costs across sub-regions on a per person basis. While other plausible methods of allocating these costs could be devised, for example by person-hours of travel, we feel that on the whole it probably makes the most sense to allocate costs on a per person basis. The reason is that this helps adjust for the fact that poorer people, while less likely to travel long distances in vehicles, are more likely to involved in crashes as pedestrians or cyclists and are more likely to drive vehicles that are not particularly safe.

We do not have detailed data on the costs of crashes across income groups. We do have data on the county where each crash is located. We assume, as we do when we calculate the external costs of crashes, that crash costs are distributed uniformly across household by the county where the crash occurs. We assume, based on Anderson and McCullough (2000), that people who do not own vehicles bear 40 percent of the costs of pedestrian and bicycle crashes. Given these assumptions about the distribution of crash costs, we determine the incidence of crashes with respect to income based on the variability of crash rates and incomes across counties. We calculate only the non-monetary costs of crashes for incidence purposes because we assume that the monetary costs are covered by insurance and therefore appear as fixed vehicle costs. We use Miller's estimate that 65 percent of crash costs are non-monetary.[22]

3.4 Internal Costs Borne by Businesses

Businesses incur a large share of the internal costs of transportation. Eventually these costs are borne by individuals through higher costs for the goods and services that businesses sell. Different types of businesses use transportation in different amounts, but we feel that on average the total value of goods and services that people in different income groups and sub-regions purchase will be roughly proportional to the transportation costs incurred by the producers. For this reason we allocate the transportation costs of businesses based on shares of regional income.

Internal costs to businesses show up in all of the categories in Table 3.1 except for the transit categories. We estimate that businesses incur ten percent of variable vehicle costs and of travel time. We assume they do not incur any of the costs in the "other time" category. These are non-monetary costs such as time spent filling a car with fuel or time spent maintaining vehicles. We also assume that businesses incur ten percent of crash costs, except for crashes involving pedestrians and bicyclists. The fixed costs of business fleet overhead in the region in 1998 and 2020 are estimated to be \$1.50 and \$2.15 billion, respectively.[23] Businesses are also assumed to bear \$1.60 billion in 1998 and \$2.43 billion in 2020 in costs for parking lots, roads, and driveways.[24] We

[21] This is consistent with the assumptions made in Section 5 of Anderson and McCullough (2000).
[22] See Miller (1997).
[23] See Table 5.3 in Anderson and McCullough (2000).
[24] Households bear most of the remaining parking costs. These costs are those of driveways and garages.

calculate that the total transportation costs to businesses were $4.38 billion in 1998 and will be $6.65 billion in 2020.

3.5 The Incidence of Internal Costs by Income Group

We used data from the Consumer Expenditure Survey to estimate the incidence of fixed and variable vehicle costs. We interpolated the data to estimate the shares of income spent by income groups that did not match up with the Consumer Expenditure Survey data. We assumed that costs paid by businesses were borne by users as a proportion of 4.8 percent of income. We know of no reason that goods and services consumed by lower-income people would be more or less transportation-intensive than goods and services consumed by higher-income people. The calculation of the incidence of internal, non-monetary crash costs by income/vehicle ownership group was discussed in Section 3.3.

Incidence by income/vehicle ownership group is summarized in Table 3.3. Overall, the share of income spent on transportation falls steadily as income rises. We assume that people without vehicles have the same travel time costs as other people, and that they just use other modes. We also assume that people without vehicles pay the same amount as others do for business-related transportation costs. (Note that Table 3.3 does not include time or business costs as these are assumed to be the same for all income levels. The monetary total includes business costs implicitly.) The burdens of the fixed costs of vehicle ownership and the non-monetary costs of crashes appear to be quite regressive, although people who do not own vehicles may be able to avoid a significant share of the costs of crashes.[25] The burden of variable vehicle costs appears to be the most regressive. This is not surprising, given the desire of people for mobility and the difficulty of avoiding major variable costs such as the costs of fuel, oil, and vehicle maintenance.

[25] This conclusion should be taken as tentative because we have not done a thorough analysis of the distribution of pedestrian and bicyclist crashes with respect of vehicle ownership. It was derived from our assumption about aggregate relationships.

Table 3.3: Internal Monetary Costs of Transportation as a Percent of Income, (business costs are 4.78% for all groups)			
Group	Fixed Vehicle	Variable Vehicle	Total Monetary
Less than $15,000, no vehicle	0.00	0.00	4.78
Less than $15,000, vehicle	24.39	11.77	40.94
$15,000 to $25,000, no vehicle	0.00	0.00	4.78
$15,000 to $25,000, vehicle	17.87	7.06	29.71
$25,000 to $35,000	13.67	5.45	23.9
$35,000 to $45,000	12.96	4.82	22.56
$45,000 to $55,000	12.24	4.18	21.2
$55,000 to $75,000	10.81	2.91	18.5
More than $75,000	8.53	2.59	15.9
Average	11.14	3.91	19.83

The internal monetary costs of transit are not shown in Table 3.3. These costs are small in proportion to the total internal costs of transportation, but they may be significant for some groups and especially for people who do not own vehicles.

It is worth noting that while households that do not own vehicles incur low monetary transportation costs, they still incur relatively high costs in terms of lost accessibility. People spend money on transportation because they want to reach destinations such as jobs or shopping; the high value of this access can be deduced from the fact that very few households who can afford a vehicle do not own one. People who do not own cars incur much higher time costs for the trips they make; because of this they make far fewer trips on average, and so effectively lose access to many desirable destinations. These implicit costs are not counted here.

3.6 Summary of Internal Costs by Geographic Sub-region

Table 3.4 summarizes the average total annual per capita payments of internal costs by three major geographic areas in 1998. With the exception of travel time, which is higher farther from the center of the region, geographic variations in these costs occur only as a side effect of geographic variations in income levels.

Table 3.4: Per Capita Annual Internal Costs of Transportation by Major Geographic Areas

	Fixed Vehicle	Variable Vehicle	Time (non-mon.)	Business	Total Monetary
Central Cities	1,362	1,019	2,864	1,252	3,633
Other TCMA	2,060	1,321	3,069	1,638	5,020
Outlying Counties	1,136	1,572	3,273	1,014	3,722
Average	1,751	1,299	3,059	1,448	4,497

These costs mostly vary in expected ways. Variable vehicle costs and time costs are lower in the center and higher at the edge, reflecting differences in the average per capita amount of driving. Business costs reflect average income levels in the areas. The only surprise is that fixed vehicle costs are higher in the central cities than in the outlying counties, even though auto ownership rates are lower. As with auto registration costs, this is probably because the method used to calculate these costs did not exclude corporate and rental vehicles.

Table B.5 in Appendix B shows these costs for each of the 78 sub-regions for 1998. Table B.6 shows the same types of costs for 2020. These differ only in that population and income patterns will be different in 2020 than 1998.

The sub-regions that we examine are small enough that variability in underlying data may exaggerate differences. It is possible, for example, that our estimate of the amount of auto travel in one sub-region is ten or twenty percent higher than actual travel, because survey data on travel in the sub-region is not representative. This would make our estimates of variable vehicle costs in the sub-region ten or twenty percent higher than they actually are. For this reason, our data are more useful for identifying patterns across groups of sub-regions, than for estimating the costs in any particular sub-region.

4 Who Bears and Imposes the External Costs of Transportation?

Determining who experiences and produces the external costs of transportation is important for both equity and efficiency reasons. The external costs that a person bears can differ greatly from the costs that the person imposes. One might produce a great deal of air pollution, for example, but experience very little of it.

The total external costs of transportation are shown in Table 4.1.[26] The largest costs are those of congestion, crashes, air pollution, and petroleum consumption. The main external costs of air pollution are damage to health and damage caused by global warming. Petroleum consumption externalities include the effects that higher consumption tends to have by driving up the price of crude oil and making the economy more vulnerable to oil price shocks. Most of the costs in Table 4.1 are expected to grow by approximately fifty percent between 1998 and 2020, but the costs of congestion are expected to grow by approximately 300 percent. Note that while these costs are expressed in terms of dollar equivalents, they are all non-monetary costs.

Table 4.1: Annual External Costs of Transportation
(Millions of 1998 Dollars)

Cost Items	1998	2020
Congestion	302	1,043
Crashes	222	336
Air Pollution (Health)	725	798
Air Pollution (Other)	273	357
Noise	16	25
Fires and Robberies	24	32
Petroleum Consumption	295	353
Total	1,857	2,944

To determine who bears and imposes the external costs of transportation we examine the travel of people from different sub-regions. This is done using the Metropolitan Council's models of the Twin Cities' transportation network. We use these models to determine when, where, and how much people from each group travel.

One difference between external costs and other cost calculations is that some external costs are imposed outside of the region. Most of the costs of global warming and petroleum externalities, for example, are imposed on people

[26] These numbers are taken from Table 6.14 in Anderson and McCullough (2000).

outside of this region.[27] Because of this, the total costs imposed are not equal to the total costs borne. To clarify how costs are allocated within the region, we break costs imposed outside into a different category. For the remaining costs, the total borne will equal the total imposed, and so differences in who imposes and bears costs will be more apparent. We do not analyze the costs imposed by people outside of this region on the people in this region because our original study of these costs examined only costs produced by residents of the region.

4.1 Allocating External Costs

Determining who bears, and especially who imposes, external costs is more complicated than determining who bears governmental or internal costs. The reason is that, for governmental and internal costs, costs depend primarily on the aggregate behavior of a group of people who live in a certain location, and whose expenditures can be tracked or estimated directly. For external costs, however, we need to know where people travel so that we can track where they impose certain types of costs, which in turn will affect how big those costs are. For example, a mile of driving in the central cities will generate higher pollution costs because more people are exposed to the pollution that is produced there.

Determining the impact of travel on sub-regions is relatively straightforward because we have good information about the transportation network and travel on the network. We calculate vehicle miles of travel, vehicle hours of travel, and congestion in each of the 66 sub-regions in the Twin Cities Metropolitan Area. These calculations are made by determining the sub-region where each part of the network is located. The network that we use was produced by the Metropolitan Council for predicting travel behavior in the Twin Cities Region. The network is quite detailed, being composed of approximately 20,000 "links" or road segments, and it produced good aggregate estimates of travel within and across sub-regions. After we match travel network links to sub-regions, we can summarize the characteristics of travel in each sub-region.

Determining the impact of people in one sub-region on people in other sub-regions is complicated because it requires keeping track of more information than was required for other calculations. Instead of needing to know, for example, the total vehicle hours of travel in a particular sub-region, one needs to know the amount of travel that people from each of the other sub-regions did in that sub-region. To summarize these impacts, we have constructed matrices for peak hour trips and for all trips. The matrices were made by examining all of the trips taken by the people in each sub-region, and determining which other sub-regions they were likely to pass through in making each trip.

4.2 Congestion Costs

We apportion congestion costs among travelers based on the Metropolitan Council's travel demand models and the congestion estimates of Anderson and

[27] Most of the costs of global warming experienced here are due to the actions of people outside of this region, however.

McCullough (2000). The costs borne by travelers are calculated as the difference between the time cost of travel on congested roads and what that time cost would be under free-flow conditions. We assume that all travelers place the same value on time spent in congestion; that is, we do not assign a higher time value to high-income people. This is consistent with the way we calculated internal time costs, and with the way we value other external non-monetary costs.

Congestion costs are apportioned based on the sub-regions where congestion occurs and the sub-regions where people travel. We assume that people do not experience congestion when they make trips within sub-regions; such trips will mostly be made on minor roads that are relatively uncongested. We estimate that the total costs of congestion were $332 million in 1998 and will be $1,147 million in 2020. Of these costs, $37 million and $128 million are borne by businesses in 1998 and 2020 respectively.[28]

Figure 4.1 shows the per capita congestion costs experienced by people in different sub-regions. Surprisingly, average congestion is low for some people in sub-regions in the center of the region. This is probably because these people have lower car ownership on average, and because they have greater transit options available, even for those households that own cars.

4.3 Air Pollution Costs

We base our estimates of air pollution costs on Anderson and McCullough (2000), and these in turn were based largely on Delucchi (1996). Delucchi ran simulations to determine the effects of changing levels of emissions on the health costs of air pollution. He concluded that costs varied almost linearly with emissions. This greatly simplifies our analysis, because it means that it is reasonable to assume that the only thing that matters in determining the cost of a unit of emissions is the density of people in the sub-region where the pollution occurs. The total level of emissions in a sub-region does not affect the cost per unit of emissions (although obviously it affects the total costs). While it seems reasonable that higher levels of emissions would lead to relatively higher costs per unit, Delucchi’s work suggests that any such effect is not terribly large.

[28] See Table 6.3 in Anderson and McCullough (2000).

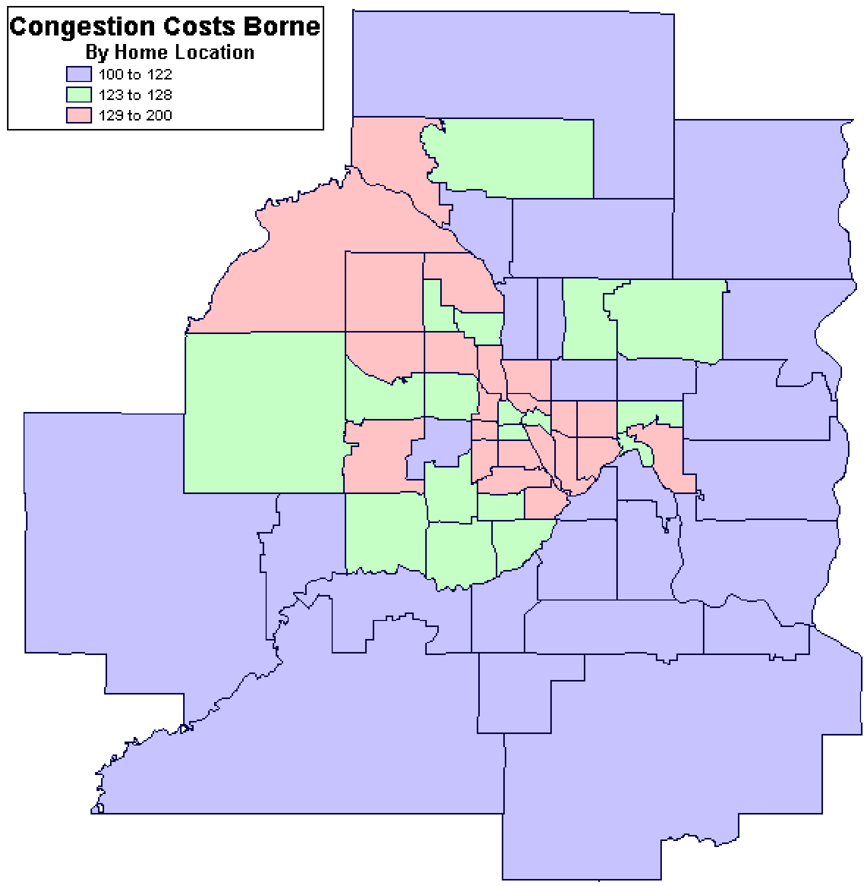

Figure 4.1: Annual Per Capita Congestion Costs Experienced by the Residents of Various Sub-Regions in 1998

Given the simplifying assumptions just discussed, we calculate the health costs of air pollution borne by people in different sub-regions based their relative exposure to vehicle hours of travel. We feel that vehicle hours of travel (VHT) is more closely related to emissions than vehicle miles of travel (VMT), because VHT helps account for the higher rates of fuel consumption, but relatively low VMT, experienced on city streets. We assume that emissions cause health damage only in the sub-region they are produced. This ignores the way that emissions disperse, but we feel it is a reasonable way to estimate costs, as generally the highest concentrations occur closest to the point of emission.

We divide the costs of air pollution into six types: effects on health, global warming, visibility, crops, materials, and forests. We assume that the effects of visibility and materials are distributed in the same way that the effects on health are. Global warming is unusual in that most of its costs are imposed outside of this region. This means that where one travels does not matter in determining the costs of global warming, and the only thing that matters is total VHT. Two relatively small costs, damage to crops and forests, are mainly imposed outside of this region. Somewhat arbitrarily, we assume that 90 percent of these costs are imposed outside of the region.

We also calculate noise costs with air pollution costs. Noise costs are quite small; they are only one or two percent of air pollution costs. Because they are so small, and because they also seem likely to vary with vehicle hours traveled, we treat noises costs in the same way as the health effects of air pollution. Figure 4.2 shows our estimate of the per capita health costs of pollution borne by the residents of various sub-regions in the Twin Cities Metropolitan Area. Pollution costs rise in almost all cases as we move towards the center of the region, with the exception of the sub-regions containing the two airports, where little surface transportation occurs. Note that our estimates of the total costs of air pollution are quite uncertain.

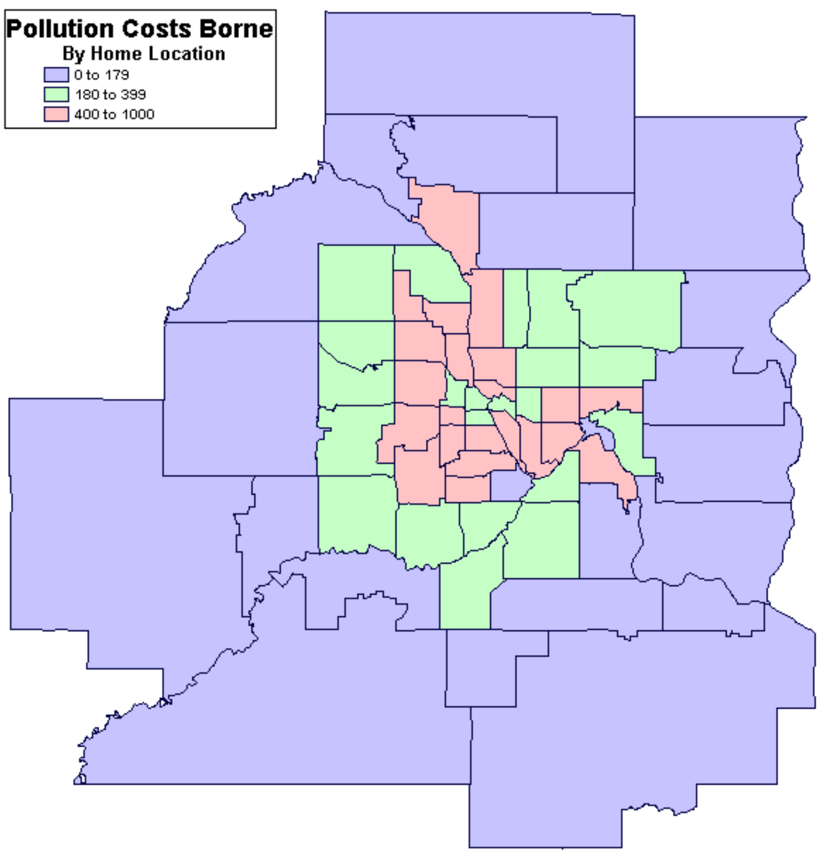

Figure 4.2: Estimate of the Annual Per Capita Costs of Pollution Suffered in 1998

The pollution costs that people impose are calculated by determining the number of vehicle hours that people drive in a given zone, then apportioning the total costs borne by that zone among the people in the region, proportional to the amount that they drive in that zone. Figure 4.3 shows the pollution imposed by people from different parts of the region. It is perhaps surprising that central city residents impose fairly high pollution costs even though they drive less than residents of outlying areas. This is because central city residents do a much higher fraction of their driving in densely populated areas, where each unit of pollution creates higher costs because more people are exposed to it. Some pollution costs, such as global warming, are imposed outside the region; these are not included here.

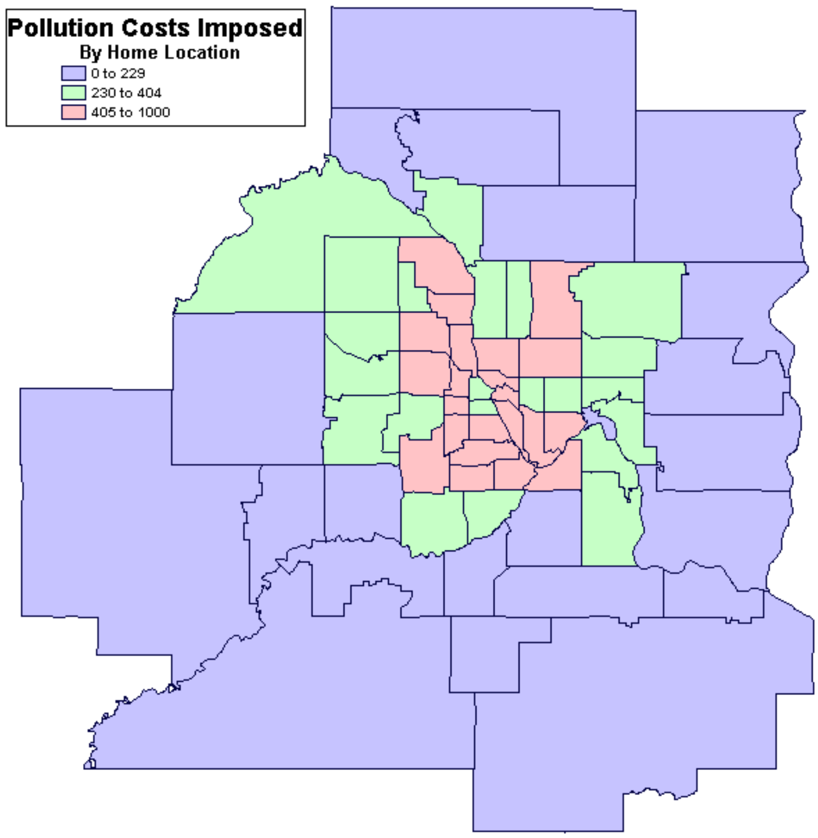

Figure 4.3: Estimate of the Annual Per Capita Costs of Pollution Imposed in 1998

4.4 Crash Costs

The costs of crashes account for a significant share of the external costs of transportation. The internal costs of crashes were discussed in some detail in Section 3.3, and we use the same approach used there to allocate these costs. External crash costs, while problematic from a methodological point of view, do not seem to present special problems in being apportioned. We only have data on crashes by the county in which the crash occurs. We assume, therefore, that most crash costs are borne and imposed by the people in the county where the crash occurs.

4.5 Other External Costs of Transportation

In addition to the costs discussed above, we also calculate the costs of petroleum consumption, the costs of vehicle fires, and the costs of vehicle robberies. The costs of fires and robberies are quite small, and we simply apportion them on a per capita basis.

The costs of petroleum consumption are due to two factors. The first is that higher consumption tends to drive up the price of crude oil. The second is that higher consumption makes the economy more vulnerable to oil price shocks. Both of these costs are difficult to measure and somewhat controversial.[29] In addition, both affect the U.S. economy as a whole, and so have little direct impact on people in this region. Because this region accounts for approximately one percent of U.S. Gross Domestic Product, we assume that the costs borne by people in this region are one percent of these total costs. Costs imposed are assumed to be equal to total costs. We allocate costs based on vehicle hours of travel because, as was discussed previously, vehicle hours of travel seems likely to be a good predictor of fuel consumption.

4.6 The Incidence of External Costs by Income Group

To calculate the incidence of external costs by income group would require determining the number of people of each income level in each sub-region, then allocating the costs incurred by each sub-region among the different income levels. The data that would be needed to do this were not easily available at the time of this analysis. Thus we do not have precise figures of costs by income level. We can make some general statements based on where people of different income levels are known to live.

For external costs of transportation, the general trends are that congestion costs rise with income and pollution costs fall. The higher pollution costs for low income people are a reflection of the fact that they are disproportionately likely to live in the central cities. The presence of higher congestion costs for higher income people probably happens both because they drive more, and because the generally suburban nature of their home and work locations usually precludes the use of transit or other non-auto modes.

4.7 Summary of External Costs Borne and Imposed by Geographic Sub-Region

Table 4.2 summarizes the incidence of the external costs of transportation by three major areas for 1998. Tables B.7 and B.8 in Appendix B show the incidence by geographic sub-region for 1998 and 2020, respectively. The tables show the costs of congestion, the costs of air pollution (both borne and imposed since these are not the same for each sub-region), the costs of crashes and other costs internal to the region, and costs imposed outside the region.

[29] They are discussed in more detail in Section 6.5 of Anderson and McCullough (2000).

Table 4.2: The Annual Per Capita Cost of Transportation (External) in 1998 (1998 Dollars)					
Region	Congestion	Pollution Borne	Pollution Imposed	Other	Imposed outside region
Minneapolis & St. Paul	136	571	511	91	100
Other TCMA	123	264	261	78	161
Outlying Counties	82	12	98	91	157
Average	118	288	288	83	147

These tables show a great deal of variation in costs borne, especially for the costs of pollution. The large differences in pollution costs borne are not surprising, because the density of travel in some sub-regions is much greater than it is in others. The lack of variation in congestion costs with respect to density is not surprising because people in outlying areas generally have to drive longer distances than people who are nearer to the city centers do. These longer drives increase their congestion costs, even though the areas where they drive are not as congested on average.

Pollution costs imposed do not vary as much as pollution costs borne. This seems natural. People may live in an area that has particularly high or low levels of pollution, but they travel through many areas so the costs they impose will more closely match the costs that others impose.

5 Summary

This report contains estimates of the incidence of major types of governmental, internal, and external costs. Incidence was estimated for nine income/vehicle-ownership groups and for 78 geographic sub-regions.

It appears that, relative to income, low-income people bear a higher percentage of each major type of cost—governmental, internal, and external—than people with higher incomes. Internal costs appear to be the most regressive, and they are also much larger than governmental or external costs. Lower income people pay a higher portion of their income on the fixed costs of vehicle ownership, and especially the variable costs of operating vehicles, than do higher income people. Governmental costs appear to be the least regressive. This is because general revenue sources, and especially the income tax, help balance out the relatively regressive effects of fuel taxes.

Geographically, transportation costs vary significantly with location, but most of the internal and governmental costs of transportation did not vary to a great degree between the cities of Minneapolis and Saint Paul, the remainder of the Twin Cities Metropolitan Area, and the outlying counties. Those differences in costs that do exist are explained more by differences in income levels than by differences in location, however. Some differences in external costs seem to be clearly related to location. In particular, differences in location affect the costs of pollution and the costs of congestion.

It is not clear that incidence will change much by 2020 for governmental or internal costs. External costs, however, will probably be more evenly distributed in 2020. The main reason for this is that congestion costs are rising much more rapidly than other costs, and they are more evenly distributed geographically than pollution costs.

Table 5.1 shows the incidence of per capita internal and government costs for three large areas—the cities of Minneapolis and Saint Paul, other parts of the TCMA, and 12 outlying counties. Differences across the areas in internal and governmental costs are driven almost entirely by differences in per capita income. However, people in the lower-income outlying counties bear higher internal costs than central city residents because they drive more on average. Internal costs are broken out into monetary and non-monetary (e.g. travel time), so that the comparison to income includes only actual monetary expenses.

Table 5.1: The Annual Per Capita Cost of Transportation (Internal and Government) in 1998 (1998 Dollars)						
Region	Population	Average Income	Internal Monetary	Govt.	Time (non-mon.)	Total Monetary % of Income
Minneapolis & St. Paul	656,000	26,850	3,633	710	2,864	16.2%
Other TCMA	1,854,000	35,150	5,020	940	3,069	16.9%
Outlying Counties	516,000	21,750	3,722	680	3,273	20.2%
Average	3,027,000	31,050	4,497	840	3,059	17.3%

Table 5.2 shows external costs divided into the same three areas. Central city residents face slightly higher congestion costs than others, because although there is lower auto ownership and use, most congestion is in the central part of the region where central city residents do most of their driving. Residents of outlying counties by contrast, drive more, but in less congested areas on average.

As expected central city residents bear the highest costs of air pollution, because concentrations are highest there. However, perhaps surprisingly, they also impose the highest costs, even though they drive the least. This happens because much of the driving by central city residents is in the central cities, where large numbers of people are exposed to the pollution that is generated. A mile of central city driving may not generate more pollution than a mile in the country, but it does generate more costs.

Table 5.2: The Annual Per Capita Cost of Transportation (External) in 1998 (1998 Dollars)					
Region	Congestion	Pollution Borne	Pollution Imposed	Other	Imposed outside region
Minneapolis & St. Paul	136	571	511	91	100
Other TCMA	123	264	261	78	161
Outlying Counties	82	12	98	91	157
Average	118	288	288	83	147

Results: Incidence of Costs by Income Group

While higher income people spend substantially more on transportation, they spend less as a share of their income. (Of course, this is true for many types of costs, not just transportation.) Taxes paid to the government for transportation-related goods and services are relatively stable across income levels, as a percent of income. While the overall burden is relatively low compared to the private costs of car ownership, it is still true that low-income car owners pay a higher fraction of their income in transportation-related taxes than do high-income people. Thus the current system of transportation finance could be considered to be a regressive tax system. Table 5.3 shows monetary costs.

Table 5.3: Monetary Transportation Costs in 1998 Expressed as a Percent of Income

Group	Internal	Governmental
Less than $15,000, no vehicle	4.8	1.35
Less than $15,000, vehicle	40.9	2.89
$15,000 to $25,000, no vehicle	4.8	1.39
$15,000 to $25,000, vehicle	29.7	2.57
$25,000 to $35,000	23.9	2.42
$35,000 to $45,000	22.6	2.27
$45,000 to $55,000	21.2	2.23
$55,000 to $75,000	18.5	2.06
More than $75,000	15.9	1.85
Average	19.8	2.48

It is also worth noting in the context of private costs that while people that don't own cars pay a substantially lower fraction of their incomes for transportation, they are still incurring a major cost in the sense that they have considerably reduced access to the destinations they might want to reach, such as work and shopping opportunities. This analysis of transportation costs does not address the issue of accessibility (or lack thereof) as an element of transportation costs.

For external costs of transportation, the general trends are that congestion costs rise with income and pollution costs fall. The higher pollution costs for low income people are a reflection of the fact that they are disproportionately likely to live in the central cities. The presence of higher congestion costs for higher income people probably happens both because they drive more, and because the generally suburban nature of their home and work locations usually precludes the use of transit or other non-auto modes.

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Appendix A: Literature Review

Our review of the literature related to cost incidence is divided into three parts: theory, general policy studies, and local policy studies. The theoretic studies are concerned with questions of how the costs of producing a good should be divided among the potential users of the good. We examine two studies that focus primarily on equitable ways to divide costs, and two that focus on efficient ways to divide costs. We summarize four general policy studies that emphasize the importance of equity considerations in transportation policy. Three of the studies argue that, while efficiency is usually an important consideration when policy decisions are made, equity is often neglected. In the last part of the literature review, we examine three local studies that are concerned with cost incidence.

1 Cost Allocation Theory and Optimal Pricing

In this section we examine four studies that address the issue of how costs should be divided. Young (1994) and Baumol and Oates (1988) focus primarily on equitable or fair ways to allocate costs. Young examines cost allocation from a very general viewpoint, and explains how and why different cost allocation rules imply different concepts of fairness. Baumol and Oates are most concerned with the equity implications of environmental policies. They argue that equity is an important consideration, and examine likely ways that policies affect people from different income groups. The American Association of Railroads (1991) and the Transportation Research Board (1996) examine efficient user charges. The American Association of Railroads argues that user charges should be set based on short run marginal cost. The Transportation Research Board examines the question of whether it is possible to determine the short run marginal costs of various freight shipments.

Young

Young (1994) studies cost allocation methods from a theoretic viewpoint. His analysis is based on the properties that characterize different allocation methods. The methods analyzed include the Shapley value, the Aumann-Shapley value, core solutions, and Ramsey pricing. These methods have mathematical properties that seem to naturally make them to correspond to various ideas of fairness. These theoretic allocation mechanisms can be applied to the setting of fees for common-use facilities such as transportation infrastructure.

Young uses a general framework to study cost allocation problems. He assumes that there are N potential users for a public service or public facility. Each of the N users will either be served at some targeted level, or not served at all. The problem is to determine the charges for each customer, based on the cost of service. If $c(N)$ is the least cost of serving all N of the customers by the most efficient means, then c is called the characteristic function of the cost game. A cost allocation method is a function *f*, defined for all *N*, and for all characteristic functions, *c*, such that

$$f(c) = (x(1), x(2), \ldots, x(N)), \text{ and}$$

$$x(1) + x(2) + \ldots + x(N) = c(N)$$

where $x(i)$ is the charge assessed to user i.

Young describes three fundamental principles for cost allocation methods—additivity, monotonicity and consistency. These principles provide a framework for determining the methods that are most appropriate to the situation at hand. There are many plausible methods of satisfying some of the basic principles, but there is no universal solution to the cost allocation problem. The method that is the best for a particular problem depends on the context, computational resources, and the amount of information available.

Baumol and Oates

Baumol and Oates (1988) examine various theoretic issues related to environmental policy. Most of the book is concerned with developing efficient environmental policy. We focus on Chapter 15, which covers the distribution of the costs and benefits of environmental protection among different income classes. The authors argue that it is important to address the distributive side of environmental policy. They feel that to do otherwise would risk undermining environmental programs politically, and unintentionally harming certain social groups.

Two models of the demand for environmental quality are considered. In both models the authors assume that environmental quality is a normal good, and that therefore wealthier people will want to buy more of it than poorer people would. In the first model, there is a pure public good. In this case, the authors conclude that upper-income groups will push for greater outlays on environmental programs and will be opposed by poorer people, because poorer people will want to devote more income to consumption goods. The opposing interests have the potential to create political problems when implementing environmental protection projects.

In the second model, environmental quality is not a pure public good. The authors argue that this is a more realistic case. The quality of the air within one metropolitan area, for example, varies substantially with location. In this case, geographic location allows individuals to purchase different levels of environmental quality, and their demands will probably vary significantly with income. Nevertheless, because poor and wealthy people cannot live completely apart, both groups will consume foul air.

The authors feel that the common view among economists is that programs that improve environmental quality attract the interests of higher-income groups, to a much greater extent than they attract the interests of the poor. Poorer people seem likely to be more concerned about basic needs, such as better food and housing, than they will be about cleaner air and water. In addition, some environmental programs threaten jobs that mainly employ low-income people. The authors suggest that "sensible redistributive provisions" must be incorporated into environmental programs, "both as a matter of justice and as a means to enhance their political feasibility."

American Association of Railroads

The American Association of Railroads (1991) analyzes the issue of optimal pricing rules for those using roads. Road pricing is examined for the purposes of maintaining roads, constructing new roads, and being equitable across freight modes. The paper examines pricing rules designed to pay for highway infrastructure, and the relationship between these pricing rules and congestion externalities. It does not examine policies to reduce externalities other than congestion, such as noise or air pollution. The paper argues for four principles of road user charges.

The first is that highway use should be priced at short-run marginal cost. That is, the government should charge highway users for variable maintenance and operating costs, and for congestion. Users fees should be equal to the difference between the short-run marginal social cost and the short-run average private cost of the trip. This conclusion, that user fees should be set so that the marginal cost to users is the short-run marginal social cost, is considered to be the consensus of most economic literature. Alternative pricing rules are discussed and it is argued that none of them are optimal.

The second principle is that short-run marginal social cost pricing may lead to either deficits or surpluses depending on whether there are economies or diseconomies of scale in the provision of road capacity. The question of whether there are economies or diseconomies is an empirical matter, but the authors feel that the evidence supports diseconomies of scale (and hence surpluses). The production of deficits or surpluses leads to wider questions of optimal tax policy, and raises administrative, political, and institutional issues that the authors do not address.

The third principle is that a road's capacity should be increased or decreased depending on the level of capacity that can be paid for with the (short-run marginal social cost) road user fees. This principle says that if there is profit from increasing road capacity then the road should be expanded, but that if a road is making losses then it is probably was overbuilt. This principle must be modified, however, if there are significant economies of scale in providing road services. If there are economies of scale, the authors argue against the statements of some economists that all roads should cover their costs like any firm in competitive industry. In particular, there is no analog among competitive industries for the rural road with its economies of scale.

The fourth principle deals with equity. It is that (i) all users who impose the same costs on the system should be treated alike and (ii) that road user charges should not be used as a mechanism for achieving social goals of income redistribution.

The authors argue that there have been numerous cases of over- and under-investment in the U.S. road system. These errors should not be repeated when constructing new roads, or when rehabilitating existing roads. In addition, past road investment mistakes do not mean that we should depart from marginal cost principles, and pursue instead a policy of cost recovery. It is felt that a policy of cost recovery would lead to under-investment in urban areas and over-investment in rural roads. An additional conclusion is that over-investment in some highways has caused significant problems for railroads, and has led to an inefficient mode split between highways and railroads.

Transportation Research Board

The Transportation Research Board (1996) brought together a variety of researchers to find out if it is possible to determine the marginal social cost of various freight modes.[30] The researchers conducted several detailed case studies of freight shipments and recommended areas for further research. They divided costs into the seven categories: infrastructure, congestion, crash, air pollution, energy security, noise, and costs borne by the shipper.

The case studies conducted by the Board demonstrate that it is possible to determine the marginal cost of freight transportation, but that the cost varies greatly with the situation. Marginal congestion and crash costs depend on the type of shipment, the corridor it travels on, and when the shipment is made. The Board conducted sensitivity analyses to try to determine the accuracy of various cost estimates. A significant problem encountered was that the study could not accurately determine the relationship between crashes and traffic volume. The Board also could not determine the health costs of motor-vehicle emissions. This led to significant uncertainty in final cost estimates.

2 General Studies of Transportation Equity

This section includes four studies that examine the issue of transportation equity. The first three—Litman (1999), O'Regan and Quigley (1999), and Forkenbrock and Schweitzer (1997)—argue that transportation equity is important and examine different aspects of it. Litman explains that transportation equity depends on how transportation is measured, and describes how it varies across different user groups. O'Regan and Quigley focus on the effects of transportation on access to employment and economic opportunity. Forkenbrock and Schweitzer attempt to develop indicators of transportation equity. The last study, Federal Highway Administration (1997), divides the costs of highway use among different classes of highway users. Costs are allocated based on vehicle type, and not on income or membership in a disadvantaged group.

Litman

Litman (1999) examines transportation equity and the role transportation equity plays in policy evaluation. Litman emphasizes that transportation has important

[30] The Transportation Research Board panel worked with the National Research Council and the Committee for Study of Public Policy for Surface Freight Transportation.

equity effects because it gives people access to goods, services and jobs. Three types of equity are introduced: horizontal equity, vertical equity with regard to income and social class, and vertical equity with regard to mobility need and ability. Analyses of transportation equity depend on how groups are defined, and on how transportation is measured. Litman examines the equity implications of alternative transportation evaluation criteria.

Litman provides a comprehensive review of the recent studies of transportation equity. He discusses the limitations of existing studies. Some focus on only one type of equity and others consider only market effects. Another limitation is that long-term effects on the total costs and benefits of transportation are often ignored.

Litman feels that transportation policies often present equity problems. He says that most studies show that that amount that a person drives usually increases with wealth and physical ability. Generally, road improvements provide the largest benefits to people with high levels of income and physical ability. Studies often find that non-drivers and people who drive little subsidize high-mileage motor vehicle users. Litman feels equity problems can be addressed by fairly distributing the overall benefits of transportation changes.

Litman argues that a total cost approach leads to a more comprehensive analysis of transportation equity than do other approaches. He applies the total cost approach to a number of alternative transportation policies. He examines the equity of (i) an automobile dependent transportation system, (ii) vehicle and road pricing, (iii) transit subsidies, and (iv) alternative traffic management strategies. Users are divided into four classes: non-drivers, low-income drivers, middle income drivers and upper income drivers. Transportation costs are divided into six different categories: user market, user non-market, external market, external environment, transportation dependency, and economic costs.

O'Regan and Quigley

O'Regan and Quigley (1999) examines the link between employment access and economic opportunities. The authors present new indications of changes in employment access for the poor and review recent studies of the effects of urban development on labor markets. The studies include the effects of extending transportation systems and changing accessibility. The authors also analyze a number of policy initiatives designed to increase economic opportunity through improved transportation.

The authors argue that low-income central city residents have inadequate access to jobs, and that this limits the residents' economic opportunities. They present two major reasons for the poor access (i) slow adjustment in housing markets to changes in job location and (ii) barriers to the mobility of low-income and minority households. The authors feel that the rapid decentralization of employment after World War II gave a locational advantage to suburban residents, and essentially improved their housing tracts.

Low-income, central-city residents have had less access to the geographical areas that have experienced rapid employment development. If there had been the construction of significant amounts of low-income housing in the suburbs that experienced rapid job growth, then low-income central-city residents would not have been noticeably disadvantaged by work place decentralization. In practice however, high transformation costs, land use and environmental policies, and political opposition created obstacles to producing new low-income housing in many suburbs.

Low-income residents of central cities also have fewer commuting options. Many do not have access to private automobiles, and rely heavily on public transportation. Public transit does not generally provide good access to suburban job centers. This problem is especially acute in older metropolitan areas with radial transit service and large minority populations.

Forkenbrock and Schweitzer

Forkenbrock and Schweitzer (1997) try to find indicators of the economic, social, and environmental effects of transportation changes, and also to identify indicators that are useful for assessing whether impacts adversely or disproportionately affect low-income and minority groups. The indicators are developed to be understandable to a wide range of people from affected regions, so that it will make it easy for these people to participate in evaluating projects. A variety of impacts were identified, based on research from related fields. The authors then conducted a detailed analysis of the impact of transportation projects to an existing urban arterial, U. S. Highway 63, which runs through Waterloo, Iowa.

This paper complements Litman (1999). It argues that economic efficiency has been one of the main requirements of transportation projects, but that most studies have neglected the issue of which parts of the population benefit from policies. In addition, some policies may even make certain groups, and especially low-income and minority groups, worse off.

The authors divide the effects of transportation changes into two types (i) the effects on overall economic efficiency for society and (ii) the distributional effects of the net benefits. If a change in policy delivers a net gain to society, but some people are made worse off, then these people should be compensated by those who become better off. Redistributing the benefits of a project can be done with tax mechanisms. The authors stress out that "a fundamental element of environment justice" is that the negative effects of transportation changes should not fall disproportionately on low-income or minority populations.

Federal Highway Administration

The Federal Highway Administration (1997) examined the costs related to highway use. The costs are estimated on a national basis for the year 2000. The costs are calculated for five primary user classes: autos, vans and pickups, buses, single-unit trunks, and combination trucks. Costs are not examined based on demographic characteristics of highway users. Costs include governmental spending on highways—construction, maintenance, and services—as well as external noise, congestion, crash, and air pollution costs. All of these costs are quantified in the study, except for those of air pollution, which will be included later.

The goal of the study was to determine both the equity and efficiency of the system of highway user fees. To determine equity, the responsibility for various costs is compared to user fees. Determining responsibility for costs is not a straightforward. Different methods were used to assign costs for pavement and bridges, and for capacity-related and transit-related costs. To determine efficiency, the marginal governmental plus external costs of transportation are compared to user fees.

3 Studies of Transportation Equity in the Twin Cities

In this section we review three local studies of transportation equity. Kannien (1995) examines the implications of three alternative transportation pricing proposals for people in a variety of demographic groups. Bailey (1992) calculates the total costs of transportation for Minneapolis, and the size of the subsidies that automobile users receive from non-users. Anderson and Mohring (1996) study the effects of congestion pricing on Twin Cities residents based on income and geographic location.

Kannien

Kanninen (1995) examines the distributional consequences of three types of transportation pricing policies (i) a $0.65 downtown peak-period congestion fee, (ii) a 10 percent gasoline tax, and (iii) a 50 percent transit fare reduction. Kannien examines the effects of these policies based on income, region, gender, and age. The policies are evaluated in terms of aggregate welfare costs, revenues, emissions reductions, and cost-effectiveness. Marginal cost pricing is not analyzed because, while it would be the most efficient way to reduce emissions, it may also have negative distributional consequences.

Kannien’s analysis demonstrates that the congestion fee and the gasoline tax are regressive. While their burden rises with income, it decreases as a share of income as income rises. Lower-income individuals would have burdens from the congestion fee that are four times as high in terms of share of household income, as high-income individuals do. A transit fare reduction, on the other hand, would provide greater relative benefits to low-income people.

Bailey

Bailey (1992) examines the costs of Minneapolis roads and the methods used to finance the roads. Bailey finds that most of costs of roads are covered by transportation user charges. Some road costs are covered by property tax assessments, however. Bailey notes that about 22 percent of Minneapolis residents do not own cars, and feels that residents without cars are subsidizing those residents with cars.

Bailey notes that not paying true costs of driving creates two problems. First, since the drivers do not cover all of their costs, it encourages greater roads use.

Second, because road subsidies are paid by people who do not own vehicles and who generally have lower incomes, it raises equity issues. Theoretically, a more equitable way to cover the costs of roads would be to impose costs directly on users.

The study explains how the gas tax would need to be raised to make sure that cars cover the true costs of roads. The primary goal of increasing gas taxes is not raising additional revenue, but to redistribute the burden of roads to road users themselves. This redistribution would lead to a reduction in the part of road costs borne by non-users.

Anderson and Mohring

Anderson and Mohring (1996) examines the effects of congestion pricing on transportation in TCMA. They are concerned primarily with determining efficient congestion pricing systems, but they also analyze the effects of their pricing system on households from four different income groups and from 187 different geographic locations. The geographic locations correspond to the minor civil divisions (cities, towns, and townships) within the TCMA. Their analysis was detailed in that it examined the effects of pricing on route choice and on the decision whether or not to travel.

Anderson and Mohring found large differences in welfare effects depending on location and income. When they assumed that trip demand was unit elastic and that all roads were tolled optimally, for example, total peak-hour trip costs averaged 33 cents more for people in the highest income quartile and 50 cents more for people in the lowest quartile.[31] Under congestion pricing, lower income people generally avoided tolls by traveling on less congested, but slower roads. Geographically, the residents of regions towards the edges of the TCMA tended to have the greatest losses from congestion pricing.

[31] Total trip costs include time costs and congestion tolls.

Appendix B: Definition of Sub-Regions and Results by Sub-Region

The 66 sub-regions within the TCMA are defined in terms of traffic analysis zones (TAZs). The TAZs have been defined by the Metropolitan Council. Figure B.1 below shows the subregions on a map. Figure B.2 is the same map, but with the central part of the region expanded for greater readability. Table B.1 lists the TAZs that make up each sub-region. Twelve additional geographic regions correspond to the counties adjacent to the TCMA..

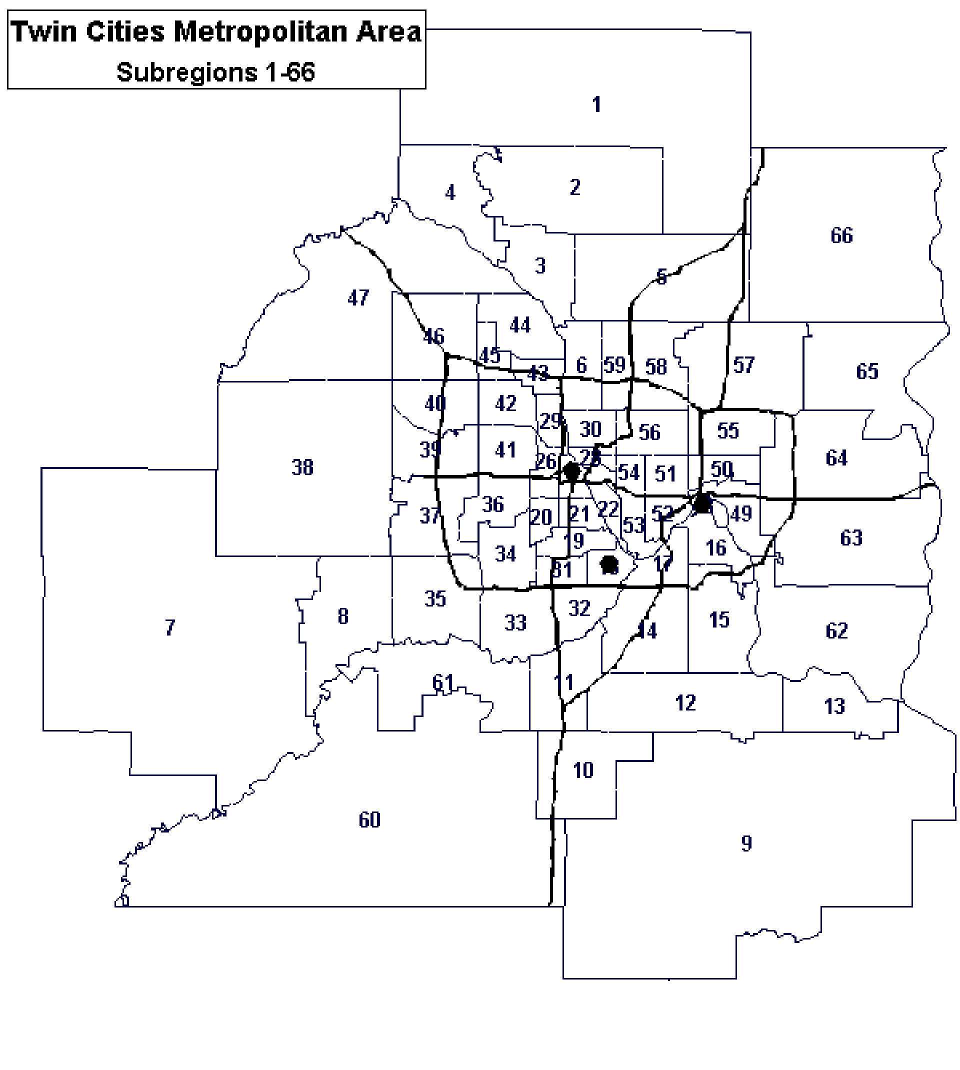

Figure B.1: The 66 Sub-Regions Contained in the Twin Cities Metropolitan Area

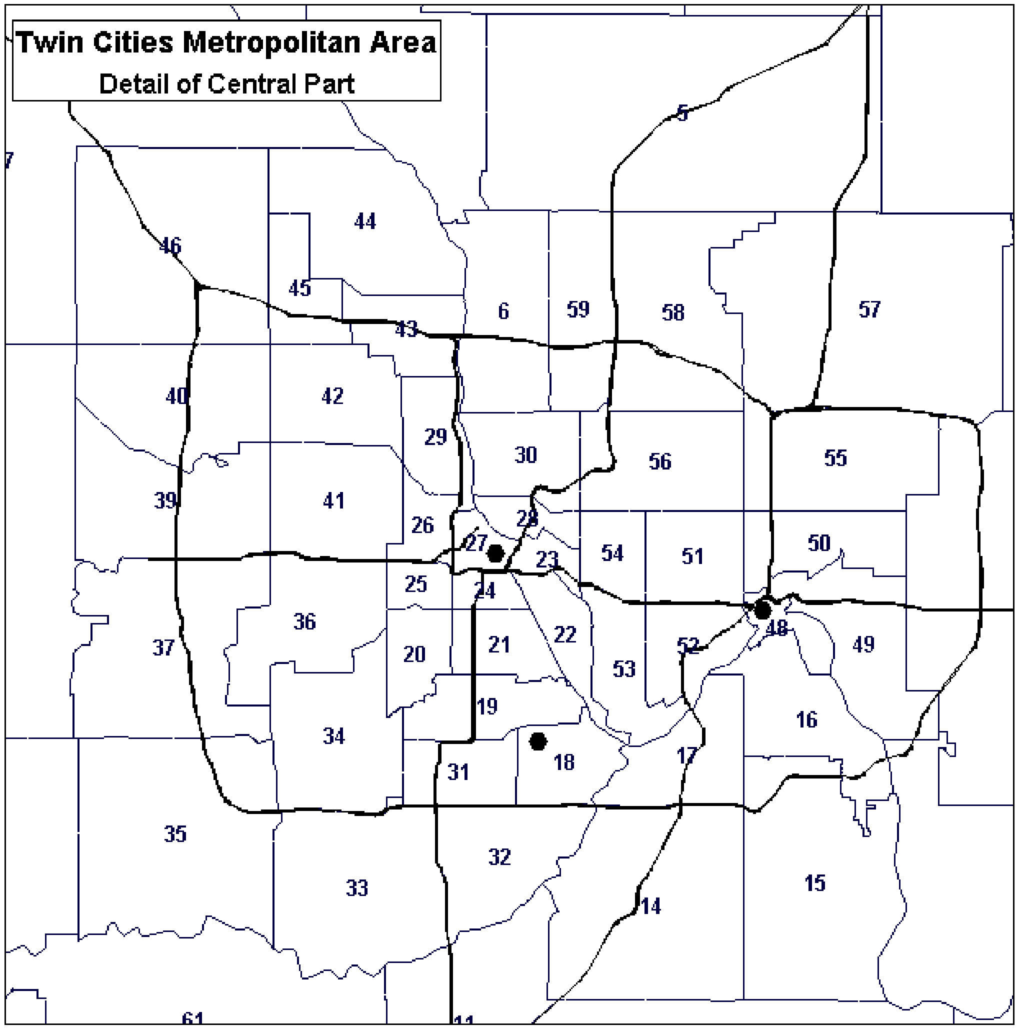

Figure B.2: The Sub-Regions in the Central Part of the Twin Cities Metropolitan Area

Table B.1: Definition of Geographic Regions to be Studied

Sub-Region Name	Num.	TAZ Numbers
Rural Far North	1	1 - 18
Ham Lake, Andover	2	19 - 30, 35 - 38
Coon Rapids	3	31 - 34, 57 - 74
Ramsey/Anoka	4	39 - 56
Blaine/Lino Lakes	5	75 - 99
Fridley/Spring Lake Park/Columbia Heights	6	100 - 124
Rural Far West	7	125 - 135
Chanhansen/Chaska	8	136 - 156
Rural Far South	9	157 - 172
Lakeville	10	173 - 185
Burnsville	11	186 - 209
Apple Valley/Rosemount	12	210 - 227
Hastings	13	228 - 233
Eagan	14	234 - 259
Inver Grove Heights	15	260 - 282
S. St. Paul/W. St. Paul	16	283 - 296, 822 - 825, 886
Mendota	17	297 - 306
Airport/Fort Snelling	18	307 - 313
MPLS Far SE	19	314 - 326
MPLS South Lakes	20	327 - 335
MPLS Mid South	21	336 -349
MPLS Hiawatha/River	22	311, 350 - 354, 364, 365
MPLS U of M	23	355 - 363, 366
MPLS Near South	24	367 - 374
MPLS North Lakes	25	375 - 378
MPLS Near North	26	379 - 387
MPLS Downtown	27	388 - 412
MPLS Near NE/Dinkytown	28	413 - 419, 423 - 427
MPLS North	29	428 - 436, 439, 450 - 452
MPLS NE Industrial	30	420 - 422, 437, 438, 440 - 449
Richfield	31	453 - 470
Bloomington East	32	471 - 488
Bloomington West	33	489 - 512
Edina	34	513 - 537

Table B.1 (Continued)

Name	Num.	TAZ Numbers
Eden Prairie	35	538 - 564
Hopkins/St. Louis Park	36	565 - 593
Minnetonka	37	594 - 621
Lake Minnetonka	38	622 - 648
Wayzata/Plymouth S.	39	649 - 672
Plymouth N.	40	673 - 687
Golden Valley	41	688 - 707
Robbinsdale/Crystal/New Hope	42	708 - 728
Brooklyn Center	43	729 - 740
Brooklyn Park E.	44	741 - 759
Brooklyn Park W.	45	760 - 771
Maple Grove	46	772 - 790
Rural Far NW	47	791 - 808
STP Downtown/Capitol/ Airport-Industrial	48	809 - 821, 826, 862, 863
STP East	49	827 - 844
STP Near North	50	845 - 861
STP Near NW	51	865 - 877
STP Near West	52	864, 878 - 892
STP Highland	53	893 - 907
STP Midway	54	908 - 917
Maplewood	55	925 - 948, 975 - 977
Roseville	56	949 - 974
White Bear Lake	57	978 - 999, 1144 - 1149
Arden Hills/Shoreview	58	1000 - 1019
Mounds View/New Brighton	59	1020 - 1036
Rural Far Southwest	60	1037 - 1059
Shakopee/Savage	61	1060 - 1078
Cottage Grove	62	1079 - 1096
Woodbury/Rural East	63	918 - 920, 1097 - 1113
Oakdale/Rural East	64	921 - 924, 1114 - 1129
Stillwater	65	1130 - 1143, 1150, 1151
Rural Far Northeast	66	1152 - 1165

Table B.2: Population, Households, Median Personal Income, and Households without Access to Vehicles in 1998 and 2020

	1998				2020			
Sub-region	Population	Hhlds.	Med. PI	No Veh.	Population	Hhlds.	Med. PI	No Veh.
1 Rural Far North	31,302	9,820	24,278	1.3%	37,540	13,336	29,724	0.8%
2 Ham Lake, Andover	26,275	7,868	27,772	1.8%	31,511	10,685	34,002	1.1%
3 Coon Rapids	70,046	23,129	24,886	3.2%	84,005	31,410	30,469	1.9%
4 Ramsey/Anoka	31,058	10,706	22,391	6.3%	37,247	14,539	27,414	3.8%
5 Blaine/Lino Lakes	68,235	22,498	25,669	1.9%	81,833	30,554	31,428	1.2%
6 Fridley/Spring Lake Park/Columbia Hghts	65,266	25,931	21,694	7.3%	78,272	35,216	26,560	4.4%
7 Rural Far West	31,888	11,018	26,961	4.2%	50,031	19,951	33,009	1.9%
8 Chanhassen/Chaska	32,786	11,328	32,348	2.1%	54,389	21,689	39,604	0.9%
9 Rural Far South	23,145	8,307	27,755	3.5%	27,693	11,164	33,982	2.1%
10 Lakeville	29,365	10,540	33,021	1.2%	34,555	13,931	40,429	0.7%
11 Burnsville	60,598	21,751	27,595	1.1%	84,184	33,939	33,785	0.6%
12 Apple Valley/ Rosemount	51,285	18,408	33,540	1.9%	61,574	24,824	41,064	1.2%
13 Hastings	19,194	6,889	25,586	4.8%	24,832	10,011	31,326	2.7%
14 Eagan	56,015	20,106	29,816	1.7%	76,702	30,922	36,505	0.9%
15 Inver Grove Heights	27,045	9,707	27,973	2.5%	34,951	14,090	34,249	1.4%
16 S. St. Paul/W. St. Paul	63,947	22,953	19,069	13.4%	95,526	38,511	23,347	6.5%
17 Mendota	11,935	4,284	39,177	0.8%	16,144	6,508	47,966	0.4%
18 Airport/Fort Snelling	2,455	1,030	24,621	2.0%	2,035	870	30,145	2.0%
19 MPLS Far SE	54,726	22,963	40,174	9.8%	64,876	27,738	49,186	6.6%
20 MPLS South Lakes	29,756	12,485	38,473	15.1%	41,531	17,757	47,104	8.7%
21 MPLS Mid South	55,908	23,459	26,533	25.4%	65,135	27,849	32,485	17.5%
22 MPLS Hiawatha/River	28,844	12,103	28,770	23.5%	37,514	16,039	35,224	14.5%
23 MPLS U of M	15,726	6,599	20,699	28.1%	14,311	6,119	25,343	24.8%
24 MPLS Near South	35,647	14,957	14,102	61.2%	46,588	19,919	17,266	37.5%
25 MPLS North Lakes	18,623	7,814	42,915	21.0%	28,010	11,976	52,543	11.2%
26 MPLS Near North	24,050	10,091	19,261	37.8%	23,502	10,048	23,582	31.0%
27 MPLS Downtown	17,166	7,203	18,694	71.3%	29,374	12,559	22,888	33.4%
28 MPLS Near NE/Dinkytown	21,217	8,903	24,424	25.4%	27,200	11,629	29,903	15.8%
29 MPLS North	43,676	18,326	24,552	23.6%	48,066	20,551	30,060	17.2%
30 MPLS NE Industrial	37,220	15,617	26,965	19.9%	46,254	19,776	33,014	12.9%
31 Richfield	35,531	14,909	32,616	8.7%	43,938	18,786	39,933	5.7%
32 Bloomington East	31,339	13,149	34,611	5.9%	36,599	15,648	42,376	4.0%
33 Bloomington West	57,867	24,281	43,840	3.4%	64,926	27,759	53,675	2.4%
34 Edina	50,185	21,057	56,344	5.7%	60,200	25,739	68,984	3.8%
35 Eden Prairie	40,464	16,979	54,124	1.0%	42,054	17,980	66,267	0.8%
36 Hopkins/St. Louis Park	57,400	24,085	32,155	11.1%	75,768	32,395	39,369	6.8%
37 Minnetonka	48,365	20,294	57,343	1.8%	51,694	22,102	70,207	1.4%
38 Lake Minnetonka	48,372	20,297	55,944	3.4%	50,710	21,681	68,494	2.6%
39 Wayzata/Plymouth S.	35,714	14,985	47,788	3.8%	38,690	16,542	58,509	2.8%

Table B.2 (Continued)

Sub-region	1998 Population	1998 Hhlds.	1998 Med. PI	1998 No Veh.	2020 Population	2020 Hhlds.	2020 Med. PI	2020 No Veh.
40 Plymouth N.	24,580	10,314	54,791	1.7%	25,246	10,794	67,083	1.3%
41 Golden Valley	38,048	15,965	41,894	5.2%	42,069	17,987	51,293	3.7%
42 Robbinsdale/Crystal/ New Hope	47,509	19,935	35,332	10.3%	54,139	23,147	43,259	7.2%
43 Brooklyn Center	29,443	12,354	31,310	9.8%	33,685	14,402	38,334	6.9%
44 Brooklyn Park E.	36,070	15,135	48,677	2.9%	34,460	14,734	59,597	2.4%
45 Brooklyn Park W.	21,632	9,077	32,918	7.4%	22,471	9,608	40,303	5.7%
46 Maple Grove	40,062	16,810	51,399	0.8%	36,774	15,723	62,929	0.7%
47 Rural Far NW	32,072	13,457	43,620	1.5%	28,660	12,254	53,406	1.4%
48 STP Dtwn/Airport-Industrial/Capitol	4,881	2,004	14,634	68.9%	8,502	3,524	17,917	32.0%
49 STP East	40,065	16,448	28,601	17.8%	43,898	18,198	35,017	13.2%
50 STP Near North	60,407	24,799	21,069	23.9%	65,148	27,008	25,795	18.0%
51 STP Near NW	54,956	22,562	22,689	21.5%	62,743	26,011	27,779	15.2%
52 STP Near West	49,792	20,442	24,064	22.2%	60,901	25,247	29,463	14.7%
53 STP Highland	44,198	18,145	35,211	12.3%	50,124	20,779	43,111	8.8%
54 STP Midway	16,862	6,923	23,886	16.4%	19,845	8,227	29,244	11.2%
55 Maplewood	43,390	17,813	34,901	6.6%	46,600	19,318	42,731	4.9%
56 Roseville	38,559	15,830	36,981	5.2%	44,050	18,261	45,277	3.7%
57 White Bear Lake	59,077	24,254	47,381	2.8%	58,555	24,275	58,010	2.3%
58 Arden Hills/Shoreview	35,839	14,713	45,172	1.3%	35,796	14,840	55,305	1.1%
59 Mounds View/New Brighton	37,610	15,440	38,289	4.4%	41,179	17,071	46,879	3.3%
60 Rural Far Southwest	47,631	15,968	26,835	2.5%	81,926	32,103	32,856	1.0%
61 Shakopee/Savage	31,400	10,527	26,738	4.3%	55,984	21,937	32,736	1.7%
62 Cottage Grove	42,160	15,072	26,260	2.8%	60,366	23,239	32,151	1.5%
63 Woodbury/Rural East	38,773	13,861	32,132	1.3%	60,914	23,450	39,340	0.6%
64 Oakdale/Rural East	42,391	15,154	28,283	2.4%	70,250	27,044	34,628	1.1%
65 Stillwater	33,617	12,018	28,785	5.5%	51,244	19,727	35,243	2.7%
66 Rural Far NE	29,545	10,562	26,782	2.9%	45,895	17,668	32,791	1.4%
67 Chisago County	40,852	13,721	21,858	2.6%	52,670	18,633	26,761	1.5%
68 Goodhue County	43,137	16,501	25,018	3.2%	47,290	20,069	30,631	2.2%
69 Isanti County	30,121	10,420	21,050	3.0%	33,910	11,383	25,773	2.2%
70 Le Sueur County	25,320	9,248	22,208	3.2%	28,080	10,818	27,190	2.2%
71 McLeod County	34,017	13,041	24,625	3.2%	40,310	15,256	30,150	2.3%
72 Pierce County	34,547	11,929	17,915	3.3%	42,052	14,867	21,934	2.1%
73 Polk County	37,046	13,081	16,576	3.2%	37,217	13,148	20,295	2.6%
74 Rice County	54,106	18,345	21,639	3.1%	58,560	20,836	26,494	2.2%
75 St. Croix County	57,113	18,177	21,905	3.0%	61,493	19,745	26,819	2.3%
76 Sherburne County	60,391	18,982	20,736	2.4%	91,620	22,021	25,388	1.7%
77 Sibley County	14,573	5,568	21,332	3.4%	14,590	5,575	26,117	2.8%
78 Wright County	85,123	28,436	23,587	2.8%	105,550	27,166	28,878	2.4%

Table B.3: Annual Total Vehicle Hours of Travel (VHT), Person Hours of Travel (PHT), and Vehicle Miles ofTravel (VMT) by Sub-Region

	1998 Annual (1000s)			2020 Annual (1000s)		
Sub-region	VHT	PHT	VMT	VHT	PHT	VMT
1 Rural Far North	9,772	15,400	330,903	13,345	20,254	459,261
2 Ham Lake, Andover	11,939	16,172	347,504	16,303	21,270	482,302
3 Coon Rapids	26,252	30,721	660,126	35,848	40,404	916,190
4 Ramsey/Anoka	13,599	16,869	362,472	18,570	22,186	503,075
5 Blaine/Lino Lakes	27,304	35,533	763,525	37,285	46,733	1,059,697
6 Fridley/Spring Lake Park/Columbia Hghts	15,904	17,353	372,883	21,717	22,823	517,525
7 Rural Far West	9,333	17,324	372,246	16,673	29,807	675,880
8 Chanhassen/Chaska	14,214	18,121	389,370	26,849	32,966	747,524
9 Rural Far South	6,705	10,022	215,341	9,134	13,150	298,180
10 Lakeville	10,516	14,838	318,838	14,090	19,148	434,185
11 Burnsville	18,416	22,834	490,650	29,130	34,787	788,820
12 Apple Valley/ Rosemount	18,766	24,593	528,451	25,654	32,381	734,256
13 Hastings	6,407	8,528	183,249	9,438	12,100	274,366
14 Eagan	18,348	23,787	511,122	28,606	35,719	809,956
15 Inver Grove Heights	8,750	10,655	228,952	12,875	15,101	342,413
16 S. St. Paul/W. St. Paul	17,532	18,522	397,996	29,821	30,343	688,036
17 Mendota	5,158	6,085	130,748	7,945	9,026	204,680
18 Airport/Fort Snelling	766	886	19,037	722	805	18,261
19 MPLS Far SE	18,679	18,496	397,428	25,213	24,045	545,240
20 MPLS South Lakes	9,483	9,524	204,649	15,070	14,578	330,559
21 MPLS Mid South	11,602	11,246	241,641	15,391	14,368	325,793
22 MPLS Hiawatha/River	7,912	6,560	140,966	11,716	9,357	212,167
23 MPLS U of M	1,671	1,463	31,445	1,731	1,460	33,116
24 MPLS Near South	2,170	1,688	36,265	3,230	2,419	54,849
25 MPLS North Lakes	3,216	3,091	66,418	5,508	5,098	115,608
26 MPLS Near North	3,199	3,061	65,769	3,559	3,280	74,377
27 MPLS Downtown	1,697	1,390	29,858	3,307	2,608	59,128
28 MPLS Near NE/Dinkytown	3,333	2,931	62,989	4,865	4,121	93,448
29 MPLS North	8,986	8,348	179,371	11,260	10,075	228,446
30 MPLS NE Industrial	9,768	8,902	191,287	13,822	12,132	275,107
31 Richfield	11,046	10,719	230,318	15,552	14,536	329,602
32 Bloomington East	9,671	9,990	214,660	12,860	12,794	290,122
33 Bloomington West	21,939	25,429	546,408	28,027	31,288	709,470
34 Edina	18,111	19,170	411,927	24,737	25,218	571,842
35 Eden Prairie	15,462	18,790	403,750	18,297	21,415	485,606
36 Hopkins/St. Louis Park	14,867	15,338	329,579	22,345	22,203	503,459

Table B.3 (Continued)

Sub-region	1998 Annual (1000s) VHT	PHT	VMT	2020 Annual (1000s) VHT	PHT	VMT
37 Minnetonka	17,953	20,529	441,109	21,849	24,062	545,620
38 Lake Minnetonka	20,789	28,074	603,250	24,815	32,276	731,865
39 Wayzata/Plymouth S.	12,912	15,497	332,988	15,927	18,410	417,462
40 Plymouth N.	7,756	9,554	205,303	9,071	10,762	244,033
41 Golden Valley	13,812	14,594	313,594	17,389	17,696	401,261
42 Robbinsdale/Crystal/ New Hope	15,304	15,360	330,057	19,857	19,195	435,264
43 Brooklyn Center	7,923	8,598	184,758	10,321	10,788	244,621
44 Brooklyn Park E.	14,656	17,516	376,368	15,943	18,351	416,116
45 Brooklyn Park W.	7,024	7,810	167,827	8,308	8,897	201,754
46 Maple Grove	17,137	22,222	477,503	17,911	22,370	507,244
47 Rural Far NW	13,346	19,676	422,795	13,580	19,282	437,231
48 STP Dtwn/Airport-Industrial/Capitol	516	600	12,883	1,022	1,145	25,966
49 STP East	7,858	8,101	174,076	9,803	9,734	220,724
50 STP Near North	10,118	9,487	203,852	12,424	11,220	254,426
51 STP Near NW	10,924	10,209	219,376	14,201	12,783	289,850
52 STP Near West	11,287	10,832	232,749	15,719	14,529	329,451
53 STP Highland	14,824	14,580	313,297	19,142	18,133	411,181
54 STP Midway	3,271	3,056	65,666	4,383	3,944	89,435
55 Maplewood	11,654	12,805	275,140	14,251	15,081	341,968
56 Roseville	13,135	14,235	305,874	17,086	17,833	404,383
57 White Bear Lake	24,110	30,428	653,813	27,210	33,073	749,950
58 Arden Hills/Shoreview	16,806	21,343	458,610	19,113	23,377	530,097
59 Mounds View/New Brighton	10,485	12,327	264,878	13,071	14,801	335,626
60 Rural Far Southwest	15,237	23,702	509,301	29,840	44,708	1,013,770
61 Shakopee/Savage	11,463	13,987	300,546	23,271	27,348	620,127
62 Cottage Grove	12,222	16,006	343,940	19,925	25,134	569,916
63 Woodbury/Rural East	14,421	20,648	443,666	25,797	35,573	806,642
64 Oakdale/Rural East	13,038	17,284	371,390	24,601	31,411	712,262
65 Stillwater	11,157	14,779	317,567	19,366	24,706	560,219
66 Rural Far NE	11,031	16,230	348,738	19,511	27,647	626,915
67 Chisago County	13,793	21,484	461,646	20,249	30,376	688,800
68 Goodhue County	14,565	22,686	487,468	18,180	27,274	618,442
69 Isanti County	10,170	15,841	340,381	13,036	19,557	443,463
70 Le Sueur County	8,549	13,316	286,128	10,795	16,195	367,221
71 McLeod County	11,485	17,890	384,408	15,497	23,248	527,160
72 Pierce County	11,664	18,169	390,397	16,167	24,253	549,942
73 Polk County	12,508	19,483	418,637	14,308	21,464	486,711
74 Rice County	18,268	28,455	611,422	22,513	33,773	765,828
75 St. Croix County	19,284	30,036	645,403	23,641	35,465	804,184
76 Sherburne County	20,390	31,760	682,446	35,223	52,840	1,198,175

Table B.3 (Continued)

Sub-region	1998 Annual (1000s)			2020 Annual (1000s)		
	VHT	PHT	VMT	VHT	PHT	VMT
77 Sibley County	4,920	7,664	164,682	5,609	8,414	190,803
78 Wright County	28,741	44,767	961,929	40,578	60,874	1,380,347
Total	959,000	1,206,000	25,914,000	1,331,000	1,618,000	36,689,000

Table B.4: Per Capita Governmental Costs Borne Annually in 1998 and 2020

	1998				2020			
Sub-region	Veh. Reg.	Fuel Tax	Other	Total	Veh. Reg.	Fuel Tax	Other	Total
1 Rural Far North	76	197	441	712	69	279	545	892
2 Ham Lake, Andover	76	287	504	865	69	406	623	1,098
3 Coon Rapids	74	236	452	763	68	335	559	962
4 Ramsey/Anoka	72	276	407	757	67	392	503	962
5 Blaine/Lino Lakes	75	252	466	793	69	358	576	1,002
6 Fridley/Spring Lake Park/Columbia Hghts	71	154	394	622	67	218	487	773
7 Rural Far West	80	185	489	756	74	262	605	941
8 Chanhassen/Chaska	82	274	587	942	74	388	726	1,188
9 Rural Far South	83	183	504	769	75	259	623	957
10 Lakeville	84	226	600	908	76	320	741	1,137
11 Burnsville	85	192	501	775	76	272	620	966
12 Apple Valley/ Rosemount	84	231	609	922	76	327	753	1,155
13 Hastings	81	211	465	757	75	298	574	948
14 Eagan	84	207	541	830	76	293	669	1,037
15 Inver Grove Heights	83	204	508	794	76	289	628	992
16 S. St. Paul/W. St. Paul	74	173	346	601	72	245	428	748
17 Mendota	85	273	711	1,066	76	386	880	1,341
18 Airport/Fort Snelling	103	197	447	735	91	279	553	915
19 MPLS Far SE	95	215	729	1,036	86	305	902	1,291
20 MPLS South Lakes	89	201	698	991	84	285	864	1,232
21 MPLS Mid South	78	131	482	704	76	186	596	865
22 MPLS Hiawatha/River	80	173	522	787	79	245	646	975
23 MPLS U of M	75	67	376	534	70	95	465	643
24 MPLS Near South	41	38	256	386	58	54	317	455
25 MPLS North Lakes	83	109	779	980	82	154	963	1,202
26 MPLS Near North	65	84	350	525	64	119	432	635
27 MPLS Downtown	30	62	339	493	62	88	420	592
28 MPLS Near NE/Dinkytown	78	99	443	634	78	140	548	772
29 MPLS North	80	130	446	667	77	184	551	819
30 MPLS NE Industrial	84	166	490	747	81	235	605	924
31 Richfield	96	196	592	880	87	278	732	1,094
32 Bloomington East	99	195	628	915	89	276	777	1,137
33 Bloomington West	101	239	796	1,127	90	339	984	1,407
34 Edina	99	228	1,023	1,342	89	323	1,265	1,671
35 Eden Prairie	104	241	983	1,315	92	342	1,215	1,641
36 Hopkins/St. Louis Park	93	163	584	839	86	232	722	1,037
37 Minnetonka	103	234	1,041	1,367	91	332	1,287	1,703
38 Lake Minnetonka	101	271	1,016	1,378	90	384	1,256	1,724

Table B.4 (Continued)

Sub-region	1998 Veh. Reg.	1998 Fuel Tax	1998 Other	1998 Total	2020 Veh. Reg.	2020 Fuel Tax	2020 Other	2020 Total
39 Wayzata/Plymouth S.	101	228	868	1,187	90	323	1,073	1,480
40 Plymouth N.	103	199	995	1,285	91	282	1,230	1,596
41 Golden Valley	99	229	761	1,081	89	325	941	1,349
42 Robbinsdale/Crystal/New Hope	94	203	641	936	86	288	793	1,165
43 Brooklyn Center	95	170	568	830	86	241	703	1,027
44 Brooklyn Park E.	102	256	884	1,232	90	363	1,093	1,540
45 Brooklyn Park W.	97	205	598	894	87	290	739	1,113
46 Maple Grove	104	270	933	1,295	92	382	1,154	1,620
47 Rural Far NW	103	263	792	1,146	91	372	979	1,435
48 STP Dtwn/Airport-Industrial/Capitol	28	67	266	410	53	94	329	494
49 STP East	73	124	519	720	68	175	642	888
50 STP Near North	68	106	383	566	65	150	473	694
51 STP Near NW	70	125	412	615	67	178	509	758
52 STP Near West	69	143	437	657	67	203	540	814
53 STP Highland	78	212	639	928	72	300	791	1,161
54 STP Midway	74	122	434	633	70	173	536	780
55 Maplewood	83	169	634	880	75	240	784	1,094
56 Roseville	84	215	671	964	76	305	830	1,206
57 White Bear Lake	86	258	860	1,195	77	365	1,064	1,499
58 Arden Hills/Shoreview	88	296	820	1,193	78	419	1,014	1,504
59 Mounds View/New Brighton	85	176	695	948	76	249	860	1,180
60 Rural Far Southwest	49	202	487	738	45	286	602	934
61 Shakopee/Savage	48	230	485	765	45	326	600	972
62 Cottage Grove	86	183	477	746	79	259	590	927
63 Woodbury/Rural East	87	235	583	904	80	333	721	1,133
64 Oakdale/Rural East	86	194	513	793	79	275	635	989
65 Stillwater	84	209	523	818	78	297	646	1,022
66 Rural Far NE	86	236	486	808	79	334	601	1,014
67 Chisago County	80	213	397	690	74	302	491	866
68 Goodhue County	77	213	454	744	70	302	562	934
69 Isanti County	73	213	382	668	66	302	473	841
70 Le Sueur County	79	213	403	695	72	302	499	873
71 McLeod County	82	213	447	743	75	302	553	930
72 Pierce County	34	249	325	608	31	352	402	786
73 Polk County	34	249	301	584	31	352	372	756
74 Rice County	72	213	393	678	66	302	486	854
75 St. Croix County	34	249	398	681	31	352	492	876
76 Sherburne County	72	213	376	661	66	302	466	833
77 Sibley County	79	213	387	679	72	302	479	853
78 Wright County	80	213	428	721	73	302	530	904
Average	79	201	564	844	71	284	684	1,039
Minimum	34	38	256	386	31	54	317	455
Maximum	91	296	1,041	1,378	84	419	1,287	1,724

Table B.5: Annual Per Capita Internal Costs of Transportation in 1998 (1998 dollars)

Sub-Region	Fixed Vehicle	Variable Vehicle	Business	Total Monetary	Time
Rural Far North	1175	1403	1132	3710	3002
Ham Lake, Andover	1277	1652	1295	4224	3101
Coon Rapids	1243	1304	1160	3707	2982
Ramsey/Anoka	1130	1511	1044	3685	3006
Blaine/Lino Lakes	1297	1472	1197	3966	3029
Fridley/Spring Lake/Col. Hgts.	1249	963	1012	3224	2883
Rural Far West	1394	1488	1257	4139	3054
Chanhassen/Chaska	1710	1513	1508	4731	3116
Rural Far South	1503	1234	1294	4031	3003
Lakeville	1831	1385	1540	4756	3093
Burnsville	1530	1128	1287	3945	2972
Apple Valley/Rosemount	1845	1333	1564	4742	3082
Hastings	1367	1263	1193	3823	2991
Eagan	1644	1229	1390	4263	3016
Inver Grove Heights	1531	1172	1304	4007	2984
S. St. Paul/W. St. Paul	926	982	889	2797	2878
Mendota	2180	1428	1827	5435	3157
Airport/Fort Snelling	1581	1268	1148	3997	2969
MPLS Far SE	2377	1306	1873	5556	3139
MPLS South Lakes	2141	1269	1794	5204	3093
MPLS Mid South	1297	993	1237	3527	2841
MPLS Hiawatha/River	1443	1078	1341	3862	2884
MPLS U of M	975	751	965	2691	2717
MPLS Near South	359	634	658	1651	2672
MPLS North Lakes	2223	908	2001	5132	2905
MPLS Near North	786	816	898	2500	2736
MPLS Downtown	352	708	872	1932	2702
MPLS Near NE/Dinkytown	1195	848	1139	3182	2770
MPLS North	1230	957	1145	3332	2817
MPLS NE Industrial	1416	1079	1257	3752	2881
Richfield	1952	1130	1521	4603	2961
Bloomington East	2136	1155	1614	4905	2984
Bloomington West	2776	1398	2044	6218	3143
Edina	3484	1293	2627	7404	3187
Eden Prairie	3512	1441	2524	7477	3256
Hopkins/St. Louis Park	1873	1056	1499	4428	2937
Minnetonka	3692	1366	2674	7732	3241
Lake Minnetonka	3542	1670	2609	7821	3398
Wayzata/Plymouth S.	3016	1383	2228	6627	3171

Table B.5 (Continued)

Sub-Region	Fixed Vehicle	Variable Vehicle	Business	Total Monetary	Time
Plymouth N.	3533	1291	2555	7379	3182
Golden Valley	2605	1295	1953	5853	3082
Robbinsdale/Crystal/New Hope	2079	1165	1647	4891	2992
Brooklyn Center	1851	1107	1460	4418	2948
Brooklyn Park E.	3100	1492	2270	6862	3227
Brooklyn Park W.	1997	1236	1535	4768	3001
Maple Grove	3342	1622	2397	7361	3321
Rural Far NW	2816	1734	2034	6584	3288
STP Downtown/Airport	292	828	682	1802	2713
STP East	1508	1031	1334	3873	2857
STP Near North	1028	928	982	2938	2767
STP Near NW	1143	994	1058	3195	2800
STP Near West	1201	1086	1122	3409	2837
STP Highland	1982	1352	1642	4976	3068
STP Midway	1282	989	1114	3385	2804
Maplewood	2092	1159	1627	4878	2970
Roseville	2249	1318	1724	5291	3035
White Bear Lake	2955	1590	2209	6754	3242
Arden Hills/Shoreview	2859	1759	2106	6724	3290
Mounds View/New Brighton	2348	1214	1785	5347	3014
Rural Far Southwest	1370	1432	1251	4053	3029
Shakopee/Savage	1340	1328	1247	3915	3001
Cottage Grove	1426	1091	1224	3741	2964
Woodbury/Rural East	1772	1408	1498	4678	3102
Oakdale/Rural East	1543	1158	1319	4020	2994
Stillwater	1519	1209	1342	4070	3016
Rural Far Northeast	1453	1427	1249	4129	3055
Chisago County	1118	1737	1019	3874	3280
Goodhue County	1447	1523	1167	4137	3480
Isanti County	1104	1543	982	3629	3229
Le Sueur County	1227	1586	1036	3849	3302
McLeod County	1427	1785	1148	4360	3455
Pierce County	935	1581	835	3351	3030
Polk County	885	1581	773	3239	2945
Rice County	1111	1474	1009	3594	3266
St. Croix County	1056	1580	1021	3657	3283
Sherburne County	994	1550	967	3511	3209
Sibley County	1231	1661	995	3887	3247
Wright County	1197	1490	1100	3787	3389
Average	1,751	1,299	1,448	4,498	3,059
Minimum	292	634	658	1,651	2,702
Maximum	3,692	1,785	2,674	7,821	3,480

Table B.6: Annual Per Capita Internal Costs of Transportation in 2020 (1998 Dollars)

Sub-Region	Fixed Vehicle	Variable Vehicle	Business	Total Monetary	Time
Rural Far North	1472	1842	1429	4743	3847
Ham Lake, Andover	1603	2176	1635	5414	3977
Coon Rapids	1570	1709	1465	4744	3821
Ramsey/Anoka	1447	1986	1318	4751	3852
Blaine/Lino Lakes	1630	1935	1511	5076	3883
Fridley/Spring Lake/Col. Hgts.	1606	1251	1277	4134	3691
Rural Far West	1814	1956	1587	5357	3915
Chanhassen/Chaska	2199	1987	1904	6090	3996
Rural Far South	1884	1621	1634	5139	3849
Lakeville	2273	1823	1944	6040	3966
Burnsville	1902	1477	1624	5003	3808
Apple Valley/ Rosemount	2299	1754	1974	6027	3951
Hastings	1727	1659	1506	4892	3832
Eagan	2049	1611	1755	5415	3865
Inver Grove Heights	1913	1536	1646	5095	3823
S. St. Paul/W. St. Paul	1236	1275	1122	3633	3685
Mendota	2705	1875	2306	6886	4049
Airport/Fort Snelling	1774	1678	1449	4901	3794
MPLS Far SE	2760	1709	2365	6834	4016
MPLS South Lakes	2584	1633	2264	6481	3956
MPLS Mid South	1610	1288	1562	4460	3627
MPLS Hiawatha/River	1809	1388	1693	4890	3684
MPLS U of M	1145	982	1218	3345	3466
MPLS Near South	648	797	830	2275	3406
MPLS North Lakes	2803	1151	2526	6480	3711
MPLS Near North	978	1062	1134	3174	3490
MPLS Downtown	916	885	1100	2901	3446
MPLS Near NE/ Dinkytown	1511	1084	1438	4033	3534
MPLS North	1495	1244	1445	4184	3596
MPLS NE Industrial	1728	1396	1587	4711	3679
Richfield	2263	1464	1920	5647	3794
Bloomington East	2442	1499	2037	5978	3824
Bloomington West	3145	1826	2580	7551	4031
Edina	3986	1684	3316	8986	4088
Eden Prairie	3949	1884	3186	9019	4179
Hopkins/St. Louis Park	2205	1364	1893	5462	3762
Minnetonka	4160	1784	3375	9319	4159
Lake Minnetonka	4006	2191	3293	9490	4364
Wayzata/Plymouth S.	3417	1807	2813	8037	4068

Table B.6 (Continued)

Sub-Region	Fixed Vehicle	Variable Vehicle	Business	Total Monetary	Time
Plymouth N.	3977	1684	3225	8886	4082
Golden Valley	2966	1689	2466	7121	3951
Robbinsdale/Crystal/New Hope	2411	1513	2080	6004	3834
Brooklyn Center	2144	1436	1843	5423	3776
Brooklyn Park E.	3493	1957	2865	8315	4141
Brooklyn Park W.	2282	1609	1937	5828	3845
Maple Grove	3753	2131	3025	8909	4264
Rural Far NW	3163	2280	2567	8010	4220
STP Downtown/Airport	710	1040	861	2611	3459
STP East	1771	1343	1683	4797	3648
STP Near North	1233	1204	1240	3677	3531
STP Near NW	1372	1287	1335	3994	3574
STP Near West	1464	1403	1416	4283	3622
STP Highland	2291	1777	2072	6140	3923
STP Midway	1512	1277	1406	4195	3579
Maplewood	2366	1505	2054	5925	3805
Roseville	2540	1717	2177	6434	3890
White Bear Lake	3302	2086	2789	8177	4161
Arden Hills/Shoreview	3186	2315	2659	8160	4224
Mounds View/New Brighton	2642	1576	2254	6472	3862
Rural Far Southwest	1790	1876	1579	5245	3882
Shakopee/Savage	1772	1737	1574	5083	3846
Cottage Grove	1713	1416	1546	4675	3797
Woodbury/Rural East	2115	1836	1891	5842	3977
Oakdale/Rural East	1853	1500	1665	5018	3836
Stillwater	1854	1573	1694	5121	3865
Rural Far Northeast	1749	1866	1576	5191	3917
Chisago County	1309	2257	1286	4852	4188
Goodhue County	1786	1998	1473	5257	4450
Isanti County	1189	2021	1239	4449	4121
Le Sueur County	1439	2074	1307	4820	4217
McLeod County	1567	2316	1449	5332	4417
Pierce County	1066	2067	1054	4187	3862
Polk County	981	2069	976	4026	3751
Rice County	1295	1937	1274	4506	4170
St. Croix County	1182	2067	1289	4538	4192
Sherburne County	843	2028	1220	4091	4095
Sibley County	1363	2167	1256	4786	4145
Wright County	1019	1956	1388	4363	4331
Average	2,007	1,686	1,794	5,487	3,908
Minimum	648	797	830	2,275	3,406
Maximum	4,160	2,316	3,375	9,490	4,450

Table B.7: Annual Per Capita External Costs 1998

Sub-Region	Congestion	Pollution Borne	Pollution Imposed	Other	Imposed Outside Region
Rural Far North	121	19	99	73	145
Ham Lake, Andover	127	75	219	73	212
Coon Rapids	121	454	265	73	174
Ramsey/Anoka	137	166	224	73	205
Blaine/Lino Lakes	122	173	219	73	186
Fridley/Spring Lake/Col. Hgts.	119	429	273	73	113
Rural Far West	119	12	43	70	136
Chanhassen/Chaska	122	143	156	70	202
Rural Far South	119	8	64	64	134
Lakeville	120	123	150	64	166
Burnsville	119	304	164	64	140
Apple Valley/ Rosemount	120	150	160	64	169
Hastings	119	118	180	64	156
Eagan	120	239	205	64	153
Inver Grove Heights	119	121	260	64	150
S. St. Paul/W. St. Paul	118	569	315	64	127
Mendota	122	213	483	64	202
Airport/Fort Snelling	139	43	422	88	145
MPLS Far SE	160	941	789	88	159
MPLS South Lakes	154	794	867	88	148
MPLS Mid South	134	813	679	88	96
MPLS Hiawatha/River	139	777	829	88	127
MPLS U of M	125	308	435	88	49
MPLS Near South	124	355	314	88	27
MPLS North Lakes	141	554	616	88	79
MPLS Near North	131	354	443	88	61
MPLS Downtown	125	267	285	88	44
MPLS Near NE/ Dinkytown	133	452	477	88	72
MPLS North	133	563	485	88	95
MPLS NE Industrial	136	451	536	88	122
Richfield	123	672	512	88	145
Bloomington East	123	334	312	88	143
Bloomington West	125	396	337	88	177
Edina	126	455	407	88	168
Eden Prairie	126	196	213	88	177
Hopkins/St. Louis Park	121	433	326	88	121
Minnetonka	129	280	262	88	172
Lake Minnetonka	126	70	164	88	200
Wayzata/Plymouth S.	127	260	288	88	168

Table B.7 (Continued)					
Sub-Region	Congestion	Pollution Borne	Pollution Imposed	Other	Imposed Outside Region
Plymouth N.	130	185	287	88	147
Golden Valley	125	434	497	88	169
Robbinsdale/Crystal/New Hope	129	567	410	88	150
Brooklyn Center	123	443	453	88	125
Brooklyn Park E.	151	332	476	88	189
Brooklyn Park W.	128	419	396	88	151
Maple Grove	143	218	344	88	200
Rural Far NW	131	48	233	88	194
STP Downtown/Airport	125	71	121	95	47
STP East	131	237	267	95	90
STP Near North	128	455	295	95	76
STP Near NW	129	556	359	95	92
STP Near West	132	592	455	95	105
STP Highland	144	852	667	95	156
STP Midway	130	273	402	95	90
Maplewood	119	283	269	95	125
Roseville	122	376	406	95	159
White Bear Lake	123	228	262	95	189
Arden Hills/Shoreview	125	341	448	95	218
Mounds View/New Brighton	122	391	388	95	130
Rural Far Southwest	118	21	67	76	148
Shakopee/Savage	119	98	103	76	169
Cottage Grove	118	68	122	55	134
Woodbury/Rural East	121	92	181	55	172
Oakdale/Rural East	119	99	174	55	143
Stillwater	119	85	131	55	154
Rural Far Northeast	119	33	88	55	174
Chisago County	82	13	98	121	157
Goodhue County	90	8	98	82	157
Isanti County	80	9	98	85	157
Le Sueur County	83	8	98	93	157
McLeod County	89	10	98	129	157
Pierce County	72	8	98	92	157
Polk County	69	5	98	92	157
Rice County	82	15	98	73	157
St. Croix County	83	11	98	92	157
Sherburne County	80	19	98	87	157
Sibley County	81	3	98	107	157
Wright County	87	17	98	76	157
Average	119	288	288	83	147
Minimum	69	3	76	9	57
Maximum	160	941	780	9	235

Table B.8: Annual Per Capita External Costs in 2020 (1998 dollars)

Sub-Region	Congestion	Pollution	Crashes	Other	Total
Rural Far North	372	18	92	90	168
Ham Lake, Andover	379	69	206	90	247
Coon Rapids	369	421	248	90	203
Ramsey/Anoka	426	154	209	90	237
Blaine/Lino Lakes	373	160	203	90	217
Fridley/Spring Lake/Col. Hgts.	365	398	259	90	131
Rural Far West	363	15	36	87	158
Chanhassen/Chaska	366	183	125	87	236
Rural Far South	365	7	64	78	157
Lakeville	367	112	150	78	194
Burnsville	364	326	146	78	164
Apple Valley/ Rosemount	366	140	157	78	198
Hastings	364	118	170	78	181
Eagan	365	253	182	78	177
Inver Grove Heights	364	121	254	78	175
S. St. Paul/W. St. Paul	362	657	277	78	148
Mendota	367	222	443	78	234
Airport/Fort Snelling	281	28	585	109	168
MPLS Far SE	308	863	769	109	185
MPLS South Lakes	290	857	777	109	172
MPLS Mid South	262	733	671	109	112
MPLS Hiawatha/River	263	782	750	109	148
MPLS U of M	243	217	478	109	56
MPLS Near South	239	359	294	109	32
MPLS North Lakes	265	644	536	109	92
MPLS Near North	270	267	502	109	70
MPLS Downtown	241	354	213	109	52
MPLS Near NE/ Dinkytown	255	448	437	109	83
MPLS North	257	479	481	109	111
MPLS NE Industrial	260	434	507	109	142
Richfield	368	642	482	109	168
Bloomington East	369	302	302	109	167
Bloomington West	371	344	341	109	205
Edina	372	422	407	109	195
Eden Prairie	374	158	229	109	207
Hopkins/St. Louis Park	368	442	308	109	139
Minnetonka	376	231	281	109	201
Lake Minnetonka	376	56	175	109	233
Wayzata/Plymouth S.	380	218	289	109	195

Table B.8 (Continued)

Sub-Region	Congestion	Pollution	Crashes	Other	Total
Plymouth N.	389	147	293	109	171
Golden Valley	374	371	493	109	197
Robbinsdale/Crystal/New Hope	393	500	389	109	174
Brooklyn Center	377	392	431	109	145
Brooklyn Park E.	482	245	517	109	220
Brooklyn Park W.	393	336	392	109	175
Maple Grove	459	155	380	109	231
Rural Far NW	404	33	263	109	226
STP Downtown/Airport	240	96	85	117	56
STP East	261	200	267	117	105
STP Near North	251	379	289	117	89
STP Near NW	251	491	346	117	106
STP Near West	255	560	426	117	122
STP Highland	281	747	653	117	181
STP Midway	252	248	378	117	103
Maplewood	365	235	267	117	145
Roseville	367	333	389	117	184
White Bear Lake	371	175	280	117	221
Arden Hills/Shoreview	373	264	475	117	254
Mounds View/New Brighton	367	331	385	117	151
Rural Far Southwest	363	28	52	94	172
Shakopee/Savage	364	135	81	94	198
Cottage Grove	363	76	107	65	157
Woodbury/Rural East	366	111	141	65	201
Oakdale/Rural East	364	127	125	65	167
Stillwater	364	101	109	65	180
Rural Far Northeast	365	39	67	65	203
Chisago County	228	13	81	150	182
Goodhue County	251	7	81	101	182
Isanti County	223	8	81	106	182
Le Sueur County	231	6	81	115	182
McLeod County	248	9	81	160	182
Pierce County	200	8	81	114	182
Polk County	191	4	81	114	182
Rice County	227	12	81	90	182
St. Croix County	229	9	81	114	182
Sherburne County	220	22	81	108	182
Sibley County	225	3	81	132	182
Wright County	241	16	81	94	182
Average	326	326	326	123	209
Minimum	191	3	55	10	205
Maximum	482	863	150	10	4,420

Appendix C: The Costs of Alternative Transportation Systems

The purpose of this appendix is to demonstrate how to use information on the costs of transportation to help in evaluating transportation alternatives. Information on the full costs of transportation is contained in *The Full Costs of Transportation in the Twin Cities Region* and information on how these costs are distributed across geographic regions and across income groups is contained in the body of this report. A list of major transportation cost categories is shown in Table C.1. This appendix demonstrates how to use data to evaluate two transportation alternatives— maintaining the status quo and improving express bus service between downtown Saint Paul and Stillwater. We examine both the efficiency and the equity of the alternatives. The alternatives were selected for illustrative purposes only, and our purpose is not to (i) identify promising policies, (ii) identify all of the relevant issues associated with particular policies, or (iii) reflect on the desirability of any actual projects.

A project is said to enhance economic efficiency if it increases the net social benefits to society. Economists generally regard enhancing efficiency as an important factor in evaluating the desirability of a project because, if a project increases efficiency, then it is possible in theory to implement the project and to make every member of society better off. A standard method of examining the efficiency of a project or policy is by conducting a cost-benefit analysis (CBA). Cost-benefit analyses merely account for all of the costs and all of the benefits of a project so they can be compared. The technique is a standard method for evaluating projects, and has been for some time.[32]

While a project that enhances efficiency can, in theory, make every person in society better off, most efficiency-enhancing projects will make some people better off and some people worse off. Understanding how the benefits and costs of projects are distributed across people is necessary for evaluating the equity, or fairness, of a project. Equity is important in its own right, and often it is also politically important. The equity of a project is seldom evaluated in isolation, however, and often must be examined along with the equity of other proposed projects. For this and other reasons, evaluating equity is generally more problematic than evaluating efficiency. We examine equity by focusing on the effects of the alternatives on travelers and non-travelers, on people in different income groups, and on people in different geographic locations.

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[32] Sen (2000) discusses cost-benefit analysis. Prest and Turvey (1965) provide a much earlier overview of the technique.

One can divide a policy-evaluation process into three steps

- predict the effects of the policy on travelers and the general public,
- determine the changes in costs and benefits that result from the policy's effects, and
- examine the efficiency and equity of the project to determine if it should be adopted.

We focus primarily on the second step, by showing how to use cost data to determine the changes in costs and benefits. We focus on the third step mainly to help show why we examine the types of cost data that we do, and show how to assemble data on cost changes in ways that are useful for evaluating projects. We assume that the effects of the policy, and especially the changes in travel behavior, are given. Travel behavior is crucial to evaluating alternative transportation projects, affecting both the magnitude and distribution of costs. We try to make plausible assumptions about effects on travel behavior, but we do not attempt to analyze travel behavior because it is not the focus of our study.[33] We focus instead on determining costs once changes in travel behavior are given.

We analyze the costs of the alternatives both for users of transit and for non-users. Because we identify and quantify a wide range of costs, we are not able go into great detail when examining any specific type of costs. In addition, we spend little time examining costs, such as capital and operating costs. These types of costs tend to be almost completely project-specific.[34] Once a project is well-defined, it is usually possible to make relatively good estimates of these costs, but knowing them is usually of little value for people trying to examine other transportation alternatives. We also spend little time examining the uncertainty, or risk, associated with the alternatives because that would greatly complicate our analysis. Our initial study of the full costs of transportation provided a range of estimates for each type of cost, but rigorously examining risks generally requires a great deal of additional data on the alternatives.[35]

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[33] Background on travel demand models and their use in the Twin Cities region is contained in Barnes (1999).

[34] Time costs, for example, are less project-specific because the value of an hour of time is often similar across projects.

[35] Data on the potential for construction delays, for example, or data on the expected range of economic variables.

Table C.1: Major Transportation Cost Categories
Governmental Costs (costs borne by any unit of government)
Streets and Highways (construction and maintenance)
Transit (capital and operating)
Parking (free or subsidized off-street parking)
Law Enforcement and Safety
Environmental Protection and Cleanup
Energy Security
Internal Costs (costs borne by the person who causes them)
Fixed Costs of Vehicle Ownership
Variable Costs of Vehicle Operation
Transit Fares & Travel Time
Travel Time in Private Vehicles and Other Personal Time
Crashes
Parking and Drives
External Costs (costs not borne by governments or the person who causes them)
Congestion
Crashes
Air Pollution and Global Warming
Petroleum Consumption
Noise, Fires, and Robberies

The next three sections of this appendix cover the steps of policy evaluation discussed above. The next section describes the alternatives in more detail, including our assumptions about the effects of the alternatives on travel behavior. Section 3 quantifies the costs and benefits of the alternatives. Section 4 discusses the efficiency and equity of the alternatives. Section 5 summarizes this appendix and discusses some of the strengths and weaknesses of using our full cost data for project evaluation.

1 The Alternatives

We will examine the alternative policies of the maintaining the status quo and improving express bus service between downtown Saint Paul and Stillwater. The improvement will increase the frequency of bus service, but will not increase operating speeds. Assume that the main effect of the service improvements will be to shift riders from autos to buses. The improved service alternative was selected for illustrative purposes. It is not our intention to identify promising policies or to reflect on the desirability of any actual projects.

Our goal is merely to show how the cost data contained in previous studies can be used to help evaluate transportation alternatives.

While the alternatives were selected for illustrative purposes, they do provide at least two advantages. One is that, because improving transit service reduces auto trips, the alternatives allow us to examine the costs of auto use. Auto use accounts for a large share of the full costs of transportation and was a major focus of our previous work. A second advantage of the alternatives is that they allow us to ignore infrastructure costs. This greatly simplifies our analysis because analyzing the costs of long-lived infrastructure is difficult. It does not, however, reduce the usefulness of the data in our previous work, because that work focused almost exclusively on aggregate annual infrastructure costs and not the lifecycle costs of particular types of infrastructure.

The first alternative is maintaining the status quo. We assume that the status quo is consistent with the transportation costs and the travel behavior assumptions made in Anderson and McCullough (2000). In particular, we assume that the trends used in making projections for 2020 hold.

The second alternative is to improve express bus service between Stillwater and downtown Saint Paul, beginning in January 2002. We assume that the improvement results because five additional buses will be employed during peak travel periods. We assume that no additional capital investments (parking lots or bus shelters, for example) will be needed. Usually, expectations about the effects of improved service on travel behavior are based on the results of a travel-demand model. We simply make assumptions about travel behavior, because we do not feel that having more realistic estimates would help us to better demonstrate how to use our cost data.[36] We assume that the improved service will attract 500 additional round-trip riders to the route, and that this ridership will not grow over time. Of the 500 riders, 400 are assumed to have formerly made the trip alone in private vehicles and 100 are assumed not to have traveled previously. The 100 additional riders make the trip because the improved service makes the trip more attractive to them. It is assumed that none of the 500 additional riders switch from other transit routes. Each one-way trip is 20 miles and it is assumed that private vehicles formerly making the trip traveled 16 miles on highways and four miles on other roads. The transit fare for each one-way trip is two dollars. Table C.2 provides a summary of the alternatives. Additional assumptions about travel demand are discussed, as they are needed, throughout this appendix.

[36] Part II of the Transportation and Regional Growth Project examines travel demand. See Barnes (1999).

Table C.2: The Alternatives		
Daily (Round Trip)	Alternative #1 Current Baseline System	Alternative #2 Improved Bus Service
Additional Auto Passengers	400	0
Additional Auto Trips	400	0
Length of Round Trip	40 miles	40 miles
Additional Auto Vehicle Miles	16,000	0
Additional Bus Passengers	0	500
Additional Fare Revenue	$0	$2,000
Additional Buses	0	5
Duration of Auto Round Trip	80 minutes	80 minutes
Duration of Bus Round Trip	120 minutes	110 minutes
Average Wait for Bus	20 minutes	10 minutes
Average Surplus of New Travelers	$0.00	$1.00

2 The Costs and Benefits of the Alternatives

In this section we quantify the costs and the benefits of improving transit service (or the benefits and costs of maintaining the status quo). The alternatives affect the following main categories of costs and benefits.

- Costs of Improving Transit
  - Increased costs to the government of providing transit (net of fare revenue)
  - Increased internal costs of additional bus passengers
- Benefits of Improving Transit
  - Reduced governmental costs of general services
  - Reduced internal costs of operating (but not owning) vehicles
  - Reduced external costs resulting from operating private vehicles
  - Consumer surplus for new and current transit passengers

The changes in auto and bus use are not large, compared to their aggregate usage, so we use marginal cost information to calculate changes in total costs. The marginal cost of travel is the cost of one additional unit of travel (usually one extra trip or one extra vehicle mile traveled). We determine the total change in transportation costs by multiplying the change in the amount of travel by the marginal cost of travel. For example, if the current cost of parking downtown is $3.00, and the number of vehicles parking downtown is reduced by 400, then the cost savings is $1,200.[37]

[37] A marginal cost approach might not be accurate if very large changes in travel were to occur. If, for example, the number of vehicles parking downtown were to decline by 5000, the change might be large enough to affect the cost of parking.

We need to have a common perspective from which to compare the alternatives. We calculate the costs and benefits on the alternatives over a ten-year period from January 2002 until December 2011. The reason we use a ten-year period is that we assume that buses last for ten years before they need to be replaced. Besides buses, there is no other difference in capital spending between the alternatives to complicate our work. We will compare the *present value* of costs and benefits over the ten-year period. The present value of a future cost is the amount society would pay now to avoid that cost. Because assets available now can be invested, and thereby made to grow, society should value current costs more highly than future costs. This is reflected in the *discount rate*. We assume that the discount rate is three percent. This means that the value of a dollar received *n* years from now is only $\$1/1.03^n$.

We make some simplifying assumptions about the growth of costs and benefits over the ten-year period that we analyze. When quantifying costs and benefits, one should examine *real* costs and ignore inflation. Inflation drives up costs and benefits, but it also drives up incomes, so real costs and benefits do not change. Even without inflation, however, costs may grow. Our previous work found it likely that many types of transportation costs will grow, in real terms, at approximately one percent per year.[38] A notable exception is congestion, which is expected to grow at three percent per year. To simplify our analysis, unless otherwise stated, we assume that all costs and benefits grow at one percent per year, except for congestion, which is assumed to grow at three percent per year.

The Costs of Improved Transit Service (Benefits of the Status Quo Alternative)

We divide governmental costs into six main types: (i) the construction and maintenance of streets and highways, (ii) transit capital and operating expenditures, (iii) free or subsidized off-street parking, (iv) law enforcement and safety, (v) environmental protection and cleanup, and (vi) energy security. We assume that the main added costs of improved transit service will be the capital cost of purchasing the buses and the cost of operating the buses. We assume that no additional capital expenditures are made, expenditures for bus shelters or commuter parking lots, for example. Other types of governmental costs are not expected to increase significantly because of the additional bus service. We assume that roads are not damaged by buses or by cars because most research shows that heavy axle-loadings cause most of the damage to roads.[39] Additional parking for private vehicles will not be needed. We also assume that increases in costs such as law enforcement, environmental protection, and energy security will be small enough to ignore, because so few buses will be put into service.[40]

[38] See Anderson and McCullough (2000), page vii, which says that most costs are expected to grow at approximately the same rate as regional income, which is growing at one percent per year.
[39] See Newbery (1988) for a discussion of the damage to roads done by heavy trucks. Buses are heavy relative to autos on a per axle basis, but few additional vehicle miles of bus travel are added.
[40] While these costs may be larger for buses on a per vehicle basis than they are for private vehicles, on an aggregate basis these costs are almost always smaller because there are so many more private vehicles.

The capital cost is assumed to be $100,000 per bus. The buses will be purchased in January 2002 so no discounting is needed. We assume that the government's cost of operating each bus is $200 per day (this cost equals government expenditures minus fare revenues). This works out $500,000 per year because we assume that each of the ten buses is operated 250 days per year. We assume that these operating costs grow in real terms at one percent per year. The present value of the governmental costs of operating the buses is $4,540,000. The total governmental costs of improving bus service over the ten-year period are $5,040,000.

The internal costs of improving transit service are the costs that people bear themselves. There are six types of internal costs listed in Table C.1, but only two of them apply to transit: transit fares and transit travel times and crashes. The other types of costs apply only to private vehicles. For simplicity, we assume that buses are safe enough that we can ignore the costs of crashes.[41] The only internal costs of improving transit service that we examine, therefore, are the costs of transit fares and of travel time associated with transit. We only examine these changes in internal costs for the people who switch from driving private vehicles.[42] Transit fares are set at $2 for each one-way trip. We assume that fares will not increase over in the first ten years of the project, so that they will stay equal to $2 in real, not nominal, terms. For simplicity we assume that fares equal $2 in real terms, not nominal terms. Fare collections will be $1,600 daily, $400,000 yearly, and the present value of these collections over ten years will be $3,463,000.

Calculating transit time costs is difficult because people generally place different values on time waiting for transit, time walking to and from transit, and time riding on transit. We did not spend much time analyzing transit time costs in our previous report because transit travel time accounted for such a small share of total costs. As we did in our previous work, we assume that the average rider values all types of transit time at $5.33 per hour. The average one-way trip takes 40 minutes while in transit, and we assume that an extra 15 minutes is needed to get to and from the bus. Total travel time for a round trip is 110 minutes per day. The daily value of this time is $3,900 and the yearly value is $977,000. The present value over ten years, given that time costs grow at one percent per year, is $8,874,000. The additional internal costs of the improved service alternative are $12,337,000.

The external costs of transportation received special attention in our previous work. This was both because external costs have sometimes been neglected when examining transportation costs and because external costs lead to special equity and efficiency concerns. Our previous work found that the most important types of external costs were congestion, crashes, air pollution, and petroleum consumption. While these costs are important for private vehicles, they are not large on an aggregate basis for transit vehicles. Our scenario

[41] This is mainly because of a shortcoming in our existing data. Because almost all of our data pertained to auto crashes, we never tried to quantify the costs of bus crashes. While buses are safe relative to private vehicles, they are still involved in crashes of course.

[42] We determine surpluses from new riders and existing riders, instead of calculating their current costs and benefits explicitly.

removes 400 private vehicle round trips and replaces them with only 10 transit-vehicle round trips.[43] Because so few transit vehicle trips are made, we assume, as we did for the general governmental costs of law enforcement and safety and environmental protection and cleanup, that transit-related external costs are zero.

Benefits of Improved Transit Service (Costs of the Status Quo Alternative)

Six main types of governmental costs are listed in Table C.1. We assume that improving transit will *not* lead to reductions in the first three types of costs—streets and highway, transit, and parking. Improving transit is not expected to reduce the costs of maintaining streets and highways because private passenger vehicles are light enough that they cause very little damage to roads. The costs of transit will not decline. We also assume that free or subsidized off-street parking costs will not decline. Most such parking is at government office buildings and, while there are many such buildings near downtown Saint Paul, we feel that parking costs will not decline because (i) most parking is provided for visitors, not workers and (ii) many commuters do not work for the government.

We do feel that reducing auto trips will lead to declines in three types of governmental costs—law enforcement and safety, environmental protection, and energy security. Unfortunately, it is difficult to determine the marginal values of these costs. Providing these services is probably subject to increasing returns, so cutting traffic volumes by half probably would not lead to a halving of law enforcement costs. Some patrolling needs to occur even on almost deserted streets. Research spending to determine the proper standards to set for fuel economy or emissions control devices, might not decline at all if traffic volumes were cut by half.

To estimate the reduction in law enforcement costs, we single out highway patrol expenditures and assume that they vary proportionately with vehicle travel. This means we ignore the fixed costs associated with the highway patrol (and hence overestimate the amount by which these costs would decline) but we compensate by ignoring other types of law enforcement costs. These other costs include those of routine patrol by local police and some of the costs of running the court and penal systems. One reason we ignore these types of costs is that we expect that commuters are not well represented among the people who commit serious traffic offenses (and hence who impose most of the costs on the court and penal systems). A reduction in vehicle travel of 16,000 miles per day would reduce total travel in the Twin Cites region by approximately 1/60th of one percent. Based on this, highway patrol expenditures would decline by $17,000 annually and the present value of this decline over ten years would be $156,000.

We feel that the costs of environmental protection vary with travel, but only to a limited extent. Government programs to research ways to cut pollution, pollution monitoring, and site cleanup probably do not vary much, especially in the short run, as travel declines. Because of this, we ignore the benefits derived to reduce environmental protection costs and compensate for this by overestimating energy security costs. Energy security covers four types of costs:

[43] We assume one round-trip per bus in the morning peak and one in the evening peak.

government-sponsored research and development, maintaining the Strategic Petroleum Reserve, subsidies for ethanol, and the military protection of oil supplies. The costs of maintaining the Strategic Petroleum Reserve and ethanol subsidies should be closely tied to fuel consumption. The costs of research and development and protecting oil supplies are subject to returns to scale, but it is difficult to say to what degree. To compensate for not including the costs of environmental protection, we assume that all energy security costs vary proportionately with fuel consumption. A reduction in fuel consumption of 1/60th of one percent would lead to a decline in energy security costs of $11,000 per year and $99,000 over ten years. The total benefits because of reductions in governmental costs are $255,000. Note that a share of these cost reductions accrue to the Federal government, and not to the State of Minnesota or to local governments.

The internal cost of operating private vehicles will decline for the people who switch from driving alone to using buses. Table 1 identifies six types of internal costs (i) fixed costs of vehicle ownership, (ii) variable costs of vehicle operation, (iii) transit fares and travel time, (iv) travel time in private vehicles and other personal time, (v) crashes, and (vi) parking and drives. It seems unlikely that improved transit service would lead to an important reduction in vehicle ownership.[44] Because of this, we do not think that the fixed costs of vehicle ownership or the costs of residential parking and drives will decline. Neither transit fares nor transit travel time declines. That leaves three categories from which we derive internal benefits—the variable costs of vehicle operation (including fees for parking), travel time costs, and the costs of crashes.

The variable costs of vehicle operation—the costs of fuel, oil, and maintenance—vary approximately in proportion with vehicle miles traveled. Fuel costs can be volatile in the short run, but over the long run they have been fairly stable so we assume that they grow at only one percent a year. We estimate that the decline in vehicle miles traveled will reduce the costs of fuel and oil by $165,000 per year.[45] We estimate that maintenance costs will decline by $252,000 per year. The present value of both of these costs over ten years will be $3,791,000.

The costs of crashes are also assumed to vary with vehicle miles traveled.[46] We estimate that crash costs will decline by $221,000 per year and the present value of these costs will be $2,003,000. We do not calculate the costs of insurance, because we assume that most of the variable costs of insurance are paid to cover crashes.[47] We calculate only variable costs, so we do not include the fixed,

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[44] This is especially true in a place like Stillwater, which is outside of the central cities. Even in the region as a whole, there is approximately one vehicle for every person who is old enough to drive.

[45] This amount does not include the fuel taxes. Taxes are not *opportunity* costs (i.e., they do not represent a real loss of resources to society), they are merely transfers.

[46] If enough data was available, we could probably improve our estimates of crash costs by examining crash rates on the specific roads and at the times that our 400 drivers would have traveled.

[47] We do not want to "double-count" the costs of insurance (i.e., to calculate them as costs of crashes and of insurance). A small share of the variable costs may also cover vehicle thefts.

overhead costs of insurance. Our estimate of the total costs of crashes includes costs paid for by insurance, out-of-pocket costs, and non-monetary costs such as those of pain and suffering.

Time costs typically account for a large share of total transportation costs. Based on our previous work, we assume that the average value of travel time is $5.33 per hour and that this value will grow by one percent per year. Each round trip takes 80 minutes, so the daily value of time is $2,800 and the yearly value is $711,000. Over ten years the present value will be $6,454,000.

We assume that each driver had previously spent three dollars per day on parking. Parking costs $300,000 per year, and the present value of will be $2,724,000. The total internal benefit to drivers over ten years is $14,972,000.

Internal benefits also accrue to the 100 people who did not previously travel.[48] We do not calculate their total benefits and total costs, we just estimate their average net benefit. This net benefit is the difference between what they pay to travel in fares and time, and the value they place on travel. We assume that the average net benefit, which would usually be determined from a travel demand model, will be $1 per day for each of the 100 new travelers. This works out to $25,000 per year and a ten-year total of $227,000.

Finally, internal benefits also accrue to current bus passengers on the route because the increased frequency of buses may reduce their waiting times or to allow them to travel at more convenient times. We assume that the aggregate benefit to current bus passengers will be $200 per day. This works out to $50,000 per year and $454,000 over ten years. The total internal benefits of the project over its ten-year life span will be $15,653,000.

As mentioned above, the external costs of transportation receive special attention because they lead to special equity and efficiency concerns. External costs are costs that are not paid for by the people who impose them. The people who switch from driving to riding the bus will reduce external costs and bring benefits to other drivers and the general public. We divide external costs into five main types (i) congestion, (ii) crashes, (iii) air pollution and global warming, (iv) petroleum consumption, and (v) noise, fires and robberies.[49] The costs of noise, fire, and robberies are small compared to the other four types of costs on an aggregate basis.[50]

Congestion is one of the four major types of external costs. The marginal cost of congestion is the amount that *all* other drivers will save if one driver makes one

[48] These people must value the trip at more than it costs them, or they will not travel.

[49] This classification of external costs is fairly standard. Global warming, while its costs are very difficult to quantify, is generally agreed to be a potentially significant external cost of transportation. Petroleum consumption externalities are more controversial. They include two effects of oil consumption (i) high oil consumption in the US driving up world oil prices and (ii) reliance on oil making the US economy more vulnerable to recessions.

[50] Unlike other external costs, the external costs of robberies (the damage done by vehicle thefts and break-ins) are costs imposed *on* drivers by the general public, not costs imposed *by* drivers on other drivers or the general public.

less trip. The marginal cost of congestion is often significantly larger than the average cost of congestion. Based on Anderson (1996), we estimate that the marginal cost of congestion will be five cents per mile on average on the freeways that the drivers are likely to use, two cents per mile on the other roads that the drivers are likely to use. Given that we estimate that the average value of travel time is $5.33 per hour, the daily benefit will be $640 on freeways and $64 on other roads. The total yearly benefit will be $176,000. Congestion costs are different from most other costs because they have been growing so quickly. We assume that congestion costs will grow at three percent in real terms. Since the discount rate is also three percent, the present value of congestion costs over ten years will be $1,760,000.

We assume that the external costs of crashes vary in proportion with vehicle miles of travel. This leads us to estimate that external crash costs will decline by $35,000 per year and that the present value of these cost reductions will be $314,000.[51] We also assume that the costs of petroleum consumption and noise vary proportionately with vehicle miles of travel. We estimate that reducing private vehicle travel will lead these costs to decline by $53,000 per year and by $468,000 over ten years. The external costs of vehicle fires and robberies are small and may depend more on vehicle ownership than vehicle miles of travel, so we assume that they are zero.

The costs of air pollution, and especially the costs of global warming, are difficult to quantify. The marginal costs of these types of pollution are likely larger than the average costs, but Delucchi concluded, based on models of air pollution costs, that they are not much larger.[52] To simplify our work, we assume that the costs of both air pollution and global warming are proportional to vehicle miles of travel. This leads us to conclude that the reductions in private vehicle travel that would result from the improved transit alternative would reduce air pollution and global warming costs by $157,000 a year. The present value of the benefits over ten years would be $1,393,000. It should be noted that our estimates of the costs of air pollution are generally more uncertain than our estimates of other types of costs. We assume that the costs of noise decline by $23,000 because of the reduction in private vehicle travel.[53] The present value of the total external benefits of the transit improvement over ten years would be $3,953,000. Table C.3 contains a summary of the costs of benefits of the transit improvement alternative.

[51] In Anderson and McCullough (2000), the external costs of congestion and crashes were nearly equal. We find the external costs of congestion to be much larger mainly because marginal congestion costs are typically three to five times larger than average congestion costs.

[52] Delucchi conducted a comprehensive study of the full costs of transportation in the United States (Delucchi (1996)) and, as a part of this study, estimated the costs of air pollution in the Twin Cities.

[53] This reduction is based on the assumption that noise costs decline in proportion to vehicle miles of travel.

3 Evaluating the Alternatives

Before examining the alternatives in more detail, we look at the effects of improving transit service on the new transit passengers. This does will not give a complete picture of the alternatives because it ignores external and governmental costs, but it will help us to put the alternatives in perspective and to check that our results are reasonable.

We assume that the average driver who would switch to transit under the alternative will make 250 round trips per year and 2500 round trips in ten years. The average daily internal cost of using transit for each driver is $12.15 ($4.00 in bus fares and $8.35 in travel time). The average internal benefit of switching to transit is $14.95. Almost half of this benefit results from saving time, $3.00 from parking, and the remainder from reduced vehicle operating costs and crash costs. To these costs we should also add the costs of fuel taxes. We assume that the state fuel tax will remain at twenty cents per gallon and the federal fuel tax will remain at 18.3 cents per gallon. This means drivers will also save approximately one dollar per day in fuel taxes. Overall, drivers will receive net benefits of $3.65 per day by switching from private vehicles to autos. Note that the fact that drivers benefit from switching to transit is consistent with the assumption that drivers actually would switch to transit given the option.

A gain to drivers of $3.65 per day is also consistent with our assumption that new travelers will receive a surplus of $1.00. The $1.00 gain means that they pay the same $12.35 in costs as drivers and they value the trip at $13.35. If they had valued the trip at more than the approximately $15.95 that it takes to make the trip in a private vehicle, it would seem surprising that they would not make the trip under the status quo alternative.[54]

Efficiency

A project is said to enhance economic efficiency if it increases the net social benefits to society. Economists generally regard enhancing efficiency as an important factor in evaluating the desirability of a project. The reason is that such projects can, in theory, make everyone in society better off. A project that would produce net social benefits of $100, by increasing Jack's income by $120 and decreasing Jill's income by $20 could also increase both Jack's and Jill's incomes by $50. If a project actually would make everyone better off, it is hard to argue that it should not be carried out.

A standard method of examining efficiency is by conducting a cost-benefit analysis (CBA). Cost-benefit analyses merely account for all of the costs and all of the benefits of a project so that they can be compared. Cost-benefit analyses are designed to account all costs and benefits including (i) indirect costs and benefits, (ii) costs and benefits to all members of society, and (iii) costs and benefits accrued at different times.

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[54] It is possible that the new travelers do not have access to a private vehicle, but the great majority of people in the region do have access to a private vehicle.

Our alternatives were relatively easy to evaluate because we have good data on the costs of transportation in the region and how those costs will change over a ten-year period. Table C.4 summarizes these cost and benefits. The project is efficient because the total benefits are larger than the total costs by $2,484,000.

Table C.3: The Costs and Benefits of a Transit Improvement
(the present value in January 2002, of the costs and benefits from January 2002 to December 2011 in 2001 dollars)

	Costs	Benefits
Governmental Costs and Benefits		
Streets and Highways	$0	$0
Transit	$5,040,000	$0
Parking	$0	$0
Law Enforcement & Safety	$0	$156,000
Environmental Protection & Cleanup	$0	$0
Energy Security	$0	$99,000
Total Governmental	*$5,040,000*	*$255,000*
Internal Costs and Benefits		
Vehicle Operation	$0	$3,791,000
Transit Fares & Travel Time	$12,337,000	$0
Travel Time in Private Vehicles	$0	$6,454,000
Crashes	$0	$2,003,000
Parking	$0	$2,724,000
Surplus to New Travelers	$0	$227,000
Surplus to Current Transit Passengers	$0	$454,000
Total Internal	*$12,337,000*	*$15,653,000*
External Costs and Benefits		
Congestion	$0	$1,760,000
Crashes	$0	$322,000
Air Pollution and Global Warming	$0	$1,4426000
Noise	$0	$23,000
Petroleum Consumption	$0	$445,000
Total External	*$0*	*$3,953,000*
Total Costs and Benefits	*$17,377,000*	*$19,861,000*

Our goal is not so much to conduct a thorough cost benefit analysis, as it is to show how cost data can be used, but there are a few general points we should make about the efficiency of this project. First, the analysis depends on the underlying travel behavior assumptions. If demand declines by 35 percent or more, then the project becomes inefficient.[55] Second, we have not analyzed the

[55] That is, if the improved service did not general 500 new transit riders per day, and instead generated less than 315 new transit riders per day. (This assumes that the proportion of drivers switching to transit to new travelers is constant at four to one.)

risks of the project. The project will look less promising if there is a good chance that we have overestimated travel demand or underestimated governmental costs. The project will look more promising if we have underestimated external costs. While we feel that we have developed good estimates of the external costs that we have quantified, it is possible that the costs of air pollution and global warming are much higher than we have estimated. Third, there are some costs that we have not been able to quantify. We have not, for example, been able to place values on the water pollution or the damage to the natural habitat that are caused by private vehicles.

Equity

While a project that enhances efficiency can, in theory, make every person in society better off, most efficiency-enhancing projects will make some people better off and some people worse off. Understanding how the benefits and costs of projects are distributed across people is necessary for evaluating the equity, or fairness, of a project. Fairness is important in it own right and also for political reasons. A policy might be rejected because, while it would enhance efficiency, it would adversely affect low-income people. Another efficiency enhancing policy might be rejected because most of its benefits would go to people in one political jurisdiction and most of its costs would be borne by people in another jurisdiction. Usually, however, it would *not* be best to reject an efficiency-enhancing project because it is not equitable. It would be better to find a way to implement the project that would make most or all people better off.

While it may seem natural to examine equity when evaluating a project, there is no simple or widely agreed upon method of evaluating equity. Examining equity is complicated for at least three reasons. First, effects on various subgroups must be determined, but there are any number of potential groups that could be examined depending on your concerns. Groups could be established based on income, race, geographic location/political jurisdiction, or by mode of travel. How groups are defined can determine whether a project seems fair. Second, notions of what is fair are not as clear-cut. Is a project fair if it provides equal benefits to people in different income groups? Should a project give larger benefits to people in low-income groups that to people in high-income groups? Is a project acceptable if it helps most people in low- and high-income groups, but harms most people in middle income groups?

Third, and particularly problematic for transportation projects, evaluating equity should be done in a broad policy context. A typical efficiency-enhancing project may benefit a large number of people and harm a moderate number. A program that implements many efficiency-enhancing projects may benefit almost everyone, however, because many people that are harmed by one project will gain more from others. This problem is further complicated for transportation policy-makers, because the main goal of transportation policy is not, and probably should not be, to alleviate social inequity. This is not to say that alleviating social inequality is not a valid goal of government policy. It is merely that it would usually be better to use other types of government policies (especial tax and welfare policies) to reduce inequality than it would be to use transportation policies. In any event, trying to determine whether one project is equitable given a broader set of policies, or trying to determine whether there are ways to implement a project and compensate those who are hurt by the project, means that a project must be examined in a larger context. This can greatly complicate the evaluation of a project.

Table C.4: Summary of the Costs and Benefits of a Transit Improvement
(the present value in January 2002, of the costs and benefits from January 2002 to December 2011 in 2001 dollars)

	Costs	Benefits
Governmental	$5,040,000	$255,000
Internal for Drivers of Private Vehicles	$12,337,000	$14,792,000
Internal Surplus to New Travelers	$0	$227,000
Internal Surplus to Current Transit Passengers	$0	$454,000
External	$0	$3,953,000
Total	$17,377,000	$19,861,000
Net Social Benefits		$2,484,000

We examine equity from three perspectives—effects on travelers and non-travelers, effects on people in different income groups, and effects on people in different geographic locations. Our previous work, Anderson and McCullough (2001), divided the people of the region into nine groups based on income and vehicle ownership and 78 groups based on geographic location. Because of the large number of groups, we do not break down costs and benefits for each group. Instead we explain the patterns that we expect to find in the ways costs and benefits vary across groups, and we discuss methods for determining these costs and benefits for various groups.

Travelers and the General Public

We define travelers to include two groups (i) the new transit riders and (ii) other people who travel on the same roads at the same times as the former auto drivers who switched to using transit. This latter group benefits from the reduction of some types of external costs. Other people, which we define as the general public, also are affected. People may be affected if they (i) pay taxes to support general government services impacted by the alternatives; (ii) are impacted by the former auto drivers who switched to using transit even though they do not travel on the affected roads; and (iii) live outside of the Twin Cities region and are affected by transportation externalities. The groups "travelers" and "the general public" are not mutually exclusive.

At the beginning of this section on evaluating the alternatives, we examined the effects of improving transit service on the new transit passengers. We found that the people who switched from driving to using transit were made better off by approximately $3.6 million, one million dollars of which came in the form of fuel tax savings. Existing passengers who use the route during peak travel times were made better off by $454,000 and new passengers by $227,000.

Governmental costs rise by approximately $4.8 million dollars and fuel tax revenues of one million dollars are lost. Somehow the government will need to raise an additional $5.8 million. In the absence of a specific tax plan for raising the money for the transit improvements, the money can be thought of as coming from the general public. The project also produces approximately $4.0 million in external benefits. The $1.8 million in congestion benefit accrues entirely to other travelers. The $322,000 saving in crash costs is divided between drivers and pedestrians and bicyclists, and somewhat more than one-half of these benefits probably go to drivers.[56] The $1.4 million benefits of air pollution reduction accrue mainly to people in sub-regions near where the vehicle-trips were eliminated. Approximately $140,000 of the air pollution benefits result from reduced global warming, and almost all of these benefits go to people outside of the region. Of approximately $74,000 in air pollution benefits resulting from reduced damage to crops and forests, perhaps $67,000 accrues to people outside the region. Approximately 99 percent of the petroleum consumption benefits go to people outside of the region.

Table C.5 summarizes the costs and benefits from travelers and non-travelers. The travelers who switch to transit or continue using transit gain approximately $4.3 million in benefits and other travelers along the route gain approximately $1.9 million. The government pays almost $4.7 million in additional costs and loses approximately on million in revenues. Finally, residents of the region gain almost $1.3 million (mostly because of reduced air pollution) and residents of other regions gain $600,000 (mostly because of reduced petroleum consumption costs).

[56] Anderson and McCullough (2000) found that 53 percent of external crash costs were incurred by drivers (Table 6.8, page 129). This probably underestimates the share of benefits that go to drivers for the transit alternative, however, because most of the reduction in travel occurred on freeways and freeway travel imposes few costs on pedestrians and bicyclists.

Table C.5: The Net Costs and Benefits of a Transit Improvement for Travelers and the General Public (the present value in January 2002, of the costs and benefits from January 2002 to December 2011 in 2001 dollars)		
	Net Costs	Net Benefits
Net Benefits to Travelers		
Net Benefits to People Who Switch from Driving		$3,635,000
Net Benefits to New Transit Riders		$227,000
Net Benefits to Current Transit Riders		$454,000
Benefits to Drivers on Affected Routes		$1,931,000
Total Net Benefits to Travelers		*$6,247,000*
Net Costs and Benefits to the General Public		
Net Cost of Government Expenditures	($4,685,000)	
Cost of Lost Fuel Tax Revenue	($1,000,000)	
Local Benefits from Reduced External Costs	$1,254,000	
Non-Local Benefits from Reduced External Costs	$648,000	
Total Net Costs to Non-Travelers	*($3,783,000)*	
Net Social Benefits		*$2,484,000*

There does seem to be the potential for conflict in this example because of the difference between gains to drivers and the general public. Travelers net approximately $6.2 million and the public pays costs of $3.8 million. The problem comes about mainly because this small project does not have a mechanism set up to insure that the funds for the government investments come from travelers.

Income Groups

The effects of policies on people in different income groups are often a primary concern when analyzing the equity of a project. As noted above, however, it is not always necessary that small projects such as this one pass equity tests. This is because public policy as a whole (and maybe even transportation policy as a whole) may be equitable, even though many projects are not. Our discussion of the effect of this policy on equity, therefore, is done mainly for illustrative purposes.

Determining who pays the governmental costs of a project can be difficult. Different levels of government may contribute to paying for a project, complicating the accounting. Governments may also pay for a project with a mixture of dedicated revenues (e.g., vehicle registration fees) and general revenues (e.g., income tax revenues). Even when the source of funding is specified, it is not always clear how to proceed. For example, the same unit of government may fund one road construction project with fuel taxes and a similar project with general revenue. Should the tax incidence of these projects be considered to be different?

Analyzing government spending in the case of our project is not possible unless we specify how the project will be funded. Rather than speculate on how this transit project might be funded, we make some general points that apply to many types of cost incidence. Government spending on general transportation-related services, such as environmental protection and general police protection, is usually funded by general revenue sources. Many of the transportation projects paid for by local units of government are funded with property tax revenue, but some are funded with special assessments such as impact fees. The Federal government often pays for transit capital. In the Twin Cities Metropolitan Area some property taxes pay for a significant share of transit operating expenses. Studies are usually available on who pays general revenues and special taxes by income (see Minnesota Department of Revenue (2001), for example).

Internal costs are sometimes neglected when analyzing cost incidence because these costs are, by definition, paid by the people who impose them. Since people voluntarily pay these costs, it is sometimes felt that it is not necessary to examine the fairness of these costs. Government spending, however, has a significant affect on transportation infrastructure, and hence can have a great effect on the internal costs that people will pay. In addition, internal costs are usually much larger than governmental and external costs—overall internal costs make up 84 percent of region-wide transportation costs.[57]

In the project that we analyze, net changes in internal costs are significant and approximately the same size as changes in governmental and external costs. In general, the benefits derived from transit projects would go to people with lower than average incomes because the people most dependent on transit tend to have low incomes. Our project probably benefits people with higher incomes than the average transit project, however.[58] This is because our project tends to benefit people who reside outside of the central cities, and the central cities tend to have more low-income residents. Our project also benefits commuters, who are by definition employed, and who generally have higher than average incomes. Our previous work on cost incidence summarized the internal costs of transportation by income group, but we would really need more detailed information to analyze the effects of the transit improvement.[59] It is not clear that the people who will benefit from the improvement are representative of either the average driver or of the average transit rider.

Reductions in the external costs of transportation would benefit (i) users of private vehicles; (ii) people who live in affected neighborhoods and suffer from air pollution, noise, or crashes; and (iii) people who live outside of the region. The users of private vehicles receive most of their external benefits from congestion relief. Our work in Section 5 of this report shows that higher income tend to bear costs equal to a

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[57] Anderson and McCullough (2000), page v.

[58] Pucher (1982) argues that government expenditures on transit may implicitly discriminate against the poor and minorities. He argues that one reason for this type of discrimination is because transit spending does not focus enough on helping people in central cities.

[59] The main part of this report analyzes the incidence of all transportation costs and, because transit costs make up only a small share of total costs, it does not analyze transit costs in much detail.

relatively higher portion of their income than do lower income people.[60] We expect that the people who use the roads affected by the transit improvement would be fairly representative of private vehicle users in the region as a whole in this respect. This means that congestion relief tends to go to higher income people.[61] The main benefit to people who live in neighborhoods is from reduced air pollution. For the region as a whole, the relative costs of air pollution tend to be highest for people with low incomes. We would expect the neighborhoods affected by the transit improvement would be fairly representative of neighborhoods over the whole region because they represent a cross-section of urban and suburban areas.

Geographic Groups

Geography is often important for equity purposes because political divisions are tied to geography. In addition, people may be segregated to some extent by race or income. The region we examined in our previous work consisted on the seven-county Twin Cities Metropolitan Area (TCMA) and a ring of twelve surrounding counties. We discuss geography from two perspectives. The first is based on whether someone lives with the 19-county region or outside of it. The second is based on 78 sub-regions within the region. Inside the TCMA, the sub-regions roughly correspond to cities and townships and outside of the TCMA they correspond to counties.

It seems natural to pay special attention to costs and benefits that affect people within this region. Governments in the region would make nearly all of the government expenditures for the transit program, unless the Federal government provides special subsidies. The Federal government may also be able to reduce spending on some general government services, by perhaps $50,000 or $100,000 out of the $250,000 in total savings. Losses in fuel tax revenues are split almost evenly between Federal and state governments (approximately $50,000 each). Changes in internal costs will only have important effects on people within the region. As discussed above, approximately $600,000 in savings from external cost reductions will benefit people outside of the region. Most of this results from externalities associated with petroleum consumption. Some of it results from the effects of global warming and the effects of air pollution on crops and forests. Overall, the most important impact outside of the region will be produced by these external costs, unless the Federal government provides a significant amount of funds for the transit improvement.

Because the project we are examining is relatively small, it will have its greatest impacts on the residents of only a few of this area's 78 sub-regions. Governmental costs may be the exception—these costs may be spread widely if state or county or TCMA funds are used to fund the transit project. This does not necessarily mean that the project is not equitable, however. It is probably not fair to analyze the project in isolation. Transit and transportation projects that are located other parts of the region should also be examined. Internal costs and benefits will likely be concentrated in the areas served by the transit improvements. External costs and benefits will also be concentrated in these areas. Given detailed information from travel demand models (information on how travel changes on various roads) and from our incidence studies, we could estimate how external costs will change in the different sub-regions. We

[60] See Table 5.2.
[61] Although the people who would switch to transit may have lower average incomes than other drivers.

would have to be careful in interpreting our results, however. Our estimates of the costs in specific sub-regions are not always precise because of data limitations. The 78 sub-regions are small enough that we do not always have good data on what is happening within each one.

4 Summary

We examine two alternatives—an improvement in express transit service between Stillwater and Downtown Saint Paul and a status quo alternative. The analysis is conducted so that we can show how our cost data can be used to evaluate transportation alternatives. We take travel behavior as given, and analyze how changes in travel behavior affect costs and benefits. Producing reasonable estimates of marginal costs is not generally difficult, but does require some knowledge of the specific types of costs. Determining marginal costs seems to be most difficult for some types of governmental costs. It is seldom easy to predict how government spending will change in response to a change in vehicle miles of travel.

After costs are determined, it is straightforward to use cost-benefit analysis to evaluate the alternatives. Examining the equity of the project is more complicated. Analyzing equity usually requires determining the costs and benefits of a project in greater detail than analyzing efficiency would. It also usually requires an understanding of how the project fits in with other government policies. Analyzing the equity of governmental costs is particularly difficult because (i) tax systems are complicated, (ii) different units of government may fund a project, and (iii) governments may use a mix of revenue sources to fund a project. The data we have assembled on the incidence of internal and external costs is easier to use. Using it does require detailed results from travel behavior models, however. In addition, information on individual sub-regions may not always reliable because of data limitations.