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# Land Use and Travel Choices in the Twin Cities, 1958–1990

## Report No. 6 in the Series:

**Transportation and Regional Growth Study**


**Prepared by**

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This report examines the effects of land development patterns on travel choices by residents of the Twin Cities area. A historical analysis studies changes in travel behavior between 1958 and 1990, focusing in particular on total daily time spent traveling. The conclusion is that daily time per traveler changed only very slightly over this time, despite very significant changes in land use.

The second major analysis in the report looks at travel choices in 1990 in greater detail. Again, the conclusion was that land use per se did not play a significant role in travel choices when other factors were controlled for. Dense central areas generated much less mileage per person, but this was almost entirely because of lower speeds, not because central city residents spent much less time driving. Overall, there was less than a 20% difference in average time spent driving per day between central city and outer suburbs, and this difference arose entirely from commute times. Non-work travel time showed no systematic variation by location, in contrast to expectations. The one area in which land use played a significant role was that large dense job locations attracted very high shares for non-auto modes.


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# 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:

1. Twin Cities Regional Dynamics
2. Passenger and Freight Travel Demand Patterns
3. Full Transportation Costs and Cost Incidence
4. Transportation Financing Alternatives
5. Transportation and Urban Design
6. 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 decisionmaking 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 decison-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.

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# Executive Summary

This research grew out of a hypothesis and an observation. The hypothesis was that different ways of developing land — for example, building at higher densities and mixing jobs, retail, and housing — could help to alleviate expected future transportation problems by reducing the need to travel. The observation, first noted by Yacov Zahavi over 20 years ago, was that average daily travel times for the Twin Cities region as a whole did not change between 1958 and 1970, despite substantial changes in land use and the transportation system.

Obviously at first glance the observation seems to contradict the hypothesis. If the amount of time people spend traveling is sensitive to the types of neighborhoods in which they live, then why was there no change in average travel times despite the considerable suburbanization that took place during the 1960s? There are two possible explanations. The first is that the hypothesis is wrong; that travel choices are not in fact particularly sensitive to development patterns. The second is that the observation is unrepresentative or misleading; that the appearance of constant travel times was a fluke that will not hold up when the time period is extended, or when other types of comparisons are made.

The objective of this report is to identify which of these two possible explanations is right. Our conclusion is that the first explanation is the correct one. Based on the factors we studied for the period 1958-1990, we find that travel behavior was not very sensitive, with some small exceptions, to the way land was developed in the Twin Cities. We examine travel times for workers and nonworkers, with worker time broken into commute time and other. We examine whether people travel at all, the mode they use, and the number of trips they make. With the exception of commute times and mode choice, none of these ways of describing travel behavior shows variations greater than 10% within the region; only mode choice is influenced by land use, and commercial land use exerts much more influence than does residential. The distance that people travel shows considerable variation, but this variation is determined almost entirely by differences in average travel speed, and thus seems more a result of the travel time choice than a decision in its own right. People with many jobs and shopping opportunities close to home typically choose to expand their range of job and shopping choices rather than reduce their daily travel time.

We use three broad lines of argument to arrive at these conclusions.

The first line of argument is historical. We update Zahavi s analysis using 1990 data (the most recent year available) and find that average daily travel times are about 3% higher than they were in 1958 (about two minutes). Compared with 1990, the Twin Cities urbanized area in 1958 covered about one fourth of the land area; was two to three times denser; contained few, if any, substantial areas of pure residential zoning; and had transit service covering almost the entire built-up area. In other words, it was exactly what currently popular land use policies are aiming for. Nonetheless, travelers in 1958 spent essentially the same amount of time per day traveling as travelers in 1990, and virtually all of that travel was by car. They did, as is well known, drive far fewer miles, but this was because speeds were so much lower, not because they spent less time traveling. Also, a smaller fraction of people traveled in a given day in 1958, but this was because there was a large class of people (mostly women and the elderly) who had never learned to drive or were economically or socially constrained from doing so.

The second line of argument considers the possibility that looking only at average travel times for the region could be misleading; in other words, that there could be important differences across places or groups of people that are lost when data are aggregated to the regional level. To examine this possibility we analyze the behavior of auto travelers (the vast majority of the population) in 1990 in more detail. We find that the only way of dividing the population that yields significant (more than 10%) differences in average travel times is by location; travelers residing in outlying rural areas average 80 minutes a day, while central city travelers average about 68.

In trying to understand the reasons for these differences, two main results emerged. First, the differences are due entirely to differences in commute times. Non-work travel, whether measured as non-commute travel by workers or as travel by non-workers, shows almost no systematic variation by location. People with plentiful shopping close to home spent just as much time on non-work travel as did residents of the most remote, purely residential suburban neighborhoods. Second, commute times are determined by regional job access, not by the availability of jobs in the immediate vicinity of the home. That is, the availability of jobs within a mile of the home had almost no impact on average commute times; the availability of jobs within a 20-minute drive did.

The first two arguments look for differences in travel times within the group of people who travel by auto. The third argument considers the possibility that the average auto travel time per person might be lower if fewer people use autos in some parts of the region. We find that the number of minutes of driving per person (rather than per traveler) varies between central city and inner ring suburb because of this; in particular, use of non-auto modes is higher in the central city. Even if the total amount of time that people spend traveling is more or less fixed, land use changes could have beneficial impacts if certain types of development cause more of that time to be spent in modes other than autos.

Indeed, this is the one area in which the style of local land use seems to have an impact on travel choices. However, the impact is quite small compared to the size of the land use changes involved. We find that an increase of 1,000 people per square mile (within the built-up area, this would amount to an increase in density of roughly 10% to 100% depending on location) is associated with at most about a 1% increase in transit share of work trips, and about a 1% decrease in overall daily driving time per person. To achieve substantial changes in auto travel through this means would require population densities without precedent in this region. Certainly it is possible that such densities could be achieved in a few neighborhoods, but at a regional level, the number of people involved would probably be too small to have much impact.

Although land use in the home neighborhood appears to have little impact on travel choices, land use in job destinations can apparently have a fairly substantial effect on mode choice. About 30 of the 1165 traffic zones in the region (less than 1% of the total land area) attract over 60% of all transit trips; these same zones also attract a substantial fraction of walking and biking trips. (These zones are the central parts of the two downtowns, and the University of Minnesota.) These zones attract average transit shares in excess of 15% even from remote (and supposedly transit-hostile) suburban locations. A possible explanation is that the very large size of these employment centers means that it is feasible to have frequent bus service, including express buses, from all over the region. This frequent and fast service, combined with parking costs and inconvenience, makes transit a more attractive choice. And large employment centers can impact enough people to create effects that are apparent even at a regional level.

Our confidence in our conclusions arises not from any single argument or piece of evidence, but from the weight of evidence. Zahavi s finding of constant travel times hinted at the possibility that land use does not exert that much influence on travel behavior. We extended and refined his analysis, and examined the question using what we felt was a comprehensive set of land use descriptors, and a large and representative set of data. With the exception of the small influence of residential density on transit share, and the somewhat larger importance of major commercial centers, we found no evidence that the style of land development had much impact on any of the many measures of travel behavior that we examined, and considerable evidence that it doesn t, at least within the range of densities found in the Twin Cities.

To summarize, our primary result, examining travel behavior in 1990, supports Zahavi s earlier finding of a daily  budget  for time spent traveling. People do not travel every single day, but on the days when they do, they spend on average about 70 minutes. Furthermore, most people want to travel; the groups who have low rates of travel for the most part have been subject to economic or social constraints. These include people with low incomes, and in the past included women and the elderly. Our secondary finding is that while there are variations in some travel choices across the region, these differences arise more from variations in job access, job location, and population characteristics, rather than from the way residential land is developed. An important point here is that non-work travel shows very little variation by location. Apparently, having more nearby opportunities means that those particular opportunities can be accessed more easily; but as with faster highways, the time that is saved is spent on additional travel or expanding the range of choices, so overall non-work travel time is essentially unchanged.

We do not, however, feel that there is no scope for policy to have a positive impact. Behavior differs substantially from the norm in certain specific situations and for certain types of people. Focusing policy on these situations and people where there is evidence that an impact is likely could yield benefits. Furthermore, not all auto travel causes major problems. While it may not be possible to reduce total auto travel much, the negative effects that this travel causes could certainly be mitigated if attention is focused directly on the problems rather than on travel in general. This leads us to three main points on the potential of land use to influence travel choices.

First, policy should focus on  problem  travel rather than treating all travel equally. In this regard, work trips are key. They are far longer than any other type of trip; they are also more congested and because they are concentrated in time, they create the need for far more highway capacity than would be necessary otherwise.

Second, increasing the density of commercial development is much more likely to have a beneficial impact on travel behavior than is higher density in residential areas. Creating transit service that is competitive with auto travel requires frequent and fast buses; this is only possible when the number of people involved is sufficiently large to fill them. As a practical matter, it seems unlikely in this region that this critical mass will ever be reached in residential neighborhoods. But it already has been achieved in commercial areas, and building on this existing success might be an effective way of integrating transit use into the regional way of life.

Finally, while a widespread reduction in auto use is unlikely, it may be possible to contain the growth of auto use through identifying and exploiting the preferences of that minority of residents who desire a less auto-intensive lifestyle. This might include, for example, students, university and downtown employees, and young people generally. Because large, ultra-high density commercial (or educational) areas serve as strong alternate-mode attractors, neighborhoods located close to these areas tend to generate high alternate-mode use. Given this, it might make sense, as long as there is demand, to create opportunities for as many people as possible to live in these  good  locations.

Our results, in short, lead us to the belief that only certain specific and focused land use policies are likely to have much transportation impact, and even in the best case the effect is likely to be restricted in location and scope. Positive results are possible, but are much more likely in the context of clear and realistic goals, and investments that are explicitly targeted to areas where there is real evidence that success is likely.

# Important Definitions

Reviewers of drafts of this report noted that there was potential for confusion in that certain words and phrases are used in the report to refer to specific objects or phenomena, while the same phrases are used more commonly or conversationally to refer to a different and often broader range of things. For example, land use in this report refers to a specific set of measurements which were empirically tested, while readers seeing that phrase might naturally envision something different. Thus the phrase land use is accurate in that the factors that were studied all fall into this category, yet it is inaccurate in that there could be other ways of describing land use that are not studied here. The best solution to this problem seemed to be to define the important terms up front, so that the natural phrases could be used, yet the reader could clearly understand that these general phrases refer to something specific.

**Land use:** A number of different ways of describing land use were tested to determine their effect on various aspects of travel behavior. The density of population, employment, and retail employment at different radiuses from the home location were the bases of description. The smallest area of measure was the traffic assignment zone (TAZ). These vary in size depending on the intensity of activity within them; in dense parts of the central cities they could be just a few blocks on a side, while at the very edges of the region they could be an entire township. The next smallest area was a one-mile radius around a TAZ, that is, the TAZ plus any other TAZs whose center was within one mile. The two other areas were a ten-minute and 20-minute driving radius of the TAZ. The idea was to understand the relative importance of land use very close to the home compared to further away. So for each of these four radiuses, the three densities were calculated, and also the ratio of population to employment, to get a rough measure of the extent of job mixing. Also, simple counts of population, employment, and retail employment at each of the four radiuses were considered. Thus there were a total of 28 different land use descriptors.

**Travel behavior:** This phrase refers to a number of different choices that people make regarding how they get from one place to another. Primary among these is the total time spent traveling each day; but it also includes the mode used, speed, the total number of trips per day, and whether to travel at all in a given day. A perhaps unusual omission is that distance traveled is not included as a behavior here, even though many people think of distance as the primary choice that people make. That is, it is normal to assume that people choose where they will go and then complete these trips in the minimum time. However, we find that the time people spend traveling each day gravitates to a certain level (about 70 minutes) regardless of the number of opportunities that are available, and that the total distance traveled is then simply a function of how fast a person is able to travel. People with many nearby opportunities do travel fewer miles than those without, but only to the extent that average speeds are different in the two places. To the extent that high density development tends to reduce speeds, it affects the distance traveled, but the density of opportunities does not in itself seem to matter very much independent of its effect on speed. Thus we consider distance traveled to be a derivative term, rather than a direct choice of the traveler in the sense that the others are.

# About the Data

The most recent data used in this report were collected in 1990, in the Travel Behavior Inventory (TBI) and the U.S. census. (The TBI is a local survey of travel behavior done by the Metropolitan Council about every ten years; in 1990 it included about 25,000 people who recorded all their motorized travel in a diary for one day. The U.S. census data include only the trip to work but are drawn from a very large sample of several hundred thousand people.) Concerns have been raised that conditions in the Twin Cities have changed substantially since 1990, and thus that this information is too old to reliably inform present policy. The following is our position on this.

Our analysis shows that certain important travel decisions did not change much between 1958 and 1990 despite significant changes in regional land use and the transportation system. Because of this we feel that these decisions will have continued to remain relatively stable in the years since 1990, and thus that the conclusions that we draw will still be relevant now. This is not to deny that there could have been major changes in population or in travel behavior trends. Indeed, some outcomes, such as central city population, vehicle miles traveled, and congestion, will likely deviate significantly from the trends established in the prior 30 years. However, the policy conclusions that we draw do not depend on these factors that we believe to be unstable over time.

It is always a leap of faith to extrapolate into the future based on what has happened in the past, but it a leap that planners, policy makers, and scientists must necessarily make. The possibility exists here, as it always does in the social sciences, that something we have failed to identify could have changed in the last ten years to render incorrect some of the analyses and conclusions presented in this report. However, until it is shown that this is the case, it is our professional opinion that it is appropriate to continue to use these data and the analysis and conclusions that come from them.

# 1 Introduction

The Twin Cities, like other metropolitan regions in the U.S., seems to have reached the limits of highway construction as a method for improving the transportation system. Popular thinking asserts that this is because highway construction is pointless:  You can t build your way out of congestion.  But this is not quite right. There are plenty of cities (albeit few large ones) that have no meaningful congestion; that have in fact built their way out of it. The problem, more precisely, is that in large urban areas you can t build your way out of congestion without incurring unacceptably large human and monetary costs. We want to be able to get around, but we also want our cities to be pleasant places to live, and highway construction in most cases would meet one goal only at the expense of the other.

Another currently popular potential solution to transportation problems has the appealing quality of appearing to meet both goals at the same time. This is the idea that changing the way land is developed, at the scale of the region or of the neighborhood, could not only make the city more pleasant, but also change travel choices to such an extent as to mitigate some transportation-related problems and improve people s ability to get around. Examples of the types of policies being proposed include mixing jobs and housing to reduce commute lengths, and developing at higher densities to reduce distances and make alternate modes such as transit more viable.

These types of ideas also have the apparent advantage of creating neighborhoods that residents find more pleasant to live in than the low-density  sprawl  that has become typical of modern suburbs. While this may well be true, our concern in this report is narrower. We wish only to understand the extent to which different types of development patterns can influence the travel choices of the region s residents. That is, if people prefer to live in dense, mixed use areas, they should certainly be allowed to do so. Our interest is more specific: Do these types of land uses create external benefits that accrue to people other than the residents of the neighborhood? For example, do they lead to reductions in car use, and hence to lower congestion and pollution, from which everyone benefits? The answer to this question will tell us whether this type of development should be actively encouraged, or even subsidized by government, rather than merely allowed.

This research grew out of a general interest in understanding the mechanisms by which land use might influence travel behavior, and specifically out of an observation made by another researcher two decades ago, who found that average daily travel time per traveler in the Twin Cities area had changed very little between 1958 and 1970 despite dramatic changes in both land use and the transportation infrastructure. Obviously this contradicts the belief that travel behavior is sensitive to land use; there are two possible resolutions. Either some of the assumptions that people commonly make are wrong (or at least exaggerated), and travel choices are not strongly influenced by land use patterns; or the evidence is not robust. For example, the observation of constant travel times might not hold up when a longer time period is considered, or when different types of analyses are done.

The objective of this report is to identify which of these two possible explanations is right. Our conclusion is that the first explanation is the correct one. Based on the factors we studied for the period 1958-1990, we find that travel behavior was not very sensitive, with some small exceptions, to the way land was developed in the Twin Cities.

We use three broad lines of argument to arrive at this conclusion. These arguments, and the evidence supporting them, are outlined in some detail in section 1.3 of this introduction. Section 1.1 preceding it introduces some of the complexities of travel behavior, and different ways of thinking about how people make travel choices. This material is important because facts need an appropriate conceptual framework for interpretation, and some of the more natural or intuitive ways of thinking about transportation are overly simplified or inconsistent with the evidence. We feel that a theory focused around time spent traveling is particularly useful; thus section 1.2 discusses the reasons why travel time is a more useful and unambiguous way of describing travel behavior than are other more common terms.

## 1.1 Conceptual Framework: System Complexity and Unintended Consequences

The fundamental insight inspiring this research comes from Zahavi (1979a), who identified apparent regularities in total daily travel time which appeared to hold both across cities and over time within a city. He found that average daily travel time per auto traveler in the Twin Cities was constant at about 69 minutes per day both in 1958 and 1970. This result is particularly striking in light of his further finding that average miles traveled (and hence average speeds) increased considerably during this time. It appears that people did not use the time savings created by high-speed freeways to spend more time at home; rather, they used this extra time to expand their range of travel. This is a substantial part of the phenomenon of  induced demand  that has led freeways to fill to capacity much sooner than expected by planners.

However, the possibility of a travel time  budget  also raises questions about the possibility of using land use as a way to influence travel decisions. For example, one claimed advantage of high-density development is that trips are shortened or eliminated altogether because origins and destinations are closer together. But it seems reasonable *a priori* to think that a similar type of induced demand might apply here; that the time people save by taking shorter trips, or by walking instead of driving, might just be applied to extending the length of other trips, or traveling to different destinations entirely. Indeed, we find evidence that this is the case. Central city workers, who tend to have shorter commutes to work, spend slightly more time on non-work travel than do their counterparts in outlying suburban and rural areas, where commutes are relatively longer.

The more general type of issue raised here is the problem of unintended consequences, or the idea that the solution to a problem will often create a new problem. The basic point with regard to travel is that while it is often summarized in simple terms such as number of trips or vehicle miles traveled, it actually encompasses a dizzying array of decisions, and attempts to influence one action can be negated by changes to others. The example given above is classic; attempting to reduce commute times by making highways faster just made it possible for people to live further away from their jobs (or to choose from a broader range of jobs), and ultimately left commute times essentially unchanged.

This is an important point, because discussions of transportation policy at the popular and even at the professional level often draw conclusions based not on directly observed facts and relationships, but rather based on deductions from  mental models  of how choices are made. And when these mental models don t fully take into account the complexity of the system, the conclusions that they produce can be badly off the mark. For example, just as increasing speeds ultimately didn t reduce total travel times, it is easy to imagine that shortening distances could have similar unintended consequences. Mixing jobs, retail, and housing might reduce the lengths of some trips by neighborhood residents, but could increase trip lengths for workers and shoppers who come from outside (typically the vast majority of the total).

The possibility of these unintended consequences, and the difficulty of predicting whether they will or won t happen, points to a fundamental weakness in our understanding of travel behavior. This is that both forecasting models and popular thinking tend to view individual trips, and individual people, in isolation rather than as elements of a larger system. Surprisingly little is known about how changes to a part of the system might affect overall daily travel habits, as opposed to the execution of individual trips; or how overall travel in the region would change, as opposed to travel by residents of a particular neighborhood.

An important problem with this standard way of thinking is that travel is treated as a cost rather than as a source of utility. That is, forecasting models (and popular thinking) essentially assume that people  have to  make a certain number of trips in a day, and that they will make them so as to minimize the amount of time that they spend (given that they also wish to travel to attractive destinations). This leads to the logical conclusion that any change that makes it possible to spend less time traveling will make people better off, and will be eagerly adopted. Unfortunately, the second part of this conclusion is contrary to the facts, as the builders of the freeways discovered.

A contrasting viewpoint is that travel, while not creating utility itself, allows people to visit destinations from which they derive utility. Proponents of this idea would claim that if people choose to spend more time or travel longer distances, then the reason must be because they get more utility from the far-away destinations that they visit than they would from closer alternatives. It might be objected that people travel long distances because there are no closer alternatives. However, in most cases this is clearly untrue (see section 3.4:  Geography and Job Accessibility). A simple piece of evidence is that high-income people, who are presumably the most in control of their own destiny, are precisely the people who spend the most time traveling, and travel the longest distances.

A third, more recent and more radical point of view is that people *like* to travel; that rather than traveling in order to visit destinations, they in fact often visit destinations in order to travel. Mohktarian (1999) finds evidence that people are happiest with commutes of about 15 minutes, not less. And many personal trips are clearly discretionary; people very often go shopping, or go out to dinner, not because there is some particular product they want (or  need ) to purchase, but simply because they want to get out of the house.

To claim that people wish to minimize the time they spend on a particular trip is entirely plausible (although Mohktarian also finds that people  take the long way  surprisingly often). However, it is wrong to extend this logic to conclude that people also wish to minimize the *total* amount of time they spend traveling. Everyone, for example, would rather pay less rather than more for a given house, but this does not imply than they want to minimize the total amount that they spend on housing. As long as additional travel generates utility higher than the additional cost, people will travel more, even if they simultaneously complain about particular trips costing more than necessary because of congestion.

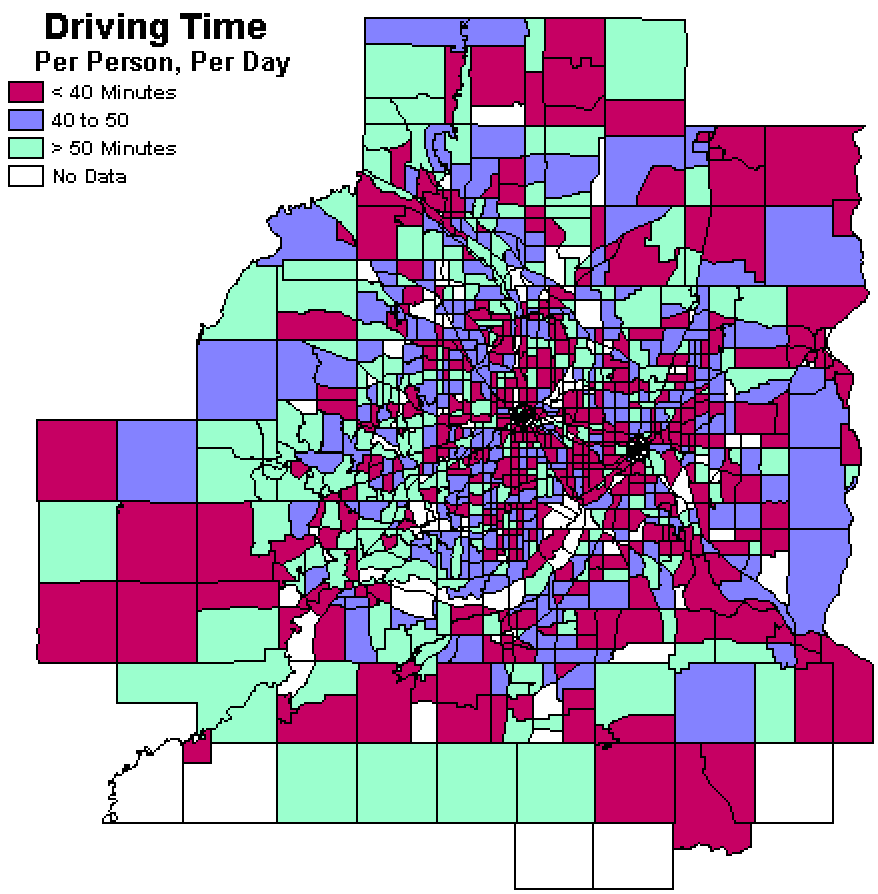
The purpose of this somewhat theoretical digression was to introduce the idea that understanding travel behavior is not just a matter of knowing  the facts,  but of having a good conceptual framework for understanding how those facts fit together. Our research here has led us to believe that a framework built around the daily time spent traveling leads to conclusions that are both intuitively believable and empirically sound. The next section discusses some of the reasons why we believe this assertion to be true.

# 1.2 Costs of Transportation and the Importance of Travel Time

There are four basic descriptors that can be used to summarize a person s, or a society s, travel patterns: number of trips, miles traveled, travel time, and mode choice. Of these, travel time is the least often cited in popular discussion, but arguably provides the most unambiguous insight into both personal and societal costs of travel. And if the results in this research are borne out in other cities (as they have been in at least some cases), travel time may usefully supplant or at least augment trips as the basic input to travel forecasting models.

The reason we want to describe the quantity of travel is because it consumes resources and generates costs. In the old days, for example, we wanted to know how much highway resource was being consumed so that we would know how much more to provide. Now our responses are different, but the purpose is largely the same; we want an easily understandable way of describing how bad problems are, both for society and for individual travelers. It is enlightening to examine what the common descriptors of travel tell us about these two categories of costs.

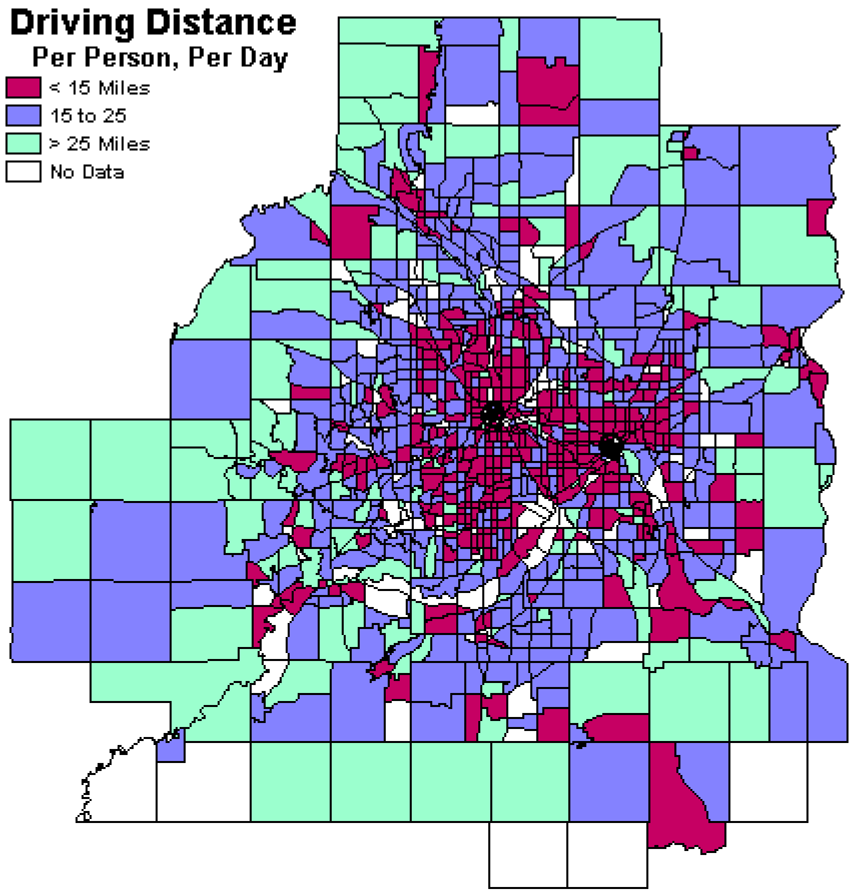
From the standpoint of personal costs, travel time is clearly the most useful fact to know. Time is a real resource that comes in limited quantities; the time spent driving a car is time that can t be spent doing other things, and if trips take longer, fewer destinations can be accessed. Other descriptors do not have this clear-cut interpretation. More trips might mean a person is better off, because speeds are faster and it is possible to make more trips in the same time, or worse off, because big stores are inaccessible, and the person must make many trips to small stores with less selection. Higher bus share might mean that people are taking advantage of additional mode choices (better off), or that congestion has reached intolerable levels (worse off).




**Map 1. 1: Daily time spent driving per person, 1990**

High driving times are scattered throughout the region. See reference maps in appendix.

The most misleading, yet most often cited, descriptor of personal costs is miles traveled. It is misleading because there is a natural tendency to assume that more miles means more time and more congestion, which it does, other things being equal. The problem is that other things are never equal; that is, differences in miles traveled from one area to another arise much more from differences in speeds than from differences in time spent traveling. People in high-density neighborhoods drive fewer miles in large part because they spend more of their time sitting at intersections and driving on low-speed local streets. Maps 1.1 and 1.2 illustrate this point. While low and high driving *times* are scattered throughout the region, low and high driving *miles* are concentrated in the center and edge respectively. The high speeds in outlying areas mean that even people who spend little time can drive a lot of miles, while the opposite is true in the generally low-speed central part of the region.




**Map 1. 2: Total daily distance per person, 1990**

High mileage is concentrated on the edges of the region. See reference maps in appendix.

From the standpoint of costs to society, it is again the case that travel time is a better indicator than miles traveled. Consider two important social costs, congestion and pollution. It is not clear that fewer miles traveled means less congestion (again, it does, other things equal, but other things are never equal). Someone driving ten miles on a road with a capacity of 500 vehicles per hour is using relatively more of that road s capacity than someone driving 20 miles on a road with a capacity of 2000 vehicles per hour. More importantly, someone driving during rush hour, when roads have little if any spare capacity, is more likely to create problems for others than is someone driving on the same road at 3 a.m. The question is not just how many miles you drive, but where and when you drive them, and how much time you are using up road capacity.

In terms of pollution, city driving yields fewer miles per gallon than does highway driving. The reduced mileage generated by city residents is thus offset to some extent by the fact that they burn more gas per mile. Furthermore, the pollution that they do generate may have a bigger impact, since there are more people in the vicinity and they are closer to the road than they would be in a suburban area, where houses tend more to be set away from major thoroughfares.

While travel time is not a perfect indicator of pollution, it is clear that the problem is more complicated than simply measuring miles traveled.

There is no disputing that people in high-density areas drive fewer miles. However, this is not automatically a good thing. The question that must be answered first is whether (and in what ways) they are actually using fewer of their own and society s resources. While the ideal way of answering this question would be a full-scale analysis of the transportation-related costs generated by residents of different areas, such an analysis has not been done (to the best of our knowledge). In the absence of such a study, considering travel time in more detail at least gives us important additional information about how areas differ in the amount and types of travel they generate.

# 1.3 Summary of Findings and Organization of the Report

The purpose of the report is to examine whether travel behavior is influenced by land development patterns, particularly in light of Zahavi s observation that average travel times did not change between 1958 and 1970 despite substantial changes in land use (Table 1.1). Based on the factors we studied for the period 1958-1990, we find that travel behavior was not very sensitive, with some small exceptions, to the way land was developed in the Twin Cities. We examine travel times for workers and nonworkers, with worker time broken into commute time and other. We examine whether people travel at all, the mode they use, and the number of trips they make. With the exception of commute times and mode choice, none of these ways of describing travel behavior shows variations greater than 10% within the region; only mode choice is influenced by land use, and commercial land use exerts much more influence than does residential. The distance that people travel shows considerable variation, but this variation is determined almost entirely by differences in average travel speed, and thus seems more a result of the travel time choice than a decision in its own right. People with many jobs and shopping opportunities close to home typically choose to expand their range of job and shopping choices rather than reduce their daily travel time.

**Table 1.1: Changes in land use, 1958 to 1990**

| | 1958 | 1970 | 1990 |
|---|---|---|---|
| Urbanized Area* (sq. miles) | 247 | 483 | 996 |
| UA population (thousands) | 1,300 | 1,701 | 2,080 |
| UA density (1,000/sq. mile) | 5,260 | 3,521 | 2,088 |
| UA miles of freeway | 20 | 140 | 294 |

* The urbanized area is that part of the region that is developed at urban densities, generally greater than 1,000 per square mile

We use three broad lines of questioning to arrive at these conclusions. Because the overall argument is somewhat complex, and because the later questions arise out of the answers to the earlier ones, we outline the both the methodology and conclusions in some detail here.

The first line of argument, in chapter 2, is historical. We update Zahavi s analysis using 1990 data (the most recent year available) and find that average daily travel times are about 3% higher than they were in 1958 (about two minutes). Compared to 1990, the Twin Cities urbanized area in 1958 covered about one fourth of the land area, was two to three times denser, contained few, if any, substantial areas of pure residential zoning, and had transit service covering almost the entire built-up area. In other words, it was exactly what currently popular land use policies are aiming for. Nonetheless, travelers in 1958 spent essentially the same amount of time per day traveling as travelers in 1990, and virtually all of that travel was by car. They did, as is well known, drive far fewer miles, but this was because speeds were so much lower, not because they spent less time traveling. Also, a smaller fraction of people traveled in a given day in 1958, but this was because there was a large class of people (mostly elderly and women) who had never learned to drive or were economically or socially constrained from doing so.

The second line of argument, in chapter 3, considers the possibility that looking only at average travel times for the region could be misleading; that there could be important differences across places or groups of people that are lost when data are aggregated to the regional level. To examine this possibility we analyze the behavior of auto travelers (the vast majority of the population) in 1990 in more detail. We find that the only way of dividing the population that yields significant (more than 10%) differences in average travel times is by location; travelers residing in outlying rural areas average 80 minutes a day, while central city travelers average about 68.

The first two arguments look for differences in travel times within the group of people who travel by auto. The third argument, in chapter 4, considers the possibility that the average auto travel time per person might vary if fewer people use autos in some parts of the region. The number of minutes of driving per person (rather than per traveler) varies between central city and inner ring suburb because of this. In particular, use of non-auto modes is higher in the central city. Even if the total amount of time that people spend traveling is more or less fixed, land use changes could have beneficial impacts if certain types of development cause more of that time to be spent in modes other than autos. However, we find that while land use does affect mode choice, the impact is quite small compared to the size of the land use changes involved.

The report appendix contains four sections. The first consists of six maps of regional density: population, employment, and the sum of the two, shown both for the entire seven counties, and in a more detailed view of the center of the region. These maps are in the appendix because questions about density arise throughout the report. Because the reader might wish to refer to these maps on a number of occasions, it seemed most convenient to locate them all together in the back, rather than buried in the text itself.

The second section gives some of the basic data used in the analysis of Twin Cities travel in 1958 and 1970, and a map of the zones Zahavi used in his analysis (and which we attempt to recreate).

The third section gives some cross-tabulations of various descriptors of travel behavior, such as number of trips, broken down by a number of different factors such as age and home location. This is intended to give a general sense of the ways in which these descriptors depend on different types of personal characteristics.

The last section of the appendix contains results of linear regression used in chapter three to determine the level of influence of different possible explanatory variables on behaviors of interest. These results are described in the main text, but the specific calculations are relegated to an appendix for two reasons: to keep the text readable for a non-technical audience, and, for those who are interested, so that all the different regressions that we tried for a given problem can be displayed together. Seeing all the regressions that  didn t work  makes it possible to understand why we conclude that some explanatory variables are more important than others.

# 2 Historical Changes in Twin Cities Travel Behavior

Much has been made of the huge increase in vehicle miles traveled (VMT) that has taken place over the last few decades since the construction of the interstate highway system. However, as was discussed in the introduction, to look exclusively at distance traveled can give a misleading impression of the changes, or lack thereof, in travel behavior. Yacov Zahavi, in a series of travel behavior studies looking in part at the Twin Cities, was one of the first to note that large increases in mileage had not been accompanied by increases in time spent traveling. Indeed, between 1958 and 1970, the percentage increase in miles per traveler was almost exactly the same as the percentage increase in average travel speeds, while time remained essentially constant.

We recreate Zahavi s analysis for 1990, and find the same phenomena that he did: since 1970 speeds increased, distance traveled increased, and time spent traveling remained essentially constant. As during the 1960s, new high-speed roads made it possible to travel faster; people used this new freedom to move to larger, more remote houses, or to expand the range of places where they would consider working. Conversely, development spread out, making it necessary to travel more miles to reach a similar set of destinations, but higher travel speeds made it possible to do this without spending more time driving.

A quote from the report summarizing the 1970 Travel Behavior Inventory gives a good idea of the changes that had taken place during the time period covered by

Zahavi s analysis, making the constancy in behavior that he found seem all the more remarkable:

> The total 1970 built-up urban area includes about 483 square miles. Since 1958, 48% or 236 square miles were added. This represents the addition of almost as much urbanized area as was constructed in the past century. This remarkable expansion of developed areas, the building of freeways (nearly the whole regional interstate system existing in 1970 of 140 plus miles was put in between 1958 and 1970), and the adding of thousands of additional miles of streets and arterial highways made the 1958-70 period unique in the history of the metropolitan area.

By 1990 the built-up area was 996 square miles, another doubling in the span of 20 years, along with more highway construction and expansion. It is remarkable to consider that in 1958, when the built-up area was one quarter of its present size, when population density was much higher, and when commercial activity was much more concentrated in the downtowns, that travel behavior, in terms of mode shares and time spent traveling, was hardly any different than today. More people travel today, but evidence strongly indicates that people who didn t travel in the past were economically or socially constrained from doing so. Even in those supposedly less auto-oriented times, the people for whom driving was an option almost always chose to drive.

(A peripheral but interesting point is that a doubling of land area in 20 years is not unusual, although it appears huge on first viewing. Historical maps indicate that the land area of the Twin Cities has been doubling every 20 years ever since they began. This amounts to about a 3% annual growth rate, which given population and economic growth, is basically no higher than the growth of consumption of any other good.)

Given these results, it is interesting to examine the reasons for the huge increase in vehicle miles traveled between 1970 and 1990 (Table 2.1, Figure 2.1). Many people seem to believe that this increase took place because each individual drove more, and that driving more means spending more time in the car. This is, however, not quite right.

**Table 2.1: Increase in VMT, 1970 to 1990**

| | 1970 | 1990 | % Change |
|---|---|---|---|
| Population, 7 counties | 1.9M | 2.3M | 22 % |
| % Travelers | 67 % | 83 % | 25 % |
| Time per day per traveler | 67.5 min. | 70.9 min. | 5 % |
| **Total person hours*** | **1.45M** | **2.33M** | **60 %** |
| Average speed | 17.1 mph | 22.4 mph | 31 % |
| **Total person miles*** | **24.8M** | **52.3M** | **111%** |
| Driver miles/total miles | 66.7 % | 76.9 % | 16 % |
| **Total vehicle miles*** | **16.5M** | **40.2M** | **144 %** |

* Rows in bold type are the product of the rows immediately above them. They do not correspond to the numbers cited in the Travel Behavior Inventory (TBI) summaries because the numbers in this table include only personal travel by residents of the region, while the TBI figures include commercial and through traffic.

The belief that VMT has increased because of basic behavioral changes is not supported here. Population is exogenous to travel behavior. Average speed is strongly influenced by technical considerations. The fraction of people who travel in a day is essentially a demographic phenomenon, as will be discussed in the next section. The decline in auto occupancy, leading to more vehicle or driver miles per person mile, may be partially due to a change in behavior. However, even this is in part due to demographics, namely a sharp decline in the number of children, who are responsible for a high fraction of trips as riders. Even the small increase in time per day per traveler is partially due to this: children travel less than adults, so having fewer of them will drive up the average even if nothing else changes.

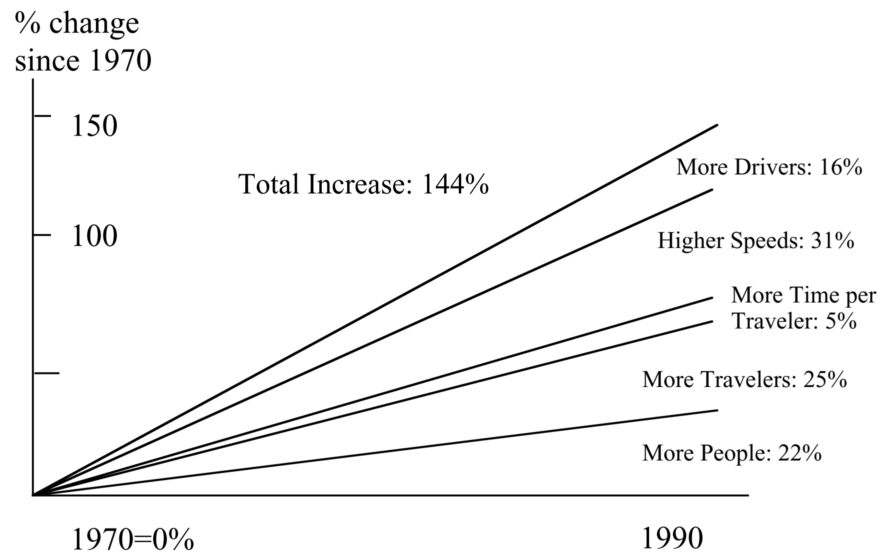



**Figure 2.1: Increase in VMT, 1970 to 1990**

This chapter consists of three sections. The first discusses methodology; that is, the way the 1990 data were organized to facilitate an analysis that would be as similar as possible to that done by Zahavi. Inevitably some incompatibilities remain; however, these are minor and do not affect the main result that average travel times are essentially unchanged. The second section examines travel facts about the region as a whole (more specifically, the subset defined by Zahavi, which excludes outlying areas), looking at both transit and auto travelers, and concluding that travel times stayed roughly constant for both groups. The final section attempts to look in more detail at specific locations within the region and how travel times have changed since 1958. Unsurprisingly, smaller areas show more variation over time than does the region as a whole, but the majority of these subareas had travel times in 1990 that were statistically equivalent to 1970. Furthermore, the variation across the region is decreasing; the areas where travel times increased had low average times in 1970, the areas showing decreases had the highest averages in 1970.

The conclusion arising from this is that Zahavi s observation of constant travel times between 1958 and 1970 was not a fluke; the constancy continued to 1990 despite continued massive changes in regional and local land uses. However, another issue does emerge. There is variation in average travel times within the region; while this variation was smaller in 1990 than it had been in the past, it was still potentially important. Chapter 3, Auto Travelers in 1990, looks in more detail at the causes of this intraregional variation.

# 2.1 Methodology

Yacov Zahavi, under the sponsorship of the U.S. Department of Transportation and others, undertook a project in the late 1970s to develop improvements to the traditional four-step travel forecasting framework, especially in regard to the forecasts of total travel that serve as the basis for the other model forecasts. His findings on this project ultimately occupied three large reports (Zahavi, 1979a and 1979b, and Zahavi, Beckmann, and Golub, 1981), and were summarized in two articles (Zahavi and Talvitie, 1980, and Zahavi and Ryan, 1980). The Twin Cities are addressed in detail in Zahavi (1979a) and Zahavi and Ryan.

His basic insight into this problem lies in treating travel like any other economic good, in which people are subject to budget constraints, of money, for example, but more importantly, of time. He cites considerable evidence to indicate that the amount of time that people spend traveling in a day is at least roughly constant across a surprisingly wide range of cities in both developed and developing countries. His research then focuses around trying to establish the precise nature of this regularity, to identify other regularities, and to explore the implications for the travel forecasting process.

Limitations on computing technology at the time of Zahavi s studies made it impossible for him to study travel behavior at the level of the individual. Thus his work examines the behavior of groups, aggregated by location within the region and by the type of travel modes used by members of the household. The seven-county Twin Cities region is divided into 20 districts, and all statements about travel behavior are then based on district averages. Households are divided into four categories based on their mode choices the day they were surveyed:

- Car-only: all household members traveled only by car
- Bus-only: all household members traveled only by bus (including school bus)
- Mixed: household members traveled by both car and bus
- None: no household member traveled on the day of the survey

It is important to understand that mode choice categories in Zahavi are the mode choice of the entire *household*, not of the individual. Thus, if even one trip by one person is made by bus in an otherwise car-only household, then that entire household is classified as mixed, not just the person who made the bus trip. Because he counted school bus trips as transit, this had the effect of pushing a large number of car-only or bus-only individuals into the mixed category.

In comparing 1958 and 1970 Zahavi kept the geographic area of analysis the same. This meant counting only people who lived within a constant cordon line, but including trips to the entire seven-county area. The area outside this cordon line is primarily agricultural even now; in the years of Zahavi s analysis even much of the area inside the line was not urbanized.

The travel times that Zahavi uses are the times reported by the survey participants. The travel distances that he uses are calculated block distances, that is, distances are calculated assuming that people could travel only along primary compass directions rather than along diagonals between two points. Network distances were apparently not easily available at the time of his study. He claims to have compared his method to network distances in a sample of cases, and to have found that the difference between the two was only 0.16% (Zahavi, 1979a, p.13).

In attempting to recreate Zahavi s analysis, we modified the data in a number of ways. Most significantly, we excluded anyone who made a trip outside the seven counties. Many of these trips were long drives to vacation destinations; these are not ordinary regional travel. We also excluded trips for work-related business, but not the travelers that made them. This approach seems the best given the types of behavior we are trying to understand. (While these trips are relevant for traffic forecasting and policy analysis, they are not for a study of personal travel choices, since they are presumably required by the employer rather than a free choice by the individual.)

However, it is not clear whether Zahavi made similar exclusions. He specifically mentions excluding trips outside the seven counties (although apparently not the travelers who made them). In another report he recommends excluding trips made for work, but he does not say anything about it in either Twin Cities report. On the other hand, it could be that these types of trips were not included in the 1970 data to start with (there is no category for work-related in the 1970 survey form). Or it could be that they were not particularly prevalent at that time, and hence did not need to be specifically excluded.

In any case, the point is that it is likely that the types of data that we are using are not exactly the same as what Zahavi used, although the error introduced by any differences is unlikely to be substantial, since there are a relatively small number of trips involved. Also, some of the differences will tend to make the 1990 numbers too high, while others will make them too low. Overall, these various minor incompatibilities will generally cancel each other out. Given the relatively minor importance of most of these factors, it seems almost certain that the true values for the two years are not more than 5% different from the numbers used in this report, and probably less than this. The general conclusion, that daily travel times didn t change nearly as much as other factors, is unaffected by such a small range of error.

More generally, the 1990 TBI data contains examples of what appear to be errors either in the original travel diary or in the coding to computer form. These are infrequent, but can be so large as to affect averages, especially of smaller groups. The fundamental bias is that errors that make a trip two hours too short will make the time negative, and are thus easy to catch in a checking process. However, errors that make the trip two hours too long are not always so obviously wrong. Depending on how prevalent such errors are in different data sets, comparisons between them can be complicated. The problem is that it is hard to think of any foolproof rules for excluding apparently bad data. Some trips might really have taken a long time for reasons that are not obvious to us, and it is hard in general to know if this is the case, or if there is really an error.

Our compromise was to eliminate any trip that took 120 minutes or more. While this might appear to bias the final results downward (because these trips really did take place, and we are not counting them), we feel that the  true  travel times are probably still smaller than those in the data. There are still many trips that were recorded at 90 or 100 minutes that certainly did not really take that long, and we make no adjustments at all to these. In general, this exclusion does not change regionwide averages much; the hope is more that it will reduce some of the large variability across traffic analysis zones or other small groups of people.

Given these caveats, the goals here will be to recreate Zahavi s aggregate analysis for 1990. We do not know the precise borders of Zahavi s zones, but we were able to construct an approximation of these zones for our analysis. This raises a final issue of comparability. People outside the built-up area travel more than people inside it. The built-up area did not extend as far as the cordon line in 1970, but now it extends past it at many points. To analyze the same land area then means studying a different group of people: Zahavi included some rural residents and we don t. To help clarify any impact that the choice of study area might have, we give aggregate results for both Zahavi s area and for the seven-county region as a whole.

# 2.2 Aggregate Results

The most interesting result of Zahavi s analysis is that, for car travelers, the substantial increase in speed that took place between 1958 and 1970 had the effect of increasing total travel distance rather than decreasing total time. That is, while higher speeds may have led to shorter times for individual trips, people used the time savings to make more or longer trips (Table 2.2). More generally, people may have used the possibility of higher travel speeds to justify moving to more spacious but more remote suburban homes.

**Table 2.2: Characteristics of auto-only households, 1958 and 1970**

| | 1958 | 1970 | % Change |
|---|---|---|---|
| Minutes/Traveler | 68.2 | 67.5 | -0.9 % |
| Trips/Traveler | 3.63 | 3.85 | 6.1 % |
| Miles/Traveler | 15.2 | 20.1 | 31.6 % |
| Average Speed | 13.4 | 17.7 | 32.6 % |
| Minutes per Trip | 19.1 | 17.2 | -9.4 % |
| Miles per Trip | 4.20 | 5.22 | 24.3 % |
| Cars/Household | 1.23 | 1.43 | 16.3 % |
| Travelers/Household | 1.93 | 2.04 | 5.7 % |
| Prob. of Traveling | 0.56 | 0.62 | 10.4 % |

The striking fact in this table, as Zahavi notes, is that the total daily time per traveler remained essentially constant despite a substantial increase in average travel speed. Travelers did not use the time savings created by the much higher speeds to spend more time on other activities; rather they used the time to travel additional distance. Also interesting is that travelers apparently used the higher speeds to access a greater variety of, as well as more distant, destinations. The number of trips per traveler rose slightly while the time per trip declined (Table 2.3).

**Table 2.3: Characteristics of auto-only households, 1970 and 1990**

| | 1970 | 1990/Z* | % Change | 1990/7c* |
|---|---|---|---|---|
| Minutes/Traveler | 67.5 | 69.6 | 3.1 % | 70.9 |
| Trips/Traveler | 3.85 | 4.59 | 19.2 % | 4.55 |
| Miles/Traveler | 20.1 | 26.9 | 33.8 % | 28.5 |
| Average Speed | 17.7 | 23.2 | 31.0 % | 24.2 |
| Minutes per Trip | 17.2 | 15.2 | -11.8 % | 15.6 |
| Miles per Trip | 5.22 | 5.86 | 12.3 % | 6.27 |
| Cars/Household | 1.43 | 2.00 | 49.0 % | 2.06 |
| Travelers/Household | 2.04 | 2.19 | 7.6 % | 2.23 |
| Prob. of Traveling | 0.62 | 0.89 | 44.5 % | 0.89 |

* 1990/z: Zahavi cordon line, 1990/7c: full seven-county area

In broad outline, this table looks much like the comparison between 1958 and 1970. People traveled substantially more miles at considerably higher speeds, while spending about the same total amount of time each day. Travelers made more trips, and the trips individually were longer in distance and shorter in time. The one striking change (in that it is much bigger than took place in the earlier period) is the huge increase in probability of traveling in a day. On the surface, this seems obviously related to the correspondingly large jump in cars per household. However, at a deeper level, both changes likely spring from demographic factors. A simple piece of evidence comes from transit-only households. While these households saw a similar increase in auto ownership, they by definition did not use a car on the day they were surveyed. However, they showed a similarly large increase in probability of traveling.

Considering the same set of statistics for transit-only households gives a somewhat different story from that seen by auto-only households (Table 2.4). Transit travelers spent about the same amount of time per day as car travelers in 1970, but covered much less distance, and made barely more than two trips per day. Bus travel speed did not increase between 1958 and 1970; because speeds did not change, bus travelers did not have the large increase in daily travel distance that car travelers did.

**Table 2.4: Characteristics of transit-only households, 1958 and 1970**

| | 1958 | 1970 | % Change |
|---|---|---|---|
| Minutes/Traveler | 63.0 | 69.0 | 9.5 % |
| Trips/Traveler | 2.11 | 2.09 | -1.0 % |
| Miles/Traveler | 7.80 | 8.61 | 10.4 % |
| Average Speed | 7.45 | 7.52 | 0.9 % |
| Minutes per Trip | 30.0 | 33.0 | 10.0 % |
| Miles per Trip | 3.70 | 4.11 | 11.0 % |
| Cars/Household | 0.33 | 0.23 | -30.3 % |
| Travelers/Household | 1.35 | 1.18 | -12.6 % |
| Prob. of Traveling | 0.56 | 0.56 | 0.0 % |

Zahavi had postulated from evidence from other countries, and from transit travelers in Washington, D.C., that there is a minimum necessary level of mobility, and that the travel time budget will be violated if it is necessary to do so to meet that minimum level. This might be happening with transit travelers here. Since two trips represents the minimum necessary to go to a destination and come back home, these travelers could no longer maintain their travel time budget by reducing the number of trips that they made. Their only possible adjustment was to spend more time traveling.

In Zahavi s analyses, the need to outspend the travel time budget usually arose from slow speeds. Here the speed of transit does not decline between the two years, but there is apparently a need to travel greater distances. That is, bus travelers are spending more time to travel more miles. Since they chose not to do this in 1958, although the option was presumably available, the reason must be because in 1970 it was *necessary* to spend more time and cover more miles to maintain, or at least partially maintain, the same range of choices and standard of living.

This might be a basis for a measure of  sprawl,  that is, that in 1970 it  appears that it was necessary to travel at least 11% more miles to maintain the same (at best) range of options as was available in 1958. Thus the 32% increase in total mileage for auto travelers is not all accessibility increase; 11 or more of the 32 percent might be canceled out by the spreading out of destinations.

On the other hand, all of this speculation regarding transit should be taken with a grain of salt. The sample sizes of transit-only households were relatively small in all these years because there is only a small fraction of people that rely exclusively on transit. In 1990, for example, the sample size was less than 300. It was likely somewhat larger in the earlier years, but still probably not more than 500. The problem is that there is a lot of variation across individuals in how much time they spend, how many trips they make, and so on. Because of this, the  average  can vary dramatically depending on exactly which people are sampled.

For example, the calculated average daily travel time could vary over a range of ten minutes or more (a 95% confidence interval) when different samples of size 300 are taken, even if they are all randomly drawn from the same population.

Thus the differences observed between years could represent real changes, as is assumed in the discussion here, or they could simply be due to inaccuracies arising from small sample sizes. This does not affect the broader conclusions of the report as they do not rely in any way on this analysis of transit riders, which is included only for completeness.

Table 2.5 jumps out, both by virtue of how different it is from the comparison of transit households in 1958 and 1970, and also by how similar it is to the comparison of auto households from 1970 to 1990. (We do not give Zahavi s cordon-line totals separately — almost all transit travel is inside the line, so considering the full seven counties adds no information.) In marked contrast to the earlier period, here transit households seem to have actually done a little better than auto households. First, they reduced their daily travel time back to the 1958 level, which appears to be a budget for this type of travel. This reduction in daily travel time seems to have been made possible by a huge increase in average speed, which made it possible to travel much longer distances while spending less time.

**Table 2.5: Characteristics of transit-only households, 1970 and 1990**

| | 1970 | 1990 | % Change |
|---|---|---|---|
| Minutes/Traveler | 69.0 | 63.7 | -7.7 % |
| Trips/Traveler | 2.09 | 2.52 | 20.6 % |
| Miles/Traveler | 8.61 | 12.3 | 42.9 % |
| Average Speed | 7.52 | 11.6 | 54.3 % |
| Minutes per Trip | 33.0 | 25.3 | -23.3 % |
| Miles per Trip | 4.11 | 4.88 | 18.7 % |
| Cars/Household | 0.23 | 0.70 | 204.3 % |
| Travelers/Household | 1.18 | 1.18 | 0.0 % |
| Prob. of Traveling | 0.56 | 0.78 | 39.3 % |

Because the higher speed made it possible for transit riders to complete the minimum two trips in less than the daily time budget, some travelers used the newly available time to make additional trips. In this sense transit travelers in 1990 actually appear to be better off than their counterparts in 1958. That is, while they spend about the same amount of time per day, they are able both to go to work and occasionally to make additional, discretionary trips as well.

It is also noteworthy that these households have a surprisingly high rate of auto ownership. Possibly some of the apparent increase in service quality is because people can now choose transit for those trips where it is competitive with the auto, rather than having to take it for every trip.

Note finally that the probability of traveling increased for this group as much as it did for auto households, adding weight to the theory that it was demographics rather than auto ownership driving the increase in that group. While there was a considerable increase in auto ownership for transit households as well, these households by definition did not use their car on the day they were surveyed. Nonetheless, they still had a high probability of traveling.

We do not analyze mixed households separately here. The vast majority of the trips in these households are by car, thus the travel characteristics are very much like those of auto-only households. There is no additional insight to be gained from this additional analysis.

# 2.3 Travel Behavior and Location

Zahavi s analysis of the relationship between travel behavior and location is somewhat less thorough than his aggregate analysis. This is understandable; the fact that his data are aggregated into large districts inherently limits the amount of geographic information available. Because Zahavi s own analysis is not well suited for comparison to 1990 (which is our ultimate objective here), we do our own analysis of Zahavi s district-level data.

Zahavi divided the seven-county Twin Cities region into 21 districts of varying sizes, of which 18 were inside his cordon line. For each district inside the cordon (except the two downtowns) we have information for 1958, 1970, and 1990 on:

- average total travel time for auto-only travelers,
- gross population density,
- population (used to weight the data since some zones are much more populous than others),
- average income (1970 and 1990 only), and
- distance from the city center.

Distance from the center is calculated by Zahavi as the distance from the closer of the two downtowns, although it is not clear at what point in the district the measurement begins. That is, points within a district could be anywhere from, say, three to seven miles from the nearest downtown. Because all these different distances are condensed into a single district average, a great deal of potentially relevant geographical information is lost.

The two downtowns were broken out as separate zones in Zahavi s studies, but no zone-level analysis was done on them, since the number of people living in them was too small to get reliable results. We do not analyze the downtowns at this level either, for the same reason. We do include the residents of the downtowns in the overall regional analysis described in the previous section, as did Zahavi.

While the available information did not permit us to recreate exactly the zones used by Zahavi in his analysis, we were able to define a set of zones that very closely match Zahavi s. Using these, we were able to answer some questions about the geographic distribution of changes in travel behavior.

The basic difficulty with geographical analysis of travel behavior is that all the likely explanatory variables tend to be correlated, making it hard to isolate the effects of each variable individually. Daily travel time, income, and population density are all strongly correlated with distance from the center. This is especially the case when the data are aggregated into such large zones, largely eliminating local variations that can sometimes help to isolate different variables.

Regression analysis is a tool for separating the relative influence of different variables on the variable of interest. Applying this method to the three years gives somewhat confusing results, in that the relative influence of the various factors is completely different across the years (Table 2.6). In 1958 and 1990 distance from the center is a strong and statistically significant influence, and density somewhat less so. But in 1970 income is the only factor that matters. Another curious point is that the influence of density, while it is statistically significant only in 1990, is in every year the opposite of what might be expected. That is, higher densities are associated with higher, not lower travel times.

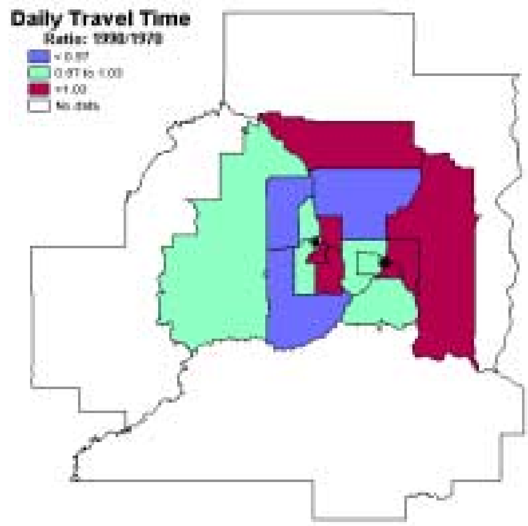
**Table 2.6: Regression analysis of travel times**

| | | Distance | | Density | | Income | | |
|---|---|---|---|---|---|---|---|---|
| | Intercept | Est. | t | Est. | t | Est. | t | $R^2$ |
| **1958*** | **53.7** | **2.2** | **3.8** | **1.5** | **1.7** | | | **0.57** |
| 1958 | 61.0 | 1.4 | 3.6 | | | | | 0.48 |
| 1970 | 62.9 | 0.9 | 1.3 | -0.3 | -0.2 | | | 0.17 |
| 1970 | 35.1 | -0.2 | -0.2 | 1.0 | 0.6 | 0.8 | 2.4 | 0.51 |
| 1970 | 35.7 | | | 1.1 | 0.8 | 0.8 | 2.9 | 0.51 |
| **1970** | **44.0** | | | | | **0.6** | **3.6** | **0.49** |
| 1990 | 60.0 | 1.2 | 3.7 | 1.6 | 2.0 | -0.0 | -0.1 | 0.64 |
| **1990** | **58.9** | **1.2** | **4.5** | **1.7** | **2.3** | | | **0.64** |
| 1990 | 64.4 | 0.7 | 3.7 | | | | | 0.50 |

***** Best regressions, in the judgment of the authors, are in boldface. Statistical significance is measured by t, values above 2.0 are considered highly significant.

Because income was not available for 1958, the possibility exists that the estimated parameter values for 1958 would have been more similar to those for 1970 had income been included. Nonetheless, the turnaround between 1970 and 1990 is striking. In 1970 income exerted a strong influence, and location (distance from center) none at all. In 1990 this was exactly reversed. One possible explanation is that income exerts a strong influence only when it is relatively low, and that by 1990 it had ceased to be much of a constraint for most households.

Map 2.1 shows how the total daily travel time for auto travelers changes between 1970 and 1990 (Zahavi did not calculate travel times for the downtowns and the outlying areas). The point that seems striking about this map is the randomness of the color pattern. Decreases in travel time seem to be restricted to suburban locations (perhaps to be expected as jobs moved outward from the downtowns), but some suburbs saw increases in travel time. Congestion might be imagined to play a role, but the suburbs with higher travel time are not those that are known for congestion, while the famously congested southwest suburbs actually saw a reduction in travel time.

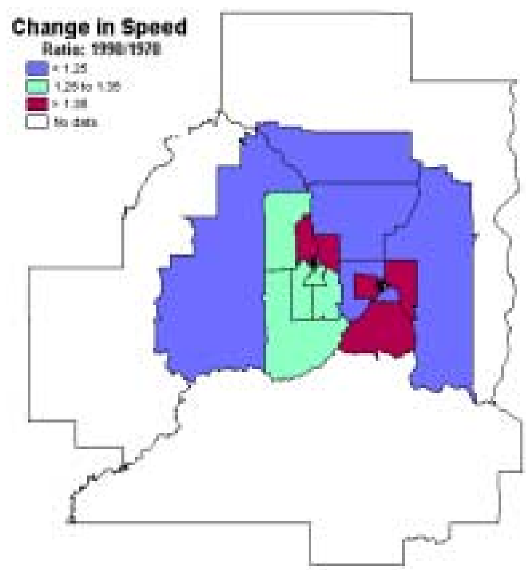



**Map 2.1: Daily travel time, 1970 to 1990**

Areas of higher and lower daily travel time are scattered randomly in both central cities and suburbs. See reference maps in appendix.

Another reasonable expectation is that changes in travel time might have to do with changes in speed; highway improvements in the suburbs might have increased speeds enough to make lower travel times possible, while other areas did not have the same advantage. But Map 2.2 discounts this idea as well. Changes in speed have only a small correlation (0.2) with changes in daily travel time.

One important point in understanding changes in travel times is that the amount of travel seems to be equalizing across the region. In 1958 the range from the lowest daily travel time to the highest was 24 minutes. By 1970 it was still 20 minutes, but in 1990 it was only 12. The places with the lowest travel times tended to see increases, while the areas with long travel times tended to get shorter. And half the zones had travel times in 1990 that were statistically indistinguishable from 1970. Thus zones that were already average tended to stay the same.




**Map 2.2: Auto speed, 1970 to 1990**

Changes in average speed are only slightly correlated with changes in total travel time.

Some of this equalization seems to be because income levels are converging across the region. In 1970 the average income level of Zahavi s central city zones was about 74% of that of the suburbs; by 1990 it was more than 80%. Clearly low-income households are still relatively concentrated in the central cities; however, this concentration actually seems to be becoming less severe, not more.

# 3 Adult Auto Travelers in 1990

Chapter 2 extended Zahavi s analysis of the Twin Cities region to 1990 and found that average regional travel times did not change over a 30-year period during which regional land use changed dramatically. This supports a tentative conclusion that land use does not have that much influence over how much time people spend in their cars. However, an interesting secondary result was that there are differences in average travel times from one place to another within the region. This chapter will study the reasons for these variations, with the hope that examining differences within the region in more detail might cast light on ways that land use affects travel behavior — ways that are lost in the aggregation when the region is considered as a whole. More general questions of mode choice and whether motorized travel is used at all will be considered in the next chapter.

We consider three general travel descriptors and then one major factor that explains almost all of the observed differences across the region. The three descriptors are travel time, trips, and distance, all measured per traveler per day. Travel time is our primary concern, as it represents an explicit choice and commitment of resources by the traveler. The number of trips can in principle vary considerably within a given travel time budget, but surprisingly shows little variation across the region (although it has grown substantially in the past). Distance traveled is the product of travel time and speed; there is substantial variation across the region, and almost all of it arises from differences in speed.

The one factor that explains almost all the variation in average travel times is location, in particular where a person lives relative to major concentrations of employment. Jobs in the region tend to be relatively concentrated in the corridor between the two downtowns, and then out to the southwest of downtown Minneapolis. People who live near these job-rich corridors tend to have shorter commutes than those who don t. The critical point here is that what matters is the distance to *major* regional concentrations of jobs, not the distance to the closest job, or the closest office building. For the average resident of the urbanized area, there are 400,000-500,000 jobs that are closer to home than the job that person actually holds. This indicates that many people place a very high value on a preferred job or home location, compared to a short commute.  These ideas are discussed in section 3.4,  Geography and Job Accessibility.

Throughout this analysis, we exclude anyone under age 18. There are both theoretical and practical reasons for this. From a theoretical standpoint, children in many cases do not make their own travel decisions; thus it is inappropriate to include them in an effort to understand the factors that influence travel decisions. Furthermore, both their  mandatory  and discretionary daily activities are fundamentally different from adults; their behavior, even when they can choose it, is likely to be motivated by different objectives.

The practical reason for excluding people under age 18 is that they do, empirically, behave differently. They make fewer trips and spend much less time per day (54 minutes vs. 74 for adults — although some of this difference might be because some households were surveyed during the summer when children were not in school). Their mode choices are completely different, as they are far more likely to ride as passengers in a car, or to ride a bus (in most cases school bus), and much less likely to drive. Thus including children in the analysis would substantially complicate the problem of comparing the behavior of different groups, since varying numbers of children could make it hard to discern differences among the adults. This is particularly important when comparing the city to the suburbs.

The final reason for ignoring children (or mostly ignoring them) is that they have little overall impact on the amount of travel by their parents. Adults with children make about half a trip a day more than adults without kids, but do not spend more time or cover more distance. They undoubtedly travel to somewhat different destinations, but in terms of their usage of the road system, this doesn t really matter. This surprising result is discussed at more length in section 3.2,  Trips per Day.

# 3.1 Total Daily Travel Time

This is the most significant of the facts about travel behavior, as discussed in the introduction, because it represents resource usage (time and road capacity) most directly. It is also interesting in that it exhibits surprisingly little variation, either across time, places, or types of people. For these reasons we examine this issue in some depth here.

As with other types of behavior, there are significant variations in individual daily travel times. Some people spend a great deal of time in their car on a daily basis, others spend little, and even a given individual will fluctuate from one day to another. Given this high degree of individual variation, it seems all the more remarkable that any *group* that one examines, whether defined by demographics, income, or home location, has an average travel time that falls within a fairly tight range. Even more surprising, even differences among groups that lead to substantial differences in other aspects of travel behavior have no impact on total travel time for that subset that uses cars.

Two examples can illustrate this point. There is a substantial difference between workers and non-workers in the likelihood that a member of each group will travel by a motorized mode in a given day. More than 90% of workers travel each day, while only about 70% of non-workers do. Nonetheless, members of each group, on the days when they do travel, spend about the same amount of time (workers, 75 minutes; non-workers, 71). Non-workers are less likely to travel, but if they do, they spend about the same amount of time as workers.

The second example is location. People who live close to downtown Minneapolis are substantially more likely to use alternate modes than are people who live elsewhere. A considerably smaller fraction of the population in this part of the region relies exclusively on the auto. But the people who do use only autos spend about the same amount of time each day in a car as do auto users in outer ring suburbs.

While total auto mileage is lower in dense areas, this is mostly because speeds are lower, not because people spend less time driving. The other major difference between high- and low-density residents is not that the first group takes shorter trips (in the sense of less time), but that they use the auto to make the trip less frequently. People in high-density areas in general use the shorter distances to expand their choices, not to reduce their trip length. (There is evidence, however, that time spent in other modes counts against auto time. This issue is discussed in the next section.)

In dividing the population according to various criteria, the method that yielded the greatest variations in average travel times was by location, specifically by distance of the home from the nearest downtown. The number of minutes of travel per day rises in a very clear way as distance from the center increases, from about 69 minutes for workers who live within four miles of a center, to just under 80 minutes for those who live more than 25 miles out.

The question is this: why would distance from the center matter? Income is traditionally thought to be an important determinant of travel behavior; incomes rise as distance increases, so the effect might just arise incidentally from the correlation with income. Alternately, population and employment densities decline as distance increases; perhaps density differentials explain the difference. Another possible explanation is that the ratio of jobs to workers is much higher in the central part of the region; thus centrally-located residents can more easily find work close to home, while at least some outlying residents must drive into more central areas.

A simple exercise in looking at differences between group averages yields some surprising insights. It appears that the apparent influence of distance arises exclusively from longer commute times. Non-commute time varies hardly at all by location.

Figure 3.1 breaks the population down according to the distance of the home from the nearest downtown. This shows both commute and non-commute times holding steady until the 10-13 mile range, at which point commute times start a steady increase, while non-commute times remain basically constant and perhaps even decline slightly. Regression analysis (detailed results in the appendix) confirms that non-work travel time, either by workers or non-workers, does not vary in any systematic way with local or even regional variations in land use.

Given that non-work travel time does not vary much, we focus our attention first on explaining commute times. We used linear regression to find the extent to which commute times are influenced by job, retail, and population density, income, and job access, where job access means the ratio of jobs to people within a given distance. It turns out that job access is by far the best explainer of commute times. When taken alone, it explains much more of the variation in commute times across zones than do either income or density. And when the different factors are regressed together, density is generally not statistically significant (or has the wrong sign), while the effect of income is significant but very small (0.2 minutes for $10,000 in additional income). (The appendix gives specific regression results.)

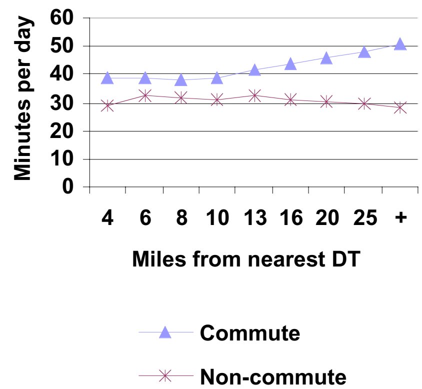



**Figure 3.1: Worker travel times by home location**

Despite the unique importance of job access in explaining commute times, it is worth bearing in mind that even job access is surprisingly insignificant as an influence. Average one-way auto commute times from the center to the edge of the region vary only over a range of about 19-25 minutes, while job access (defined here as the ratio of jobs to people within a 20-minute radius of the home) varies by a factor of three. (Other ways of defining job access, including simple number of jobs, did not explain the data as well.) An interpretation of the regression results says that increasing the number of jobs within 20 minutes of a zone by 10%, while holding the population constant, would reduce average commutes by about one minute. (And since these jobs would have to come *from* somewhere, such a move would likely increase commute times somewhere else in the region.) Again, when more jobs are easily accessible, people just expand their range of choices, rather than shortening their commutes.

Why do job and population density appear to have no impact on commute times? The easiest way of seeing this is by noting (in Figure 3.2 and Table 3.4) that the innermost ring (out to four miles) is three times denser than the ring from eight to ten miles out, yet commute times do not increase at all (in fact they decrease slightly). By contrast, the number of jobs per person varies hardly at all across this range, and this lack of variation corresponds closely to observed commute times. (Overall, from central city to remote rural areas, density varies by a factor of 1,000, and average commute times increase by six minutes over this range.) While land is much less densely developed in the suburban locations, speeds are also higher, which keeps the number of jobs within a given commute time basically constant out to a ten-mile radius. Also, while there are fewer jobs per square mile, there are also fewer people competing for them, so the overall availability of jobs does not change much for the first ten miles from downtown. This begins to change at the 10-13 mile ring, which is also where commute times start to increase.

This situation may be inevitable. Firms, for many reasons, prefer to locate in the central parts of urban regions. With a few exceptions, firms get less value from being close to the edge, while many people seemingly get more. Given this, it is probably unavoidable and possibly desirable that the outer edge of the built-up area will have more residents than jobs.

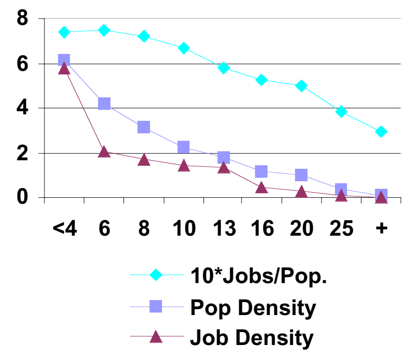



**Figure 3.2: Density (1000/sq.mi.) and job access by distance from center**

It is also surprising that income matters so little. Intuitively one would think that higher income people would be willing to drive farther to work; perhaps this is offset to some extent by higher income people having more choice among jobs. The other factor that implies that commute times might be longer for high-income people is that total travel times are slightly longer; apparently most of the difference arises from non-work travel.

Variations in non-commute travel by workers are almost entirely random. To the extent that there is any systematic variation from one location to another, it arises because workers with longer commutes tend to spend less time on non-work travel. An extra minute of one-way commute time is associated with about 45 seconds less total non-commute time. The greatly superior shopping and other opportunities available in the center of the region do not induce the local residents to spend less time on non-work travel; if anything they spend a little more. The travel time budget, rather than convenient access, seems to be the operative influence here.

The same general point, that land use has little impact on non-work travel choices, arises when examining travel by non-workers. It is influenced by income, which is reasonable and even expected, and by distance from the city center. However, measures such as access to retail or employment (as a measure of opportunities more generally), or various measures of density, are not statistically significant as determinants of variations in travel time.

One possible explanation for this is that the sample is self-selected. That is, the observed differences in behavior might not arise from characteristics of land use but rather from the people who live there. People with a higher tolerance for driving are more likely to move to outlying areas where they will be likely to spend more time driving. Presumably high-income people, for example, could afford to live closer in (since many low-income people do) if they wished to. It is important to bear in mind that the differences are not huge. The range of non-worker daily travel time is from 67 to 76 minutes. And as with non-commute travel by workers, essentially all of the observed variation is random.

## 3.2 Trips per Day

While each auto traveler makes substantially more trips than was the case in the past (from 3.6 to 4.6 between 1958 and 1990), total time per traveler has not increased; apparently people are making more trips and spending less time on each one. And interestingly, despite this large variation over time, there is very little variation at present. For an *adult* auto traveler, the average number of trips per day is about 4.7; virtually no way of dividing the population yields much range on either side of this.

Consider income, for example. With the exception of the lowest income group (<$15,000), which also had much lower-than-average daily travel times, the variation is from 4.5 trips at low income to 4.8 at high income. Looking at distance from the center, the range is from 4.45 at less than five miles, to 4.85 at 10-15 miles, then dropping again to 4.4 at more than 20 miles.

There appear to be three factors that influence the number of trips that a given individual makes; each of these appears to have its effect in a discrete fashion. If a person is poor (defined here as household income less than $25,000), that person will make fewer trips than a person with an income above this level. If an adult has children in the household, that adult will make more trips than one without children. Finally, people who don t have jobs make more trips than people with jobs.

These factors account for about half the observed variation in trip quantities across the region. There is still a puzzling phenomenon in which the number of trips per auto traveler increases from the central city out to about ten miles, then declines, dropping considerably in the outermost rural areas. Some might argue that central city residents are substituting walking for driving trips, but this seems unlikely to be a good explanation of the lower trip rates in rural areas. Farmers often work  at home  and hence don t have commuting trips, but even rural non-workers make fewer trips than their urban counterparts. Perhaps trips are necessarily longer from remote rural areas, thus residents must make fewer trips to keep their total travel time from rising unpleasantly high.

It is interesting to examine in more detail the impact of children on travel by adults. Both in forecasting and in popular discussion, household size is taken as an explainer of trip quantities. However, while the presence of children may pull down the average number of trips per person (because children make fewer trips), when analysis is restricted to adults, it turns out that it is the presence of children, rather than household size itself, that matters (Table 3.1).

**Table 3.1: Effect of children on number of trips**

| Children: | 0 | 1 | 2 | 3+ |
|---|---|---|---|---|
| 1 adult | 4.4 | 5.3 | 5.4 | - |
| 2 adults | 4.4 | 4.7 | 5.0 | 5.2 |
| 3 adults | 4.5 | 4.9 | 5.0 | 5.1 |

Apparently having a child in the household adds about half a trip per day for every adult in the household, and more than this for single parents (although those two cells are relatively small samples). The fact that trip quantities for adults is insensitive to the number of adults in the household implies that household size may be less important than is commonly thought as an input to the forecasting process. It may be the case that if we know how many adults there will be, then we can predict how many trips will be made without the additional step of figuring out how many households they will organize themselves into.

It is even more interesting to look at the total daily travel time for these categories (Table 3.2).

**Table 3.2: Effect of children on total daily travel time**

| Children: | 0 | 1 | 2 | 3+ |
|---|---|---|---|---|
| 1 adult | 71 | 82 | 74 | - |
| 2 adults | 73 | 74 | 75 | 74 |
| 3 adults | 76 | 76 | 80 | 76 |

It seems that while people with children make more trips than those without, they do not spend more time doing it. (While the 82 minutes for one-adult, one-child households is large, it seems likely to be a small-sample aberration, since the number goes back down to 74 when another child is added.) For two-adult households, the increase in trips from 4.4 to 5.2 as the number of children increases from zero to three or more, results in essentially no change at all in total daily travel time. As would be expected, parents make more trips, but contrary to expectations, they don t seem to spend more time doing it.

# 3.3 Total Daily Travel Distance

Distance is travel time multiplied by speed. That is, unlike other ways of describing travel, it is a combination of behavior and technology. This is an important point. It is natural, but generally incorrect, to assume that twice as many miles means twice as much time (a change in behavior). But in fact, variations in mileage arise almost entirely from variations in speed (technology-induced). Because of this, and because we have already analyzed the determinants of travel time, this section on distance is devoted largely to understanding what factors influence average speed.

The belief that variations in distance arise from variations in travel time implies an underlying belief that everyone travels at about the same average speed. This seems plausible and even obvious; wherever you drive, everyone else is going at about the same speed that you are. The mistake in the logic, of course, arises from the fact that traffic moves at different speeds on different roads, and people don t all allocate their time to fast and slow roads in the same proportion. While I am driving as fast as the car next to me now, we may not be going the same speed five minutes from now when we are on different roads.

The most obvious influence on average travel speeds is the location of one s home, in that relatively more driving tends to be near there. Streets are narrower and the grid denser in the central cities; thus speed limits are lower and stop signs and traffic signals are encountered more frequently. Further from the center, the road network was developed later, and thus was often designed more explicitly to accommodate higher-speed auto travel. Perhaps more importantly, densities are lower and thus intersections more widely spaced. Thus, generally speaking, the further from the center of the city one lives, the faster one will be able to travel on average.

The other important general fact that emerges from analysis is that work trips are faster than non-work travel. Work trips are longer than others, and are more likely to use freeways or other high-speed roads. This speed difference is substantial and holds regardless of location or any other factor.

As can be seen in Figure 3.3, commute speeds are four to five miles per hour higher than other trips almost everywhere. Non-commute trips, that is, trips by workers excluding trips to and from work, are generally slightly faster than trips by non-workers, although this could be somewhat due to demographic and economic differences between the two groups.

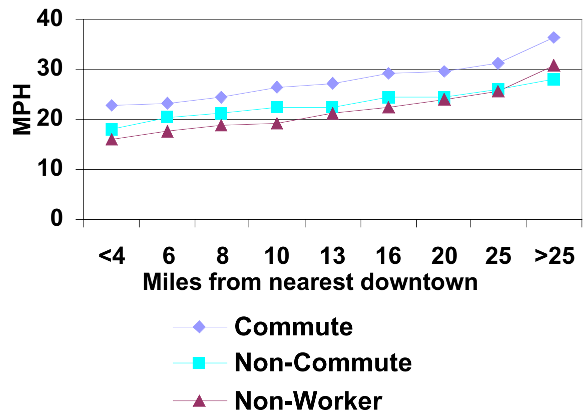



**Figure 3.3: Speed by location**

For both work and non-work travel, the same factors matter. The most important factor for both types of travel is the distance of the home from the nearest downtown. This descriptor is no doubt standing as a proxy for the general types of roads that one is likely to encounter in ordinary daily driving. A second important factor is the density of development around the home, which has the effect of making speeds lower as it increases.

In general, all types of density (employment, retail, and population) have the effect of reducing speeds as they increase. It is interesting to note, however, that the effect of a given increase in retail density is at least twice as big as a corresponding increase in general employment or population density. This is logical; the number of trips generated is much higher for a retail job because these jobs imply many customers for each worker. It leads one to wonder, though, about the virtues of mixed use development. Having retail mixed in with neighborhoods will make trips to those particular establishments somewhat easier for local residents (although maybe not for customers coming from outside), but it will also tend to slow down every other trip those locals make. This is a point that should be more carefully studied and discussed.

Two other factors exerted a smaller, but statistically significant influence on speed of travel. People with higher household income traveled on average at higher speeds than those with lower income (recall that we are considering only auto travelers here — the difference is not because low-income people are riding the bus). More strangely, increasing age was associated with lower speeds. This was not just leisurely retiree drivers. Average speed was highest for the 18-30 age group, and decreased consistently for every subsequent group. It appears that somehow people use different types of roads as they age (or as their income changes); there may be implications for traffic forecasting and highway investment.

It is helpful to summarize the sources of the large differences in miles per person between the central city and outer suburbs or rural parts of the region. Table 3.3, which shows the average values for all adult travelers in two parts of the region, illustrates very directly the point that the vast majority of the large difference in daily miles traveled between the center and edge of the region results from higher travel speeds rather than from more time in the car. (The rural column is not a large sample, but the increases in both travel time and speed are quite regular as distance from downtown increases, so there is no reason to believe that these numbers are misleading.) Distance alone is not a very useful descriptor of system usage, since so much of it is technological rather than behavioral, in the sense that it depends mostly on the characteristics of the road system rather than the people using it. (It appears that a simple way to reduce aggregate VMT would be to reduce speed limits on every road, and install more intersections with poorly-timed traffic signals.) In any case, distance is an output rather than an input; that is, it measures what we re accomplishing rather than how many resources we re using. Increased mileage might not be a bad thing if it can be achieved while reducing resource usage and costs more generally. Conversely, reduced mileage might not be a good thing if it happens because of speed reductions due to congestion.

**Table 3.3: Travel time, speed, and distance**

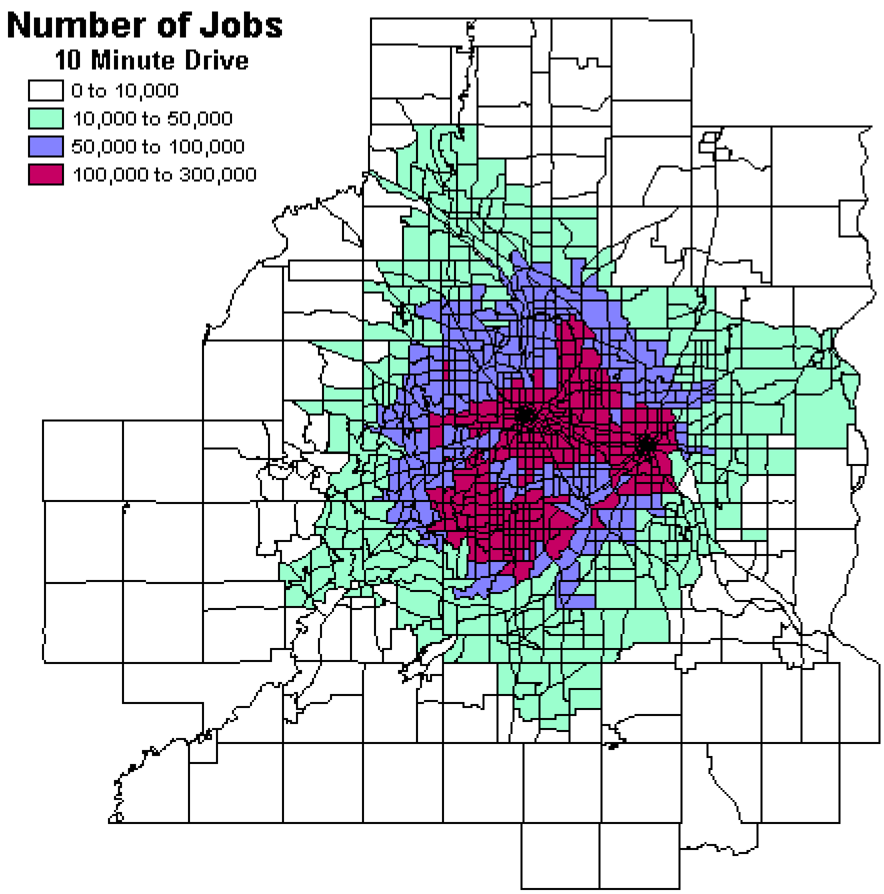
| | Cent.City (<4 Miles) | Rural (>25 Miles) | % Diff. |
|---|---|---|---|
| Travel Time (min.) | 67.7 | 79.8 | 17.9% |
| Avg. Speed (mph) | 18.7 | 33.9 | 81.3% |
| Distance (miles) | 20.9 | 43.4 | 107.6% |

Differences in travel behavior across individual auto travelers can be ascribed to two broad categories: demographic and economic characteristics of the individual such as age and employment status, and characteristics of the places where the individual lives and works. This latter category includes such factors as job access, population density and quality of transit service. In the next section we describe some of the more important factors and give a general sense of the kinds of impacts they have.

# 3.4 Geography and Job Accessibility

Access to jobs, in a regionwide rather than a local sense, is an important influence on travel behavior. A substantial fraction of non-auto trips originate or end in one of the downtowns or the University of Minnesota. Because central city residents are closer to these areas, they are more likely to work in them and make trips to them, and hence are more likely overall to use alternate modes. This, it turns out, explains a substantial part of the lower level of driving exhibited by central city residents.

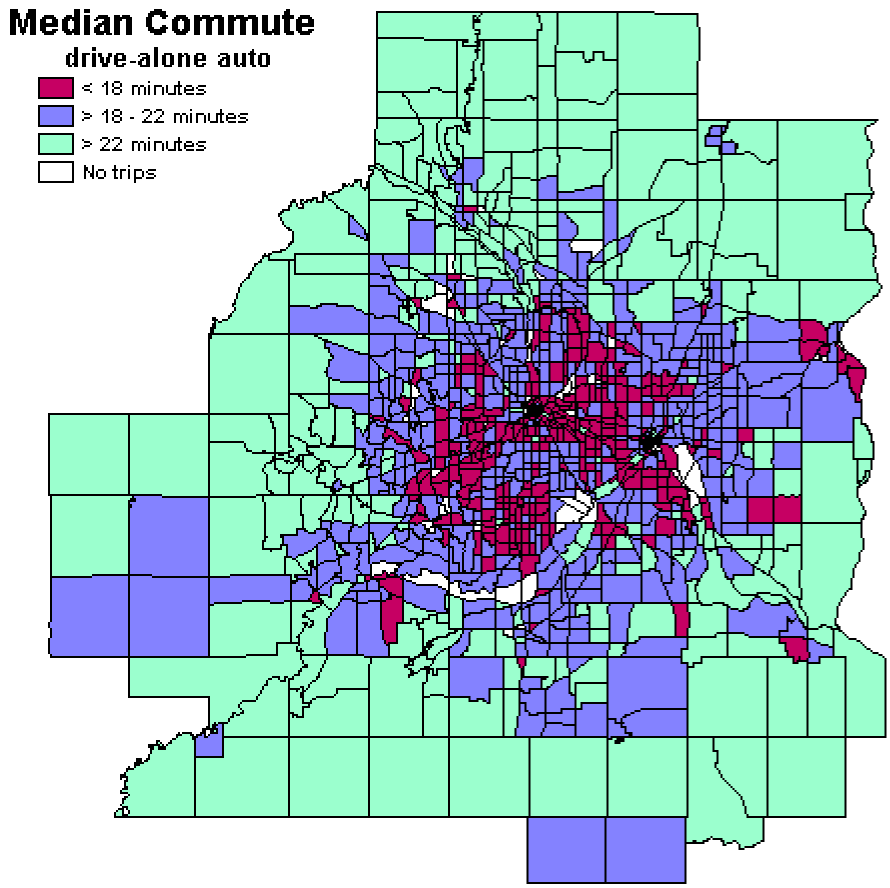
On the other side of the accessibility spectrum, people who live in outer ring suburbs (more than ten miles from the nearest downtown) are farther away from the bulk of the region s jobs than are more centrally located residents (Map 3.1). Half the region s residents live more than ten miles from the nearest downtown, while half the jobs are less than seven miles out. Thus, for people who live in this part of the region, not only are there fewer jobs to choose from, but there are relatively more people competing for them. As a result, residents of these areas must drive farther on average to work. And this turns out to explain almost all of the higher level of driving seen in residents of outer ring suburbs.




**Map 3.1: Job accessibility from home locations**

The central part of the region and the southwest suburbs have the best job access. Half the region s jobs are located less than seven miles from a downtown. See reference maps in appendix.

The primary point that emerges from this analysis of job access is that there are very large differences in job accessibility (even within the urbanized area), but that these lead to relatively small differences in commute times (Map 3.2). Apparently good job access is like high-speed freeways: people tend to use the better access to expand the range of jobs that they choose from rather than to shorten their commutes. Conversely, people with worse job access simply choose from a smaller selection, so as to keep their commute time from becoming inordinately long. Figures 3.4 and 3.5 show that while access varies by several times from the center to the edge of the built-up area, median commute times vary by only about 30%.




**Map 3.2: Median auto commute times**

Low times correspond roughly to areas of good job access. There is little variation across the built-up parts of the region. See reference maps in appendix.

Obviously at every location there are people with very long commutes, and others with short ones, but the *typical* commute time from a given home location varies hardly at all from one part of the urbanized area to another. While many zones have average commutes under 18 minutes, virtually none go below 16. A range of 16 to 22 minutes describes essentially the entire urbanized area. This is particularly interesting in the areas of excellent job access. People living in these areas had in excess of 100,000 jobs within a ten-minute drive of their homes, yet the median person in these areas typically chose to drive about twice this far.

This has important implications for a key idea of modern planning. It is commonly thought that long commutes are to some extent due to the separation of jobs and housing. But our analysis does not support this idea. There are two primary points. First, the presence of a large number of nearby jobs does not noticeably increase the probability of working close to home (Table 3.4).

**Table 3.4: Commuting statistics**

| | Central Cities | <10 mile suburbs | <20 mile suburbs |
|---|---|---|---|
| Ave. no. of jobs, < 1 mile | 6703 | 2744 | 1625 |
| Percent < 1 mile commute | 12% | 10% | 9% |
| Ave. no. of jobs, <10 minutes | 138,000 | 89,000 | 49,000 |
| Percent < 10 min. commute | 22% | 26% | 23% |
| Percent <10 min. (model) | 41% | 39% | 32% |
| Ave. reported commute minutes | 19.6 | 19.0 | 21.8 |
| Ave. no. of jobs, <20 minutes | 524,000 | 434,000 | 241,000 |

The second point is the one hinted at above. To claim that the problem is separation of jobs and housing implies that people are taking the closest available (suitable) jobs, but still must drive substantial distances to get to them. But people clearly do not take the closest available job. Almost everyone in the built-up part of the metro area has at least a quarter of a million jobs within a 20-minute (at congested speeds) drive of home, yet nearly half of workers reported traveling farther than this to work. Are all of these 250,000 jobs unsuitable, or unavailable? And if they are, then what difference would it make if they were mixed in with housing rather than zoned into separate (and generally more accessible) areas?

One possible issue is that perhaps central city job access is not as good as our measures might indicate. When we calculated the number of jobs within ten minutes, we measured time based on the congested times between zones as predicted by traffic forecasting models. Given these assumed travel times, the number of people working within ten minutes of home (in the fifth row of the table) is substantially higher than the number who actually report that their drive took less than ten minutes. The difference between model times and reported times is especially large for central city residents. One possible explanation is that out-of-vehicle time is longer in the central cities, due to the difficulty of finding (or affording) convenient parking downtown. However, if this is the case, then the number of jobs within ten minutes may be considerably lower than we have assumed here, based on the forecasting model.

Regardless of how job access is measured, comparing the first, third, and last rows of the table gives some insight into the reasons for long commutes. Even in the central cities, for most people there simply are not very many jobs within walking distance of home, especially compared with the number available if one is willing to drive ten minutes. Then, as a mathematical point, to double the time one is willing to drive will roughly quadruple the amount of area that can be covered (a circle of radius two has four times the area of a circle of radius one), and thus will roughly quadruple the number of jobs that one can choose from. Alternately, if one has a job and is looking for a home, the number of choices increases with the square of the distance traveled. Thus accepting a longer range of travel will both make it easier to find a job or home, and makes it more likely that one will be happy with the job or home that is chosen. While there may be people who prefer a short commute and are willing to restrict the jobs they consider to achieve this aim, clearly for the great majority of people choice is more important than a short commute. This, not a lack of nearby jobs, seems to be why people commute long distances.

Another point to consider is that while there are more nearby jobs in the central cities, there are also more nearby people who might be expected to compete for them. While this is true, it turns out in fact to further support the point that central city commutes should be shorter than they are, if job access were the only consideration. While population *is* denser in the central cities, jobs are relatively denser still. That is, in the central cities, not only are there more jobs within a given distance of home, but there are relatively fewer people competing for them. Surprisingly, this is true of low-wage as well as higher paid work.

Central city residents not only have more nearby jobs, but they have more nearby jobs per person (Figure 3.4). This imbalance is especially pronounced among higher income workers. Low-income workers and jobs, contrary to popular belief, are actually much better balanced by location than are their counterparts with higher incomes, although in both cases central city residents are better off than suburban dwellers.

Another interesting and perhaps counterintuitive point that emerges from this analysis is that low-income workers are surprisingly well spread throughout the region, rather than being especially concentrated in the central cities.

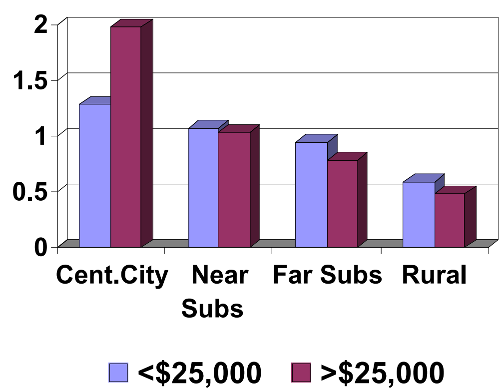



**Figure 3.4: Jobs per resident worker, by personal income**

The first interesting point from Figure 3.5 is that in all locations, the majority of low-income (<$25,000) workers come from high-income (>$25,000) households. The second is that in all locations, the total number of low-income workers exceeds the number of high-income. The third is that while low-income households are relatively concentrated in the central cities, in absolute numbers there are more in the suburbs.

An important implication of these charts is that building affordable housing in the suburbs would not be especially helpful to low-income households as far as job access is concerned. While there are not a lot of low-income *households* in the suburbs, there are plenty of low-income *workers*, entering the workforce as the second or third wage earners of higher-income families. Truly low-income people seeking suburban jobs would have to compete with all these (very likely better qualified) non-poor but still low-wage workers. There are more low-wage jobs *per low-wage worker* in the central cities.

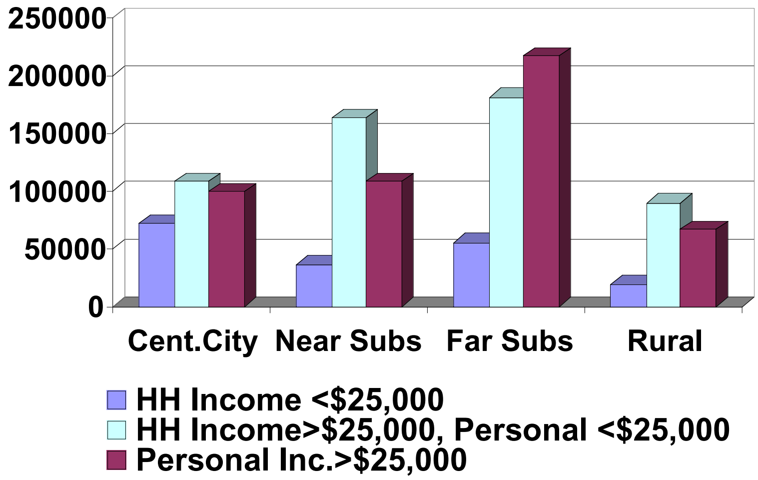



**Figure 3.5: Number of workers, by household and personal income**

The general point of this digression into income levels and job access is that the generally good balance of jobs and people in general is not contradicted by noticeable imbalances arising from inappropriate matches of wages and skills at particular locations. It appears that not only are there plenty of nearby jobs at most locations, but these jobs match, in a general sense, the skills of the local residents. People probably live far from their jobs because they value a particular job or house more than a short commute. Indeed, high-income people, who as a group are most likely to be able to afford to move closer to their jobs if they want, are in fact the group with the worst job access.

# 4 All Travel (All People, All Modes) in 1990

This chapter attempts to find the reasons why people in different places make different choices about whether to travel and what mode to use, to quantify the differences observed across the region, and in particular to identify the role of land use.

The previous two chapters focused largely on auto travelers, who constitute the vast majority of the population in the Twin Cities. The primary findings were that average daily travel times for this group have not varied much historically, and do not vary much currently across the region; and that the observed variations arise from poor access to the regional job base from outlying areas.

This chapter moves beyond this limited analysis to examine travel in general in 1990. One of the most widely held beliefs about high density neighborhoods is that people are able to complete trips by modes other than auto. That is, even if the average auto traveler is about the same everywhere, the average *person* may not be, if fewer people use autos or they use them less frequently in some parts of the region. Thus the purpose of this chapter is to understand *all* the factors that influence the amount of auto travel, in particular to see whether auto travel may be reduced by use of alternate modes even if total travel time doesn t vary much.

We find evidence that this is true, although the difference across the region again is not very large. The average adult living in the central cities spends about 45 minutes a day driving a car, compared with 50 minutes for the average inner suburb adult resident. The difference arises from two main sources. Central city residents are slightly less likely (about 3%) to use motorized transport in a given day, and those that do are more likely to use transit and (to a much smaller extent) carpool.

The main finding is that land use does impact transit use, but that commercial land use appears much more significant as a determinant of mode choice than does residential density. The point basically is that a fairly small area of the region, consisting of the two downtowns plus the University of Minnesota, attract a wholly disproportionate share of alternate (non-auto) mode use. Indeed, about 30 of the 1165 traffic zones in the region (less than 1% of the total land area) attract more than 60% of the region s bus trips. (These are the two downtowns and the University of Minnesota.) A large share of walking and biking trips also go to these zones. Thus people who live close to these zones are much more likely to use alternate modes than are people who live further away. This happens both because increasing distance makes walking and biking (and to some extent transit) more difficult, and because people who live farther away from a place are less likely to travel there at all.

Because the areas near the downtowns and the university are conveniently located, they tend to be densely developed. However, while we can t claim to have analyzed this question from every possible angle, our findings to this point lead us to believe that it is the convenient location, rather than the density of development, that makes the difference. To clarify and support this point is an obvious avenue for further research. The difference between the two points of view is critical from a policy standpoint. If we are right, then simply increasing density will make little difference to travel patterns. What will matter is increasing the density of areas that, because of their location, have the potential to generate low travel rates.

# 4.1 Traveling vs. Staying Home

A basic problem in understanding travel behavior is to determine the factors that influence whether a person is a traveler at all. Traveling is defined here as making a trip by motorized vehicle: car, bus, motorcycle, or taxi (this would also include rail if this option were available). Walking and biking are not considered here. Except for trips to work we have no information on use of these modes in the Twin Cities. However, evidence from other similar cities indicates that excluding these modes is probably not creating too much bias in the results. The Nationwide Personal Transportation Survey (NPTS) of 1995 specifically asked about travel by nonmotorized modes. In cities the size of the Twin Cities only about 1.5% of people reported traveling by nonmotorized modes but not by motorized modes. That is, in almost all cases when people don t travel by motorized modes, it is not that they are walking places instead of driving, it is that they don t travel at all.

## *4.1.1 Relevant Factors*

Whether a person travels in a given day seems to be almost entirely determined by whether that person is employed or not. Adults who are employed have a 92% probability of traveling; adults who are not employed have a 70% chance. Differences in travel rates by other dimensions (age, household size, etc.) are fully explained by differences in employment rates. It is possible to predict travel rates of almost any subgroup within 2-3% by simply multiplying the fraction that are workers by 0.92 and the fraction that are nonworkers by 0.70.

Surprisingly, while older people are less likely to travel, the difference is essentially entirely due to the fact that they are less likely to have jobs (Table 4.1). Age seems to have no additional influence on this particular aspect of travel behavior.

**Table 4.1: Probability of motorized travel by age**

| Age | Predicted | Actual | % Diff. |
|---|---|---|---|
| 19-29 | 0.88 | 0.84 | 4.8 % |
| 30-54 | 0.88 | 0.89 | -1.9 % |
| 55-64 | 0.81 | 0.81 | -0.3 % |
| 65 + | 0.73 | 0.71 | 1.9 % |

Again, differences in employment rates track well with differences in traveling rates by income (Table 4.2). The one significant difference (indeed, the only group of any kind that was poorly predicted) is people in households with income under $15,000. Zahavi discussed money as another constraint on travel behavior, and perhaps that is what is happening here. That is, it could be that the other groups earn enough income that the money constraint is no longer binding, and only the time budget influences travel behavior, while the lowest income group is still constrained by lack of money as well.

**Table 4.2: Probability of motorized travel by income**

| Income | Predicted | Actual | % Diff. |
|---|---|---|---|
| <$15,000 | 0.78 | 0.70 | 11.0 % |
| $15,000-25,000 | 0.81 | 0.81 | -0.8 % |
| $25,000-45,000 | 0.85 | 0.86 | -1.4 % |
| $45,000+ | 0.88 | 0.89 | -1.3 % |

Employment rates do not vary much by distance from the city center. As a result, the predicted probability of motorized travel does not exhibit as much variation as actually occurs (Table 4.3). Nonetheless, the variation by location is surprisingly small given the widespread belief that the central cities are far more conducive to non-motorized modes. It is also interesting that the actual rate of motorized travel is lower than the predicted value in rural areas, where people don t use non-motorized modes much.

**Table 4.3: Probability of traveling by home distance from city center**

| Miles from center | Predicted | Actual | % Diff. |
|---|---|---|---|
| <5 | 0.85 | 0.82 | 2.6 % |
| 5-10 | 0.85 | 0.85 | -0.3 % |
| 10-20 | 0.87 | 0.88 | -1.7 % |
| 20+ | 0.86 | 0.84 | 2.5 % |

### *4.1.2 Historical Changes*

While employment rates seem strongly correlated with the probability of travel, the question remains of why the probabilities are what they are. For example, the probability of traveling for non-workers must have increased since 1970, since the overall rate of travel including workers at that time was only 67%, compared to 70% for non-workers now. The important question for forecasting purposes is this: how stable is this rate, and what factors influence it?

The case can be made that the rise in this rate was a one-time result of the oldest generation, who were far less likely to travel than younger people, being replaced in the population by a new generation which traveled more at the population average. Another important factor seems to have been greatly increased mobility of children, possibly due to higher auto ownership by their families, and to the increased likelihood that older children will have jobs. The final factor influencing the probability of traveling was widespread entry into the workforce by women, which moved them into the higher travel category.

We don t know the probability of travel by age in 1970, but it is possible to make an educated guess based on trip rates then and now. It appears that the probability of traveling by age quartile might have been something like 0.5, 0.9, 0.8, 0.4 in 1970, while it is about 0.8, 0.9, 0.9, 0.7 now. This would lead to an overall rate in 1970 of 0.65, which is consistent with the known total rate from then.

Given that travel probabilities are now virtually constant across all ages (the lower rate among the elderly is because they are less likely to work, not because they make different travel choices), it seems plausible to claim that the rates will not change much in the future, in the absence of large changes in employment rates. Another way of testing this hypothesis is to determine if there are groups within the current population with much higher than average probabilities of traveling. These could be considered to be  leading  groups, which others will eventually catch up to.

Workers in every group have about a 0.92 probability of traveling. For non-workers, almost all groups are within 1-2% of 0.7, with two significant exceptions.

First, non-workers in the 30-39 age group have a probability of traveling of 0.79. While this is much higher than older age groups, it seems unlikely to represent the leading edge of a new trend, since the next younger group, the 19-29 year-olds, has a probability of 0.55, which is far below the average. These variations seem more likely to be a result of lifecycle factors than an indication that the 30-39 group is a sign of the future.

A more important factor is income. Here the probability of traveling among non-workers ranges from 0.63 for incomes under $15,000, to 0.70 for $15-25,000, to 0.72 for $25-35,000, to 0.75 for more than $35,000. This makes it appear that the overall rate of travel for non-workers could rise as high as 0.75 as incomes rise and monetary constraints on travel become less binding. For still higher income, the rate does not continue to rise, giving some confidence that 0.75 might represent an upper bound.

# 4.2 Determinants of Mode Choice

The final general issue that significantly influences the amount of auto travel in the region is the choice of travel mode. Modal decisions play an important role in generating measurably different driving rates when central city residents are compared with suburbanites. Since these differences are a primary point of emphasis among advocates for central-city-type neighborhoods, it is important, if these differences are to be exploited effectively in other contexts, to understand how big they are and from what sources they arise.

## *4.2.1 Transit*

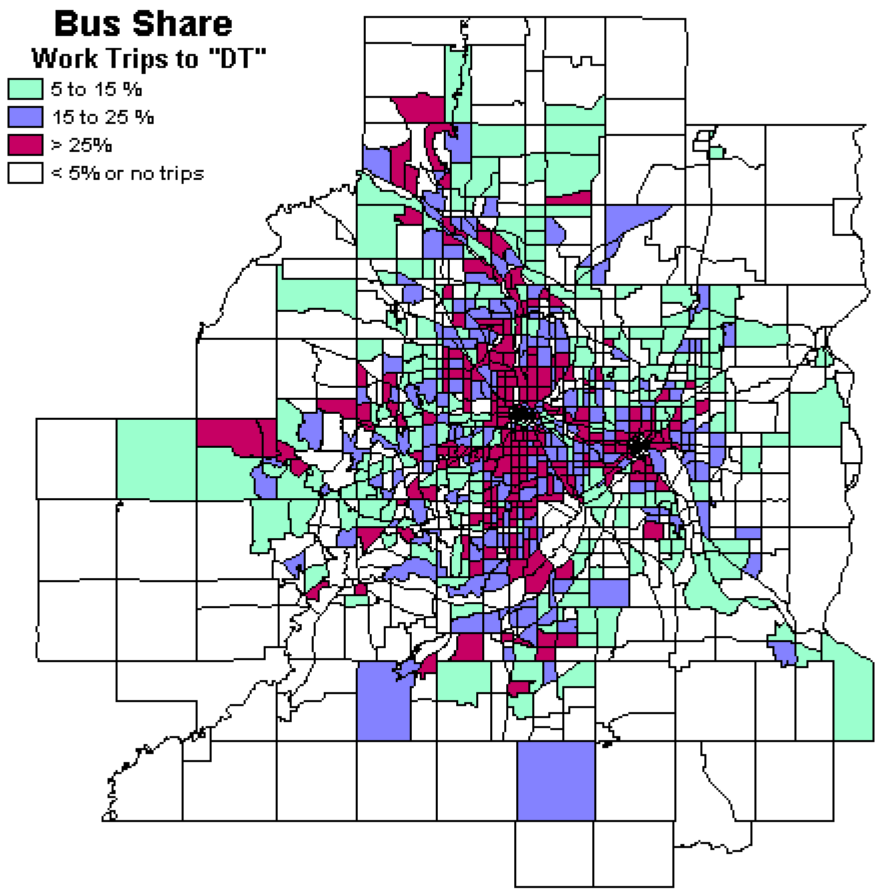
Central city residents use transit far more frequently than do suburbanites, using transit for 6.4% of their trips compared with 1.7% in the suburbs. (This includes both adults and children. Transit means public buses, not school buses or vanpools.) The reason for this is typically believed to be land use patterns: higher densities make it possible to maintain a denser bus network, and this in turn makes it easier to access the system. Because people can easily walk to the nearest bus stop, they are more likely to use transit than are suburbanites, who must often drive or be driven to a place where they can catch a bus.

The facts here are not disputable, but the explanation is. The fact that cities are higher density, and that they have higher transit shares, does not in itself prove that one caused the other, even though it may be logical. At the very least, it is necessary to examine at least some alternative explanations. The two considered here are differences in income, and in destination choice.

The first of these is simple to explain. Low-income people (household income below $25,000) are three times as likely to use transit for a given trip than are people with incomes above this level. And as discussed in the last section, while low-income people are not exclusively confined to the central cities, they do make up a considerably higher fraction of the population there than they do in the suburbs. This does in fact explain some of the difference in transit shares.

More of the difference, however, is explained by the second, more subtle issue of destination choice. A majority of transit trips either originate or end in downtown (defined here as the dense commercial area of downtown Minneapolis, downtown St. Paul including the Capitol area, and the three campuses of the University of Minnesota). Residents of the central cities are more likely than suburbanites to travel to these areas, for two reasons. First, people who work or attend school in these areas have more reason to live relatively nearby, which tends to concentrate them in the central cities. (This phenomenon happens in suburban job areas as well, although in that case obviously it leads to employees concentrating in suburban residential neighborhoods.) Second, people everywhere tend more often to seek shopping or recreational opportunities close to home, which for central city residents sometimes means downtown or the University.

What emerges from analysis is that trips to or from downtown are ten times more likely to use transit than are other trips, *regardless of the location or density of the residential neighborhood on the other end of the trip*. Trips between downtown and suburbs have a transit share in excess of 15%; this is true even in many outer ring suburbs. On the other hand, even central city residents are relatively unlikely to use transit for trips that do not go to or from downtown. The combination of the facts that trips downtown are more likely to use transit, and that central city residents are more likely to make trips downtown, explains much of the difference in transit usage rates between central city and suburbs.

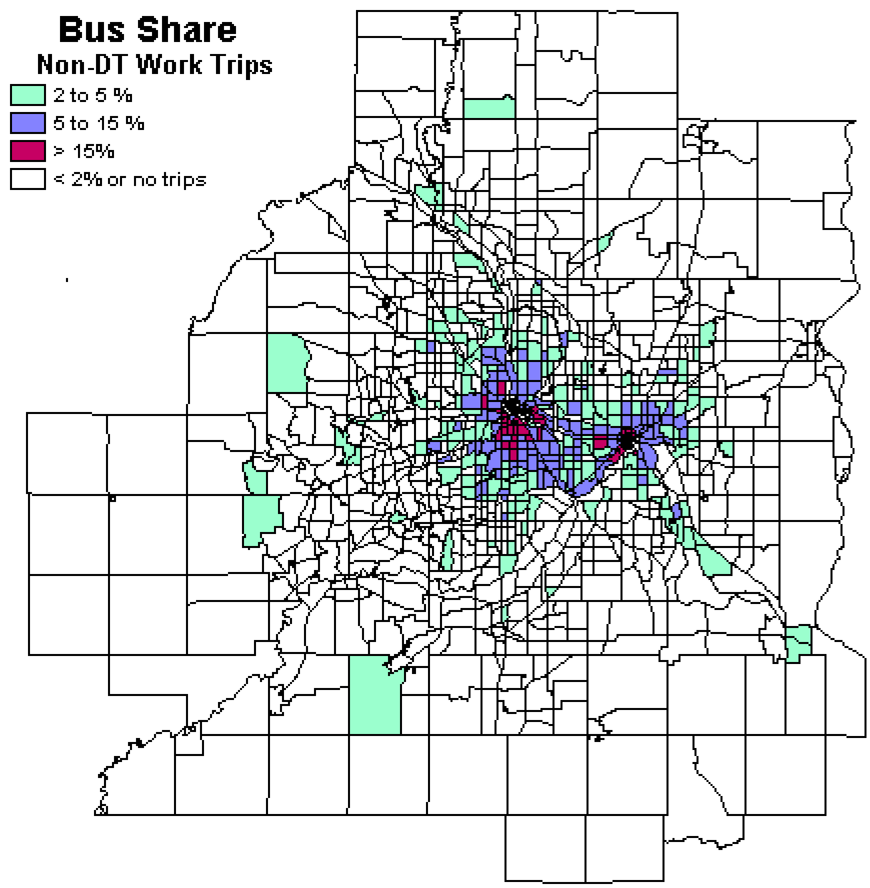



**Map 4. 1: Bus share, work trips to extended downtown**

Share exceeds 15% far beyond the dense areas of the central cities. See reference maps in appendix.

Map 4.1 shows the bus share for work trips going to our conceptual downtown (including the central downtowns of Minneapolis and St. Paul, and the University of Minnesota). The casual observer, used to believing that transit is insignificant in the Twin Cities, can hardly help but be astonished at this picture. The bus share for work trips to these areas is in excess of 15% over an area that extends in every direction far beyond the traditional high-density, transit-friendly areas of the central cities. From downtown Minneapolis, there is an unbroken corridor of high transit share extending 15 or 20 miles or more in most directions.

Given the low residential densities prevailing over most of this area, it seems inevitable that most of these people must be driving or riding in a car to a place from which they catch the bus downtown. If people are indeed this willing to drive to a bus stop, then perhaps the supposed need for high density housing to generate bus ridership ought to be reconsidered. It appears, in fact, that the density (and likely the cost of parking) at the *work* end of the trip is a far more influential factor.




**Map 4. 2: Bus share, work trips to non-downtown destinations**

Share exceeds 5% only in parts of the central cities. See reference maps in appendix.

Map 4.2 furthers this point. This shows the bus share for work trips to places other than downtown. Here only a very small area generates shares in excess of even 5%, and local residents will recognize that much of this area is the low-income neighborhoods of north and near south Minneapolis. The data we used to make this map did not allow us to distinguish between low- and high-income households, but given our results elsewhere, we can only believe that the high transit share areas of the map would shrink considerably if just higher-income households were considered. Table 4.4 shows the striking difference between households of different income levels in mode choice, regardless of the home or destination neighborhood.

**Table 4.4: Transit share by household income, trip ends (all trips)**

| | <$25,000 | >$25,000 | Total |
|---|---|---|---|
| Central city/downtown | 51.9% | 20.6% | 26.8% |
| Central city/non-downtown | 6.3% | 1.9% | 3.0% |
| Central city total | 12.3% | 4.7% | 6.4% |
| Suburban/downtown | 35.0% | 14.8% | 16.2% |
| Suburban/ non-downtown | 1.8% | 0.6% | 0.8% |
| Suburban total | 3.4% | 1.5% | 1.7% |

Table 4.4, while compelling as a demonstration of the importance of income and destination in determining mode choice, is not helpful in understanding how much difference these factors make to the total shares. To see this, an exercise was performed in which the fraction of trips to each destination by each income level (for example, trips downtown by low-income people) was set to be the same for central city residents as for suburbanites, while keeping mode share for each type of trip at the levels shown above. In other words, we want to know what would happen if the shares of high- and low-income households were the same in both places, and people in both places were equally likely to travel downtown. Defining a type of trip to be a combination of an income level and a destination, there are four types of trip. Table 4.5 shows the percentage of each type of trip in each location; the numbers add up to 100% within the central city box and within the suburb box.

**Table 4.5: Fraction of total trips by income, destination**

| | <$25,000 | >$25,000 |
|---|---|---|
| Central city/downtown | 2.7% | 11.7% |
| Central city/non-downtown | 17.7% | 67.9% |
| Suburban/downtown | 0.5% | 5.3% |
| Suburban/ non-downtown | 9.4% | 84.7% |

In the experiment, then, the percentage of trips by low-income central city residents to downtown was set to 0.5% of total trips by central city residents, to equal the percentage of this type of trip by suburban residents. The mode share for this type of trip was kept at the observed level of 51.9%. This adjustment was then applied to the other three types of trips by central city residents, to make the likelihood of that type of trip equal to the level observed in the suburbs, while leaving the mode share unchanged.

Table 4.6 shows that fully one-third of the transit mode share for central city residents is due to the fact that they are much more likely to make trips downtown than are suburbanites (they are more likely to travel downtown by all modes, not just transit). The overall transit share for low-income drops from 12.3 to 8.5, while high-income drops from 4.7 to 3.0, when destination choices are set to be equal to those made by suburban residents.

**Table 4.6: Normalized central city bus shares (all trips)**

| | <$25,000 | >$25,000 | **Total normalized** | Total observed |
|---|---|---|---|---|
| Downtown | (51.9%) | (20.6%) | **23.3%** | (26.8%) |
| Non downtown | (6.3%) | (1.9%) | **2.3%** | (3.0%) |
| **Total normalized** | **8.5%** | **3.0%** | **3.5%** | (6.4%) |
| Total observed | (12.3%) | (4.7%) | (6.4%) | |

Holding income levels similar to those in the suburbs has a significant impact on mode share for non-downtown trips (from 3.0 to 2.3), which are the vast majority of the total (by all modes), even in the central cities. Overall, when both income and destination differences are controlled for, nearly half of the central city bus share disappears. The normalized share, at 3.5%, is still twice as high as the suburban share of 1.7%, but increasing transit share by 1.8% does not seem like a particularly strong argument for higher residential density. It is certainly less compelling than the quadrupling implied in the unnormalized share of 6.4%; and it is much less striking than the 20% share created by the high job densities of the downtowns and the University.

The most important conclusions to be drawn from these numbers seem to be that the characteristics of residential neighborhoods seem to have much less impact on mode choice than is usually thought, and that characteristics of the destination have a great deal more. For both income levels, trips downtown are ten times more likely to use transit than trips to other destinations, and in the suburbs the difference is 20 times. Suburban residents traveling downtown are six to seven times more likely to use transit than are central city residents (of the same income level) traveling to a non-downtown destination.

A possible problem with this line of reasoning is that transit service in the Twin Cities is very focused toward serving the downtowns. Thus a reasonable case could be made that there is little bus share to non-downtown destinations because there are not very many buses going to these places. There is a chicken and egg problem here. Is sparse non-downtown bus service the cause of low non-downtown bus shares, or is it an effect, a response to lack of interest in these routes? This is a question that we cannot yet answer. However, it should be noted that a major part of the reason why bus service downtown is so much better is because there are so many more people that want to go there. It would be extremely costly to provide equally good service to most other places because there is insufficient job density to provide an adequate customer base for good bus service.

Simple regression analysis (detailed results in the appendix) supports the idea that simple residential population density doesn t impact transit use very much. These regressions consider transit share by home zone, without considering (except indirectly) the income level of the riders or the destination of the ride. So if anything some of the effect of these other factors is being captured as being the result of population density. Nonetheless, while population density is statistically significant as an influence on transit share, *the influence is not very big*. Increasing the density of a square-mile area by 1,000 per square mile (a big density increase in a residential neighborhood) is associated with somewhat less than a 1% increase in transit share to work (for example, from 5% to 6%), other things held constant (or conversely, a decline in auto share from say 90% to 89%). Analysis of other cities (Barnes, 2001) shows that this general relationship holds across the U.S.

The apparent lesson here is that, at least in the Twin Cities, increasing land use in commercial areas is more likely to impact transit usage than is higher residential density. This is partially because higher commercial densities will likely encounter less political opposition, but also because commercial densities can be driven much higher, and many more people impacted. Furthermore, high commercial density appears to be nearly a necessary condition, while high residential density is merely helpful. The example of suburban residents traveling downtown shows that if people have a compelling reason to take the bus, they will find a way to take it, even if their home neighborhood is not transit-friendly according to the usual criteria. And the example of non-downtown trips by central city residents shows that if the destination is not well served by transit, not many people will use it, no matter how transit friendly their home neighborhoods might be. Another way of looking at this is that it is not a high population density *per se* that makes transit viable; rather it is a high density of people *traveling to the same destination*. Such high destination-densities may also exist at some places in the suburbs.

It is worth dwelling a moment on this point. Transit is a reasonable competitor to the auto in cases where the bus can fill itself with a small number of stops, drive directly to the destination, and discharge all the passengers with an equally small number of stops. If the bus has to stop 15 times at the beginning of the route, or at the end, the trip will simply be too time consuming to be competitive for anyone with a car at their disposal. The question then is: how is it possible to achieve this ideal low-stop scenario? First, the end of the route needs a densely built area with a large number of jobs within easy walking distance of the bus route. In downtown, because the buildings are tall and close together, there are tens of thousands of jobs within walking distance of any bus route. In suburban areas, by contrast, buildings are generally short and separated by large surface parking lots, so that a bus would have to stop at every building individually, and each building would be the destination of fewer people.

What about the home end of the trip? Here the well-known formula is high housing density, so that many people will be within walking distance of the bus route. But there are two points against this idea. The first is that mentioned above, that people do not in fact seem that unwilling to drive their cars to catch the bus. It seems not improbable that this might be because once they get to the bus, it drives directly to their destination. A bus that stops within walking distance of your home is probably also stopping within walking distance of many other people s homes; the convenience of walking to the bus may be cancelled by the inconvenience of stopping dozens of times to pick up other people who have done the same thing. (A friend of the author has a local route downtown close to her home, but she chooses to drive a mile to a place where she can catch an express bus.)

The second point against high home density as a promoter of transit use is that, as mentioned earlier, it is important not only to have a lot of people, but to have a lot of people going to the same place. Having 10,000 people in a square mile, but traveling to 9,000 different destinations, does not make transit particularly viable. And highly dispersed work locations are in fact the case over most of the region. In practice it appears, especially in the suburbs, that people solve this problem by creating temporary density, by driving their cars to designated high-density areas (bus stops), which may not be particularly close to any of their homes. It may be possible, by exploiting this idea, to provide good bus service to high-density suburban job centers surrounded by low-density housing. Further increasing the density of the suburban job centers would make this task easier yet.

Although it certainly needs further study, these results imply that transit share could be increased by greater focus on providing good service to popular but expensive suburban destinations, such as those subject to severe congestion, perhaps sacrificing some service to residential areas. These results also suggest that land use policy, to the extent that increased transit usage is an objective, ought to focus on increasing the density of commercial areas and perhaps show less concern with residential development patterns.

It could be objected that driving to the bus will not help reduce pollution since much of the emissions occur in the first few minutes. But the cold-start penalty seems like a problem that can be solved by technology. (Hybrid-electric or fuel-cell vehicles would pollute no more at the beginning of the trip than at any other time.) And if emissions were more proportional to trip length, then an extensive park-and-ride system could have a significant impact on total emissions in addition to its more immediate and potentially sizeable effect on congestion. Given that the alternative seems to be that people don t ride the bus at all for most trip destinations, then a park-and-ride system at least wouldn t make pollution any worse. Finally, while parking spaces would still be needed, at least some of them would be moved out of commercial areas, making even higher job densities feasible.

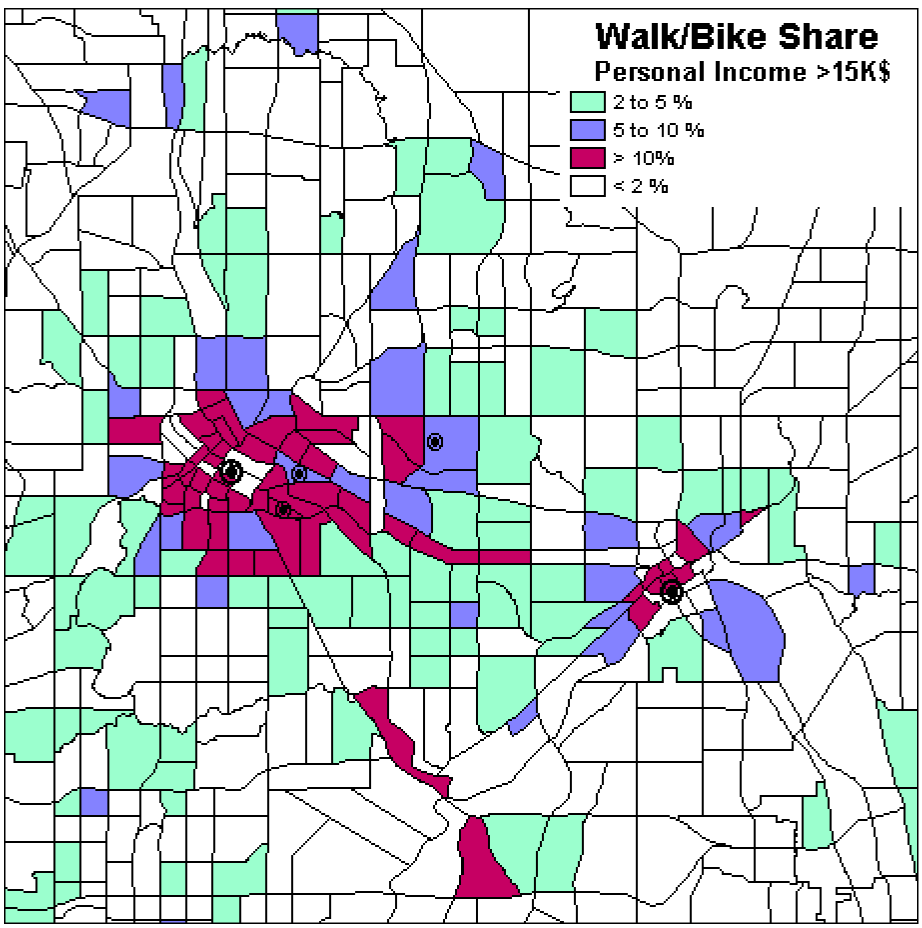
### *4.2.2 Walk and Bike*

Mode shares for walking and biking exhibit similar patterns to those found in the transit mode (Table 4.7). That is, being low-income or working downtown appear to have a much larger impact than do residential land use patterns. For these modes, we have information only on the trip to work. Thus trips were divided into types based on income and, for central city residents, by whether the person worked downtown.

**Table 4.7: Walk and bike shares, by location and household income**

| | <$25,000 | >$25,000 | Total |
|---|---|---|---|
| Central city/downtown | 19.0% | 7.6% | 9.0% |
| Central city/non-downtown | 6.7% | 2.6% | 3.4% |
| Central city total | 9.7% | 3.9% | 4.8% |
| Near suburbs (<10 miles) | 3.3% | 1.2% | 1.4% |
| Far suburbs (>10 miles) | 1.6% | 0.7% | 0.7% |

As with transit, being low-income and working downtown (including the University) contribute substantially to the mode share for walk and bike. For non-downtown workers, central city residents are more likely to walk and bike than are suburbanites, but the difference is not as large as might be expected, given the generally much better pedestrian infrastructure.




**Map 4.3: Walk/bike share, work trips, personal income >$15,000**

Areas with high walking and biking are concentrated around the downtowns (the two large dots) and the campuses of the University of Minnesota (the three small dots). The walk/bike share drops rapidly with distance from these areas. See reference maps in appendix.

The view of the central part of the region in Map 4.3 illustrates these two points. The two striking points about this map are the extent to which the areas with high walking and biking (for people with income above $15,000 per year) are concentrated around the downtowns (the two large dots) and the campuses of the University of Minnesota (the three smaller dots). There are only a handful of zones where walk/bike share exceeds 5% that are more than a mile from one of these attractors.

The second striking point about this map is the rapidity with which the walk/bike share drops from more than ten percent to less than two, as the distance from the major attractors increases. This further supports the point that, as with transit, it is the characteristics of the destination more than the home neighborhood that lead to high alternate mode use. Population density does not drop off nearly as rapidly as the rate of walking does, nor does the quality of sidewalks.

Another point that bears further emphasis is that walking and biking are very much modes used by low-income people. In the census data, people with personal income less than $15,000 per year make (in both cities and suburbs) more than 70% of the total walk and bike to work trips, despite constituting at most 40% of the population (in the cities, and less than this in the suburbs). Much of this no doubt is teenagers and college students working part-time jobs, but the general point still holds — people who can afford not to walk generally don t. (And more generally, don t even work within walking distance of their home.)

Table 4.7 is not directly comparable with the similar one for transit (Table 4.4). This table includes only work trips (because that is all the data available), while the transit table included all trips. The transit share of work trips is undoubtedly higher than is its share of total trips. However, this is hard to determine exactly because many trips to work apparently were not recorded as such in the TBI data. (Only 75% of workers report making a trip to work on the day they were surveyed.) This does not affect the conclusions drawn here, since they were based on the relative, not the absolute sizes of transit shares in different locations.

However, despite problems of comparability, it is clear from these data that overall, and especially for non-downtown work trips, walking and biking are of the same order of importance as transit. This suggests that a greater focus on encouraging these non-motorized modes, and on providing safe access to them, could conceivably pay substantial dividends in reducing local rush hour congestion.

### *4.2.3 Carpool*

The final alternate mode studied here is carpooling. The number of people who get to work by riding as a passenger in a car is considerably larger than the number who use transit, on a region-wide basis. Given this, it seems worth putting some effort into understanding carpool behavior, in case there are policy ideas that could be exploited.

Auto occupancy rates (the number of people per car) have an interesting history. The numbers below are taken from the 1990 Travel Behavior Inventory Summary Report (Table 4.8). (Note that there are other types of trips in addition to those shown here; All trips is not the average of work and shopping.)

**Table 4.8: Auto occupancy, 1949 to 1990**

| | Work trips | Shopping trips | All trips |
|---|---|---|---|
| 1949 | 1.12 | 1.67 | 1.55 |
| 1958 | 1.12 | 1.79 | 1.57 |
| 1970 | 1.19 | 1.48 | 1.50 |
| 1990 | 1.08 | 1.31 | 1.29 |

Overall occupancy declined precipitously between 1970 and 1990 after holding steady for the 20 years preceding that; hopes of regaining earlier behaviors might have driven some of the desire for dedicated carpool lanes. But surprisingly, occupancy rates for work trips, despite a small upward blip in 1970, have never been particularly higher than they are now. Even in 1949, when cars were relatively hard to come by (and transit and walking were considerably more popular than they are today), carpooling to work was not an especially common occurrence.

The large decline in occupancy rates since 1970 is due to decreases in occupancy for shopping and other types of trips. This in turn stems to a large extent from two sources. First, through 1970 there were substantial numbers of adults (elderly and women) who could not drive or were discouraged from doing so. These adults provided a captive audience for non-driving modes, including carpooling (and walking and transit). Second, the post-war baby boom generated a large number of children, most of whom were still at home, riding as passengers with their parents (and raising non-work trip occupancy rates) through 1970, but driving their own cars as adults (and with fewer children as passengers) by 1990.

Unfortunately, we do not have data on mode choice by age groups for time periods before 1990, so it is impossible to calculate directly how much of the observed change is due to demographic shifts and how much to actual changes in behavior on the part of individuals. It is interesting, nonetheless, that children account for more than half of all trips as auto passengers (10,000 of 18,500 such trips in the TBI data). And given that children are only 23% of the regional population now, compared with 33% in 1970, it seems likely that this demographic change might be responsible for a substantial part of the recent decline in overall auto occupancy.

A final point of interest is how much of the carpooling observed in the data is actually made up of members of different households, who might be influenced by incentives, as opposed to members of the same household, who presumably would likely travel together anyway. It is possible to determine this: when two members of the same household make a trip from the same origin to the same destination, at the same time, one as a driver with passenger and one as a passenger, then they can be safely assumed to be traveling together. Looking at only adults, 64% of trips as passenger were made with a member of the same household. It could be objected that this is including shopping and other trips, and that work trips would be more likely to include actual two-household carpooling. But restricting the time period to morning rush hour (which presumably eliminates most recreational trips) does not change the rate at all. A substantial majority of carpooling, even for work trips, is made up of members of the same household.

Carpooling seems very little affected by land use. As with transit, one factor that might matter is destination land use, specifically a lack of adequate parking, or parking incentives for carpools. But overall auto occupancies both for work trips and for all trips are nearly identical between central city and suburbs.

# 4.3 Overall Driving Rates Across the Region

The fundamental question that all this analysis in this chapter boils down to is this: How much does the average adult drive in a given day, in different parts of the region? Table 4.9 gives the answer, taking into account both differences in mode choice and in time spent traveling.

**Table 4.9: Average driving time, adults**

| | Min. per Driver | Daily % Drivers | Minutes per Person |
|---|---|---|---|
| Central Cities | 66.6 | 67% | 44.9 |
| Near (<10 miles) Suburbs | 65.4 | 76% | 50.0 |
| Far (10-20 miles) Suburbs | 70.5 | 81% | 57.3 |

The average adult in the far suburbs spends 27% more time driving a car each day than does the average adult in the central cities. At first glance this seems like a huge difference; however it is important to recall the reasons for it. The difference between the central cities and the near suburbs happens, as can be seen, because central city residents are less likely to drive a car in a given day. The difference between near and far suburbs is a combination of this and the longer driving times arising from worse job accessibility.

The lower probability of driving by central city residents arises, as discussed earlier, from a combination of being less likely to travel at all, and being more likely to use non-auto modes (Table 4.10).

**Table 4.10: Travel probabilities by mode**

| | All Auto | Some Transit | No Travel |
|---|---|---|---|
| Central Cities | 71.5 | 10.7 | 17.8 |
| Suburbs <10 miles | 81.7 | 4.1 | 14.3 |
| Subs 10-20 miles | 85.1 | 2.8 | 12.1 |

Both of these facts are influenced by the higher concentration of low-income households in the central cities, as these people travel less overall and are considerably more likely to use alternate modes when they do travel. Among higher income households, the higher rate of alternate mode use arises at least in part because of proximity to the job concentrations in the downtowns and the University of Minnesota. These destinations attract high bus shares even from the suburbs; in the central city the share is a little bit higher, and a higher fraction of people work downtown, making the overall mode share substantially higher.

People in the outer suburbs are more likely to drive in a given day, although here the difference is more demographic and economic than because of mode choice. Residents of outer suburbs are slightly more likely to work, to have higher incomes, and to have children. All of these factors contribute to higher travel rates. Those people that drive in a given day also spend more time doing it than do people who live closer to the center of the region. This is because residents of outlying areas (generally, beyond the beltway) must drive farther to access the main regional job base.

For total average driving time, as with more specific travel behavior characteristics, land use in the immediate vicinity of the home has a measurable but small impact. Table 4-11 gives the results of regression analysis of average daily total driving time per adult versus local land use density.

**Table 4-11: Regression analysis of adult daily drive time by density**

| | | Density | | |
|---|---|---|---|---|
| | Intercept | Est. | t | $R^2$ |
| Central City Job Density | 45.6 | -0.21 | -2.73 | 0.039 |
| Central City Pop. Density | 52.4 | -0.70 | -3.48 | 0.065 |
| Central City P+J Density | 48.4 | -0.24 | -3.57 | 0.069 |
| Inner Suburbs Job Density | 50.8 | -0.09 | -0.32 | 0.005 |
| Inner Suburbs Pop. Density | 54.4 | -0.68 | -1.95 | 0.014 |
| Inner Suburbs P+J Density | 52.9 | -0.28 | -1.37 | 0.004 |
| Outer Suburbs Job Density | 58.9 | -0.70 | -2.41 | 0.016 |
| Outer Suburbs Pop. Density | 61.2 | -0.80 | -2.66 | 0.020 |
| Outer Suburbs P+J Density | 61.2 | -0.61 | -3.26 | 0.031 |

While the regression results in this table show that increasing density has a consistent impact on driving times across all the rings, the impact is consistently small. An increase in population density of 1,000 per square mile is associated with about a 0.7 minute decrease in total daily driving time per adult, or about 1% of total daily driving time. In other words, doubling the density of a neighborhood would, for all practical purposes, be expected to double the amount of driving that takes place in it. The decreased driving per person does not even make a dent in the increase in total driving due to the greater number of people.

Another interesting point is that the logic behind the idea that higher density can reduce driving is that destinations will be more convenient. But curiously, higher *job* density, which presumably is measuring the convenience of destinations, has relatively little impact on total driving time, compared to population density (except in the outer suburbs, where jobs are scarce). Higher population density is probably associated with greater access to retail and other destinations *in general* (explaining why high population density leads to less travel time) but whether those destinations are within a mile of the home appears to be unimportant.

Finally, it is also clear that a given density level can generate very different driving rates depending on where it is. Residents of the outer ring suburbs are far from the major regional job centers; this leads to long commutes and overall long daily driving times. While higher density is associated with lower daily travel times in this area, the base daily time from which the reduction is taken is much higher than in more central areas. Thus, it may make sense, from a driving reduction standpoint, to try to make it possible for more people to live in places with the potential for low travel rates (although these areas may also already be the most congested, so this approach might make problems worse rather than better). The primary examples of such areas would be places within a mile or so of the downtowns or the University of Minnesota.

# 5 Conclusions

The ultimate question we have been trying to address in this report is this: How does the way land is developed influence the way people travel? More specifically, as regional population grows in the coming decades, can the transportation problems that those new people create be mitigated by changes to the density or style of the areas where they are housed or employed?

Intuitively, it seems plausible. In central city neighborhoods, buildings are close together, making walking and biking more viable, and transit coverage is dense. By contrast, in sprawling suburban areas, every trip requires the use of an auto. It seems inevitable that residents of such areas must drive a great deal more than do central city dwellers. And indeed, many studies have shown that low density suburban areas generate more miles of travel per person.

However, it is not quite safe to jump to conclusions based on this information. There are two ways that logic might lead us astray here. First, the number of miles of travel might not be a very good measure of how people are actually behaving, that is, the amount of resources being consumed or the amount of costs being generated. Before we can conclude that suburbs are a much more costly or problematic way to develop land, we need to look at other ways of describing travel behavior to see if the observed differences in mileage really arise from different choices, and whether they really lead to more problems.

The second problem is that even if there are behavioral differences between city and suburb, this does not in itself prove that it is land use that creates these differences. No one would look at a blue Neon and a black Porsche, compare prices, and conclude that black paint must be much more costly than blue paint. Everyone knows that the difference in cost arises from factors that can t be visibly observed. But the reason we know that is because we know how cars work, and what sorts of things make them inexpensive or costly. However, we don t really understand that well how cities work, and how people make travel decisions. Thus we run the risk of making the mistake that a Martian might make in comparing the two cars — that we assign too much importance to the things that we can see, namely the size and shape of buildings and how close together they are, and too little importance to more significant but less easily observable factors.

The purpose of this report was, in effect, to  look under the hood,  to look for hidden but potentially important determinants of travel behavior, with the ultimate aim of isolating the significance of the visible factors and the mechanisms by which they have their impact.

# 5.1 Summary of Travel Behavior and Land Use Findings

Based on the factors we studied for the period 1958-1990, we found that travel behavior was not very sensitive, with some small exceptions, to the way land was developed in the Twin Cities. We examined travel times for workers and nonworkers, with worker time broken into commute time and other. We examined whether people travel at all, the mode they use, and the number of trips they make. With the exception of commute times and mode choice, none of these ways of describing travel behavior show variations greater than 10% within the region; only mode choice is influenced by land use, and commercial land use exerts much more influence than does residential. The distance that people travel shows considerable variation, but this variation is determined almost entirely by differences in average travel speed, and thus seems more a result of the travel time choice than a decision in its own right. People with many jobs and shopping opportunities close to home typically choose to expand their range of job and shopping choices rather than reduce their daily travel time.

We use three broad lines of argument to arrive at this conclusion.

The first line of argument is historical. We updated Zahavi s analysis using 1990 data (the most recent year available) and find that average daily travel times are about 3% higher than they were in 1958 (about two minutes). Compared with 1990, the Twin Cities urbanized area in 1958 covered about one fourth of the land area, was two to three times denser, contained  little of the kind of sprawling, unwalkable development that is often blamed for our current problems, and had transit service covering almost the entire built-up area. In other words, it was exactly what currently popular land use policies are aiming for. Nonetheless, travelers in 1958 spent essentially the same amount of time per day traveling as travelers in 1990, and virtually all of that travel was by car. They did, as is well known, drive far fewer miles, but this was because speeds were so much lower, not because they spent less time traveling. Also, a smaller fraction of people traveled in a given day in 1958, but this was because there was a large class of people (mostly elderly and women) who had never learned to drive or were economically or socially constrained from doing so. (This evidence is discussed in chapter 2.)

The second line of argument considers the possibility that looking only at average travel times for the region could be misleading; that there could be important differences across places or groups of people that are lost when data are aggregated to the regional level. To examine this possibility we analyze the behavior of auto travelers (the vast majority of the population) in 1990 in more detail. We find that the only way of dividing the population that yields significant (more than 10%) differences in average travel times is by location; travelers residing in outlying rural areas average 80 minutes a day, while central city travelers average about 68.

In trying to understand the reasons for these differences, two main results emerged. First, the differences are due entirely to differences in commute times. Non-work travel time, whether measured as non-commute travel by workers or as travel by non-workers, shows almost no systematic variation by location. People with plentiful shopping close to home spent just as much time on non-work travel as did residents of the most remote, single use suburban neighborhoods. Second, commute times are largely determined by regional job access, not by the availability of jobs in the immediate vicinity of the home. That is, the availability of jobs within a mile of the home had almost no impact on average commute times; the availability of jobs within a 20-minute drive did. (These points are discussed in chapter 3.)

The first two arguments look for differences in travel times within the group of people who travel by auto. The third argument considers the possibility that the average auto travel time per person might vary if fewer people use autos in some parts of the region. The number of minutes of driving per person (rather than per traveler) varies between central city and inner ring suburb because of this. In particular, use of non-auto modes is higher in the central city. Even if the total amount of time that people spend traveling is more or less fixed, land use changes could have beneficial impacts if certain types of development cause more of that time to be spent in modes other than autos.

Indeed, this is the one area in which local land use characteristics seem to have an impact on travel choices. However, the impact is quite small compared to the size of the land use changes involved. An increase of 1,000 people per square mile (within the built-up area, this would amount to about a 10% to 100% increase in density depending on location) is associated with at most about a 1% increase in transit share of work trips, and about a 1% decrease in overall daily driving time per person. To achieve perceptible changes in auto travel through this means would require population densities without precedent in this region. Certainly it is possible that such densities could be achieved in a few neighborhoods, but at a regional level, the number of people involved would be too small to be noticeable.

Although land use in the home neighborhood appears to have little impact on travel choices, land use in job destinations can apparently have a great deal. About 30 of the 1165 traffic zones in the region (less than 1% of the total land area) attract over 60% of all transit trips; these same zones also attract a substantial fraction of walking and biking trips. (These zones are the central parts of the two downtowns, and the University of Minnesota.) These zones attract average transit shares in excess of 15% even from remote (and supposedly transit-hostile) suburban locations. The very large size of these employment centers means that it is feasible to have frequent bus service, including express buses, from all over the region. This frequent and fast service, in turn, makes transit a more attractive choice. And large employment centers can impact enough people to create effects that are apparent even at a regional level. (The results in these three paragraphs are explained in chapter 4.)

We are very confident about these results. While there were a few difficulties with comparing historical results to 1990, they were not of a magnitude to cast any doubt on the main findings. The analysis of the 1990 data is based on the Travel Behavior Inventory, which was a survey of about 10,000 households, a size which again leaves no doubt about the robustness of the results. The analysis of commute times and mode choice was based on the 1990 census, which surveyed hundreds of thousands of commuters. In a sample of such a size, any significant relationships between variables should emerge fairly clearly; when they don t, the conclusion that such relationships don t exist is hard to avoid.

These results are also consistent with other research on travel times. Purvis (1994) finds similar travel time constancy for the San Francisco area, and cites a host of other studies. Levinson and Kumar (1994), studying the Washington D.C. area, find constant commute times and a slight lengthening of overall daily times. Schafer (1998) finds that travel times vary within a small range across many cultures and parts of the world, including areas with little motorized vehicle use. Rutherford, et al. (1997), find a very tight range of travel times across Seattle neighborhoods.

Given that these results, and indeed much other research, indicate that residential land use has only limited effects on travel behavior, one might reasonably wonder why so many people have embraced it as a transportation policy. There seem to be two primary reasons. The basic one is logic: If people could buy the things they  need  close to home, then they would not  need  to travel so far. The problem is in believing that people travel and shop because they need to rather than because they want to, and that they would reduce their travel if only they could. Logical, but unfortunately, we find, not true (see section 3.4:  Geography and Job Accessibility  ).

The second reason why these policies have garnered support is that there is a large volume of research that appears to support the importance of residential land use. While some of this research is of good quality, much of it derives its results from flawed methodology or questionable assumptions. (Crane (1998) is a good introduction to this topic. Pickrell (1999) discusses the issue at much more length.) There are two major types of problems. First is that some research is based on the results of forecasting models, which incorporate the questionable assumption that shortening or eliminating a trip will not impact the length of other trips. Second is that other factors that might be influencing the results are not controlled for. Most noticeable here is that results are reported in vehicle miles traveled (VMT), without controlling for differences in speeds. The (false) implication is that high-density residents drive far fewer miles because they spend far less time driving.

For example, the widely-cited LUTRAQ study from Portland, Oregon, is a good example of both types of problem. It is based on simulation model outcomes rather than observed facts, and the apparent transportation benefits of the high-density scenario actually derive mostly from other factors such as increased parking costs (Guiliano 1995). The technical body of the report shows little impact of land use *per se* on travel choices, but this finding does not appear in the more widely distributed summary documents.

To summarize, our primary result, examining travel behavior in 1990, supports Zahavi s earlier finding of a daily  budget  for time spent traveling. People do not travel every single day, but on the days when they do, they spend on average about 70 minutes. Furthermore, most people want to travel; the groups who have low rates of travel for the most part have been subject to economic or social constraints. These include people with low-incomes, and in the past included women and the elderly. Our secondary finding is that while there are variations in travel behavior across the region, these differences arise more from variations in job access and population characteristics than from the way land is developed.

More generally, land use (meaning density of population, jobs, and retail, and the extent of mixing of these) in the immediate vicinity of the home (roughly a radius of one mile or less) has very little impact on any of the aspects of travel that we considered. It seems that having more nearby opportunities means that those particular opportunities can be accessed more easily; but as with faster highways, the time that is saved is spent on additional travel or expanding the range of choices, so overall behavior is much less affected than one would expect.

The sources of behavioral differences fall, in our analysis, roughly into four categories. The first is land use, by which we mean the style of local development in terms of population density and availability of nearby jobs and retail. We find that this has relatively little apparent impact on behavior. The second factor is location, meaning where a person lives relative to the rest of the region, especially in terms of jobs. This has somewhat more impact, in that the regional job base is more centrally concentrated than is housing, and people who live outside the area of dense employment tend to have somewhat longer commutes (although the difference is surprisingly small).

The third factor is the highway system, that is, the general quantity and mix of freeways, high-speed arterials, and low-speed surface streets. This influences the speed of travel, and through this, the number of miles traveled. The final factor influencing behavior is the people of the region. Different  types  of people, for example, adults vs. children or workers vs. non-workers, generate substantially different travel choices. We find that a non-negligible part of the differences both across time and place is due to the presence of different types of people. In 1990, for example, the population was dominated by adult workers, who as a group tend to travel a lot, while in 1958 low-travel children and non-workers were much more prevalent.

In analyzing the role of land use in more detail, it appears that there are two major influencing factors. First, travel to the downtowns or the University of Minnesota is by far the most important factor in mode choice. Even suburban residents who travel to these destinations have a high transit share, indicating that land use (and especially the cost of parking) at the destination may be much more important than is land use in residential neighborhoods. The other important factor is the location of jobs, in a regional sense. Jobs are much more concentrated in the central part of the region than are homes; people who live outside of this central area have longer commutes on average (although the difference is only two or three minutes each way). The number of jobs in the immediate vicinity of the home has no apparent impact on average commute lengths; the influence is reserved for access to jobs as a whole.

## 5.2 Implications and Recommendations

It seems logical that sprawling suburban neighborhoods must generate more auto travel time than do compact urban neighborhoods. But sprawl has its own logic, and it turns out that the obvious conclusion is based on two faulty assumptions. First is an intuitive assumption that longer distances must correspond to longer travel times. But in fact the longer distances in the suburbs are almost exactly offset by higher speeds, so that travel times are almost identical everywhere.

The second, more subtle but equally important mistaken assumption is that people everywhere make the same kinds of trips. An urban resident can walk to the corner grocery to buy milk or other convenience goods, and Al Gore once worried that sprawl will reach the point where people burn a gallon of gas to buy a gallon of milk. But sprawl residents don t make a special trip to get a gallon of milk, precisely because it is so time consuming. Instead, they are more careful to stop at one of the 15 or 20 convenience stores that they pass on the way home from work, or to get everything they need during their weekly grocery shopping. There are no stores close to their homes because they don t need them; people are not confined to their own neighborhood anymore.

While people everywhere need to do the same kinds of things, there is a great deal of flexibility in how they get them done, and a number of different ways of organizing land use that are compatible with getting them done. A central city neighborhood might have smallish grocery stores frequently placed; residents can buy a small quantity of groceries several times a week without traveling much. Residents of distant suburbs, on the other hand, have a different situation. Stores there are large and widely spaced, and if residents there made several small trips a week they would indeed spend a prodigious amount of time on the roads. But they don t make several small trips; instead they make one large trip. Both are equally valid ways of accomplishing the grocery shopping function, and both ultimately create about the same amount of total travel time. The inconvenience associated with the suburban method accrues to the individual (who made the choice to live there), not to society at large.

Sprawling suburban neighborhoods look very different from compact urban ones, but for the most part they generate the same types of impacts on the transportation system. Central city residents drive on different types of roads, and they cover fewer miles at lower speeds, but overall they spend just as much time in their cars as anyone else. The widespread belief that compact, mixed-use development can lead to substantial reductions in auto travel time is strongly contradicted by the evidence. While it is possible to find a few, closely defined neighborhoods that generate much lower than average auto travel time, in almost every case this desirable behavior arises from a location that is convenient to desirable major work destinations (or from a high concentration of poor people or students), rather than from any special characteristics of the neighborhood itself.

The evidence leads us to conclude that a general reduction in auto travel is unlikely. There has been little change in travel behavior since 1958 (or perhaps earlier) despite the city growing substantially in physical area and declining considerably in density and employment concentration. These land use changes are far more significant than anything policy is likely to achieve, and given that they had little impact on travel behavior, it is hard to be optimistic that any future policy will either.

We do not, however, feel that there is no scope for policy to have a positive impact. Behavior differs substantially from the norm in certain specific situations and for certain types of people. Focusing policy on these situations and people where there is evidence that an impact is possible could yield benefits. Furthermore, not all auto travel causes major problems. While it may not be possible to reduce total auto travel much, the negative effects that this travel causes could certainly be mitigated if attention is focused directly on the problems rather than on travel in general. This leads us to three main points on the potential of land use to influence travel choices.

First, policy should focus on  problem  travel rather than treating all travel equally. In this regard, work trips are key. Our data show that non-work travel time varies little by location; while distances are longer in the suburbs, residents compensate for this through a combination of higher speeds and better trip planning (chaining). Work trips are far longer than any other type of trip; they are also more congested and create the need for far more highway capacity than would be necessary otherwise. While visions of walking to the grocery store are widely discussed, the fact is that these routine short trips are a small part of the total and are not a major source of problems, either for the person making them or for society more generally. Any policy that does not focus primary attention on travel to work seems unlikely to have much impact on the overall transportation system.

Second, increasing the density of commercial development is much more likely to have a beneficial impact on travel behavior than is higher density in residential areas. Business density appears, at least in this region, to have far more impact on mode choice than does residential density, and people who would never live in an apartment or even a small house have no problem with working in a dense office area. And while low-density commercial areas are inherently difficult or impossible to serve competitively with transit, low-density residential areas, contrary to popular belief, are not. A bus that has to stop at thirty individual buildings, discharging one or two passengers at each, will not be appealing no matter how high the residential density on the other end of the trip might be. But residential density matters less because at home people have the option of driving their car (or in the future perhaps small electric vehicles) to the most convenient bus stop, an option that a large number of suburbanites apparently exercise if they work downtown.

Finally, while a widespread reduction in auto use is unlikely, it may be possible to contain the growth of auto use by identifying and exploiting the preferences of that minority of residents that desires a less auto-intensive lifestyle. This might include low-income households, and could also include students, university and downtown employees, and young people generally. Because large, ultra-high density commercial (or educational) areas serve as strong alternate-mode attractors, neighborhoods located close to these areas tend to generate high alternate-mode use. Given this, it might make sense, as long as there is demand, to create opportunities for as many people as possible to live in these  good locations.

In this light, it is worth making a short statement about the poor. People with household incomes below $25,000 are three times as likely to use transit, or to walk or bike, than are people with incomes above this level. This result holds regardless of the location of the home or of the destination of the trip. There are not that many people with incomes this low, but they make up a substantial fraction of transit riders, and an even bigger fraction of walkers. Furthermore, for many of these people transit and walking are not just an alternative to the car, but are in fact the only available option. Given this, it seems desirable, from the perspective of encouraging alternate mode use, that more explicit thought should be given to the transportation needs of the less fortunate.

Our results, in short, lead us to the belief that only certain specific and focused land use policies are likely to have much transportation impact, and even in the best case the effect is likely to be more restricted in location and scope than is commonly thought. And if the needs of low-income people are not explicitly considered, the impact is likely to be smaller still. Positive results are possible, but are much more likely in the context of clear and realistic goals, and investments that are explicitly targeted to areas where there is real evidence that success is likely.

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# Appendix: Supporting Materials

There are four categories of supporting materials: density maps, historical data used in Zahavi s analysis and our follow-on, results on characteristics of auto travelers, and regression results on the factors influencing the behavior of auto travelers.

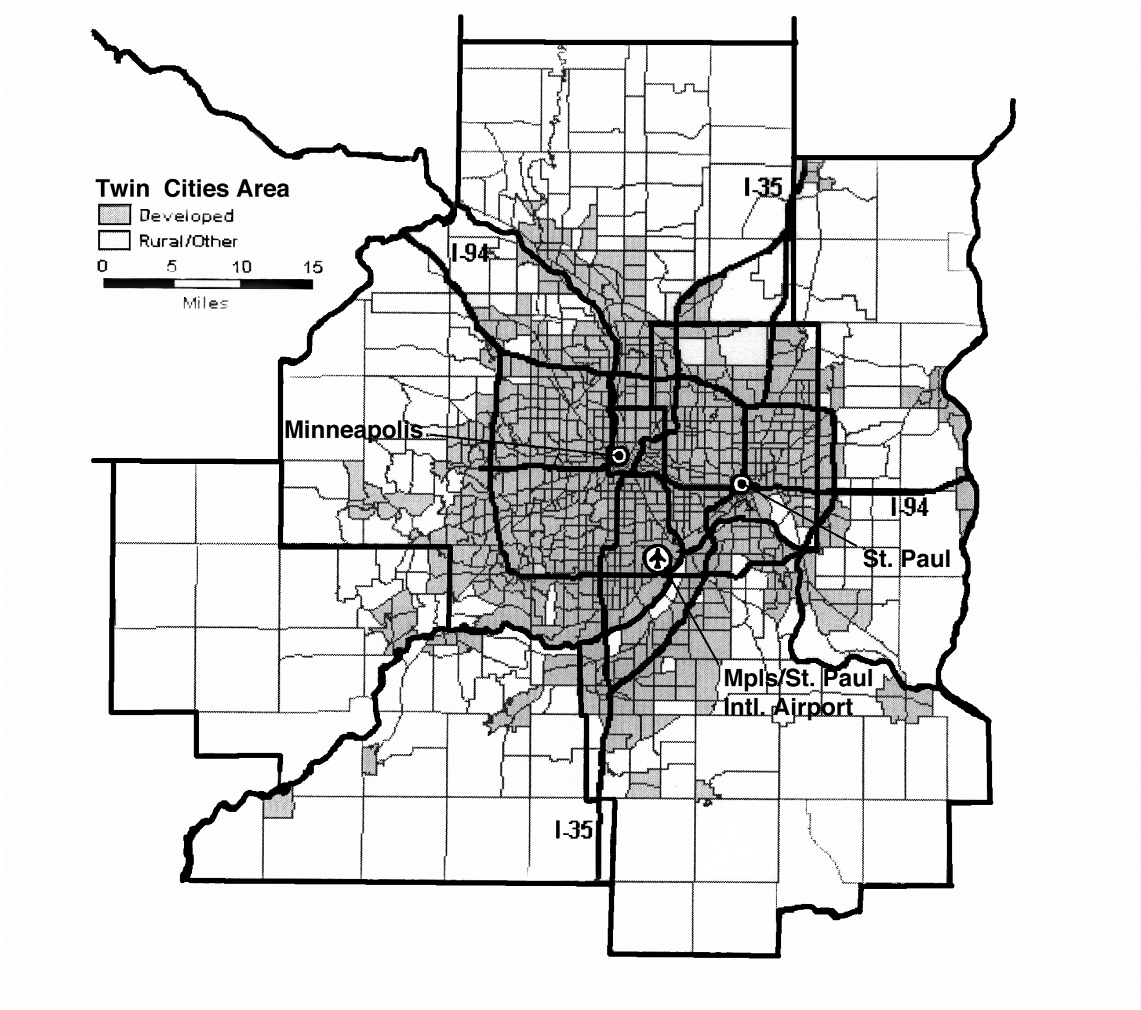
## Reference Point and Density Maps

A running theme throughout this report is the correlation of various aspects of travel behavior with land use density. In order to avoid showing maps of density in each case where this issue arises, we offer the following maps for general reference.

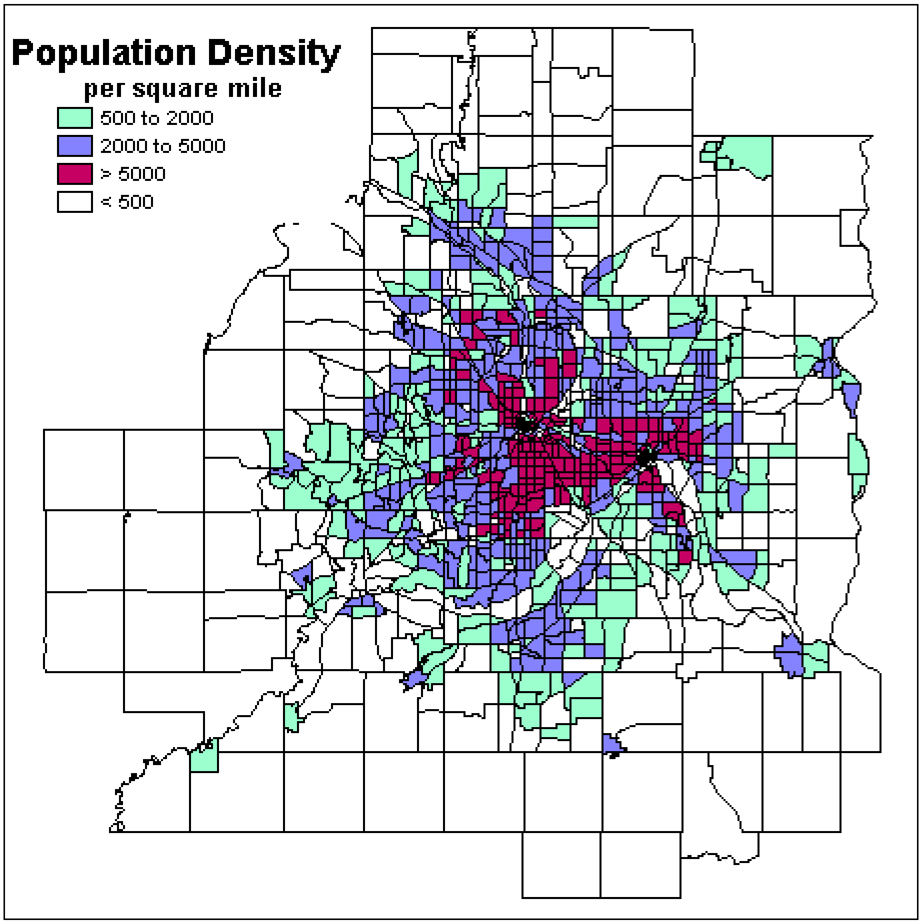
There are three depictions of density here, each shown in two ways. The types of density shown are population, employment, and aggregate, which is just the sum of the other two. Numbers are given per square mile. The two vantage points are first, the entire seven-county Twin Cities Metropolitan Area, and second, a magnified view of the central part of the region. These magnified views are centered on the downtowns, and extend at the edges roughly a couple of miles past the beltway. This view of the central part of the region divides it into higher density categories than are used in the regional map, making it possible to distinguish differences in the relatively higher density areas of this part of the region.

This first map is included to give the reader a sense of the location of important landmarks; it is hoped that this will make it easier to interpret the maps in the text. The six density maps follow.

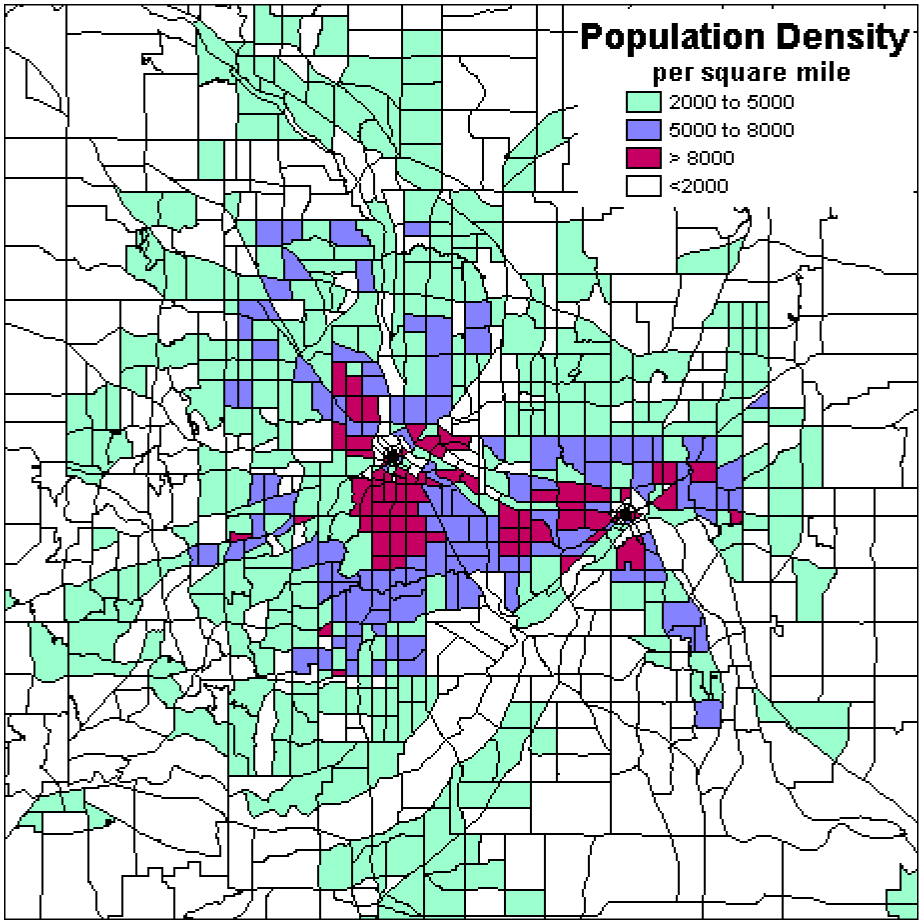
The shaded areas are developed (population plus employment density greater than 1,000 per square mile). The dark lines are interstate highways; the thin lines are traffic analysis zone (TAZ) boundaries. The maps in the report use the TAZs as the geographic unit of analysis. The medium-weight dashed lines are county boundaries.



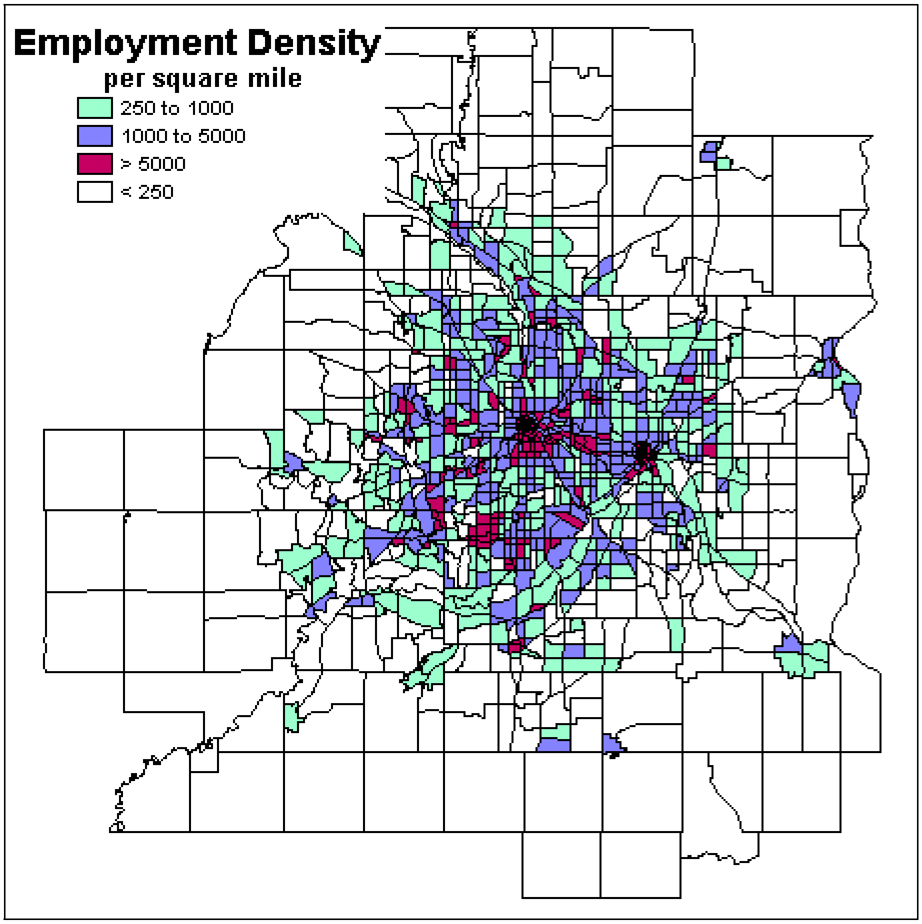

**Reference Map, Seven-County Area, 1990**



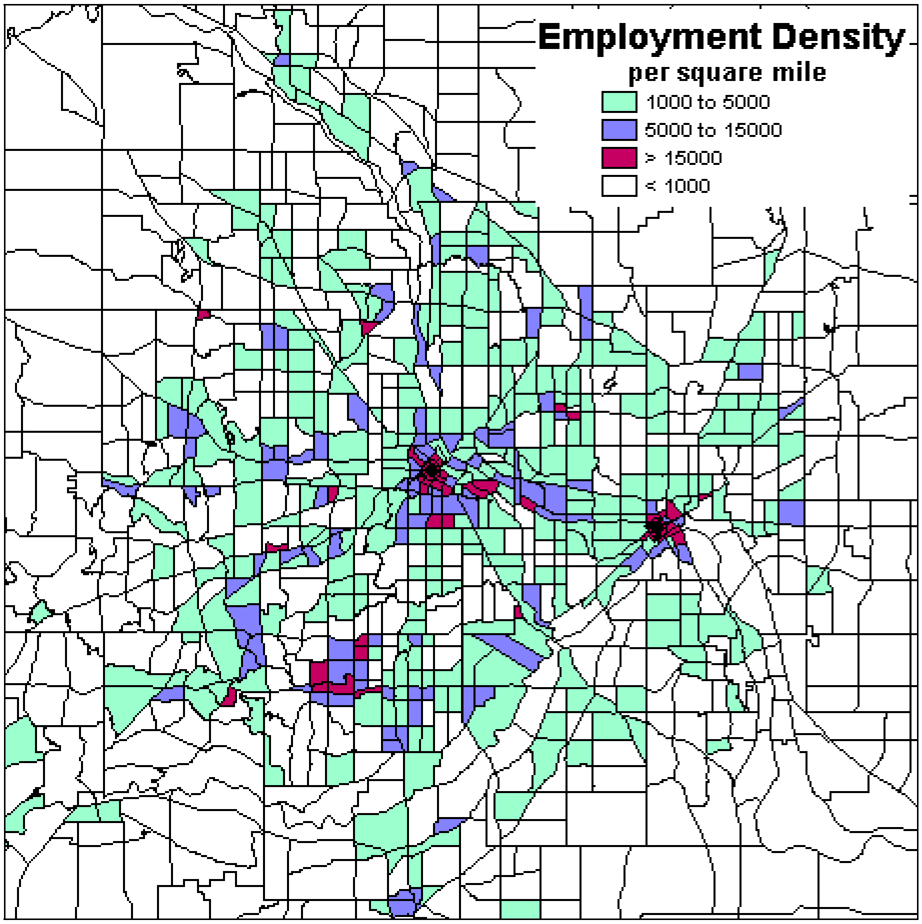

**Population Density, Seven-County Area, 1990**



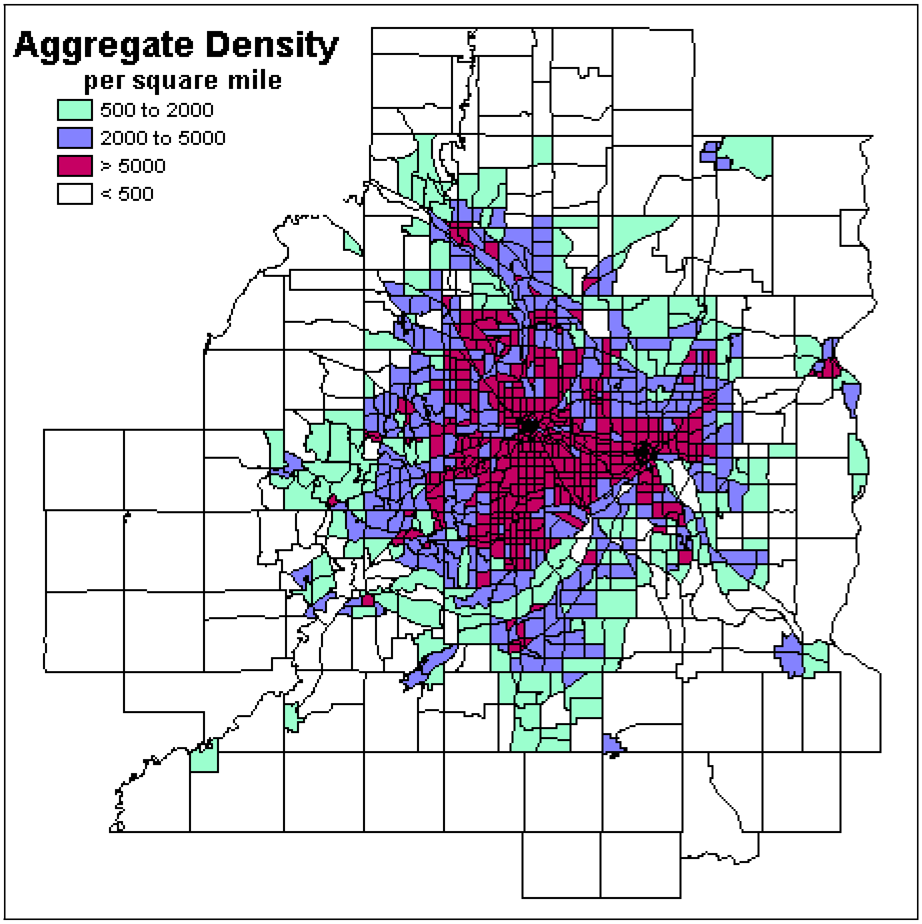

**Population Density, Central Area**



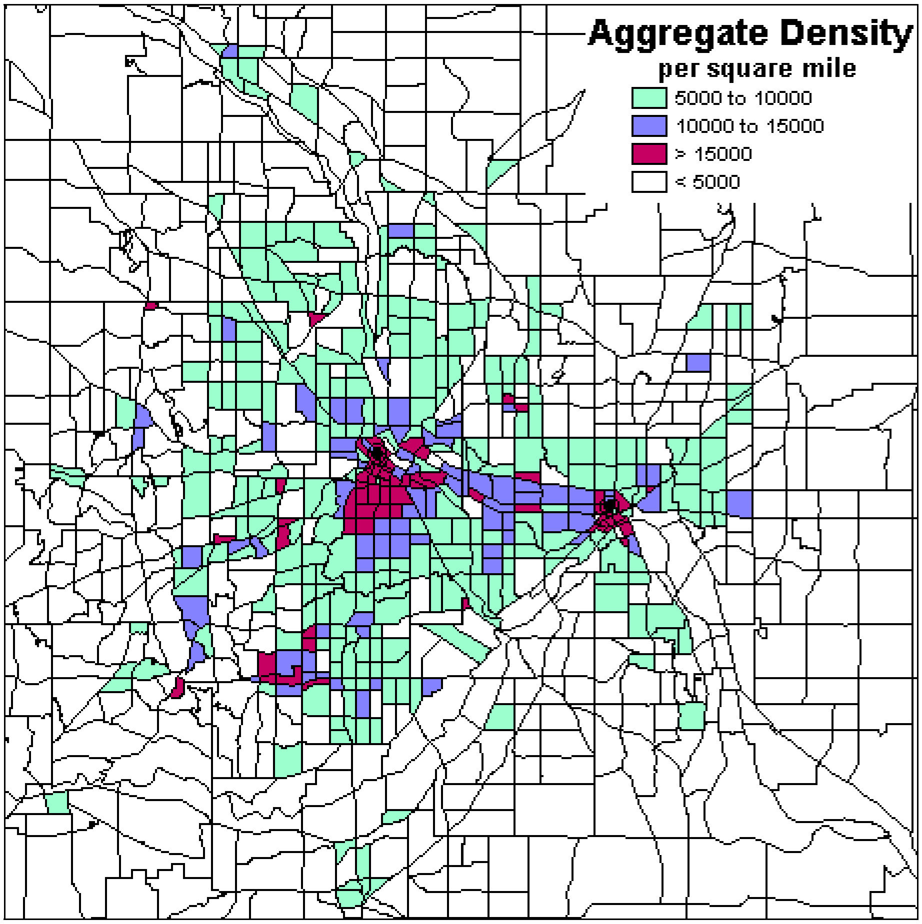

**Employment Density, Seven-County Area**




**Employment Density, Central Area**



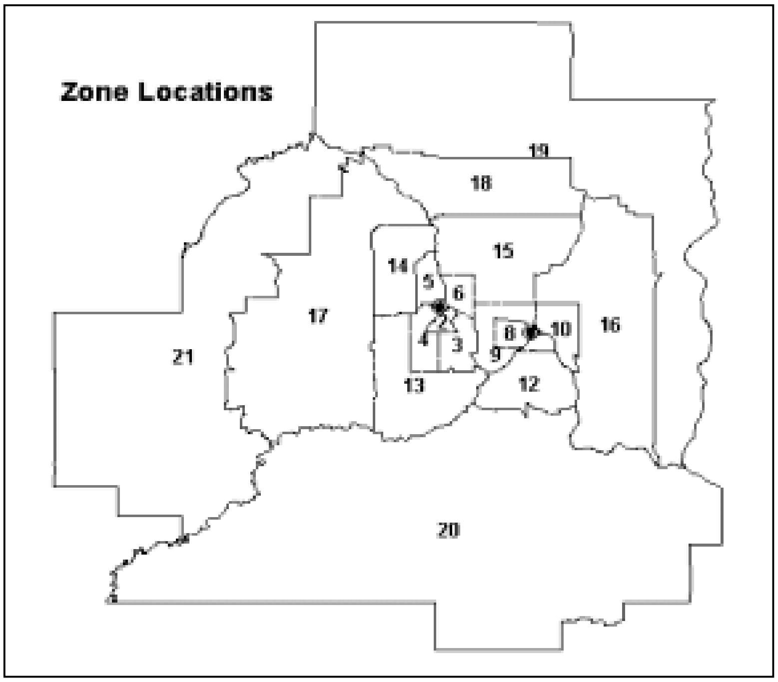

**Aggregate Density (Population plus Employment), Seven-County Area**




**Aggregate Density (Population plus Employment), Central Area**

# Historical Data

This is simply a record of the locations of the zones and the historical and current data used in the analysis in chapter 2. It gives a sense of the fairly radical changes that have taken place in some parts of the region since 1958. Note that Zahavi did not have data for the outlying zones 19-21, or for zone 1 (downtown Minneapolis) or zone 7 (downtown St. Paul). Population densities are given in thousands per square mile.




| District | Miles From Center | Area (Square Miles) | Pop. 1958 | Pop. 1970 | Pop. 1990 | Income 1970 (1990$) | Income 1990 |
|---|---|---|---|---|---|---|---|
| 2 | 1.6 | 11.9 | 81.7 | 59.1 | 53.1 | 27.39 | 26.7 |
| 3 | 4.1 | 31.5 | 101.7 | 89.3 | 109.1 | 35.12 | 37.6 |
| 4 | 3.6 | 30.8 | 109.1 | 87.5 | 99.9 | 36.83 | 41.3 |
| 5 | 2.8 | 21.8 | 88.7 | 67.7 | 64.0 | 30.30 | 33.2 |
| 6 | 2.5 | 29.3 | 76.4 | 66.3 | 51.2 | 31.00 | 34.4 |
| 8 | 1.8 | 15.7 | 78.0 | 60.3 | 64.2 | 31.24 | 36.3 |
| 9 | 4.8 | 60.3 | 131.0 | 105.4 | 108.0 | 36.45 | 37.9 |
| 10 | 2.9 | 56.8 | 73.9 | 85.3 | 85.0 | 33.31 | 34.0 |
| 11 | 1.2 | 9.6 | 21.4 | 15.9 | 15.2 | 29.16 | 31.8 |
| 12 | 4.0 | 84.4 | 42.9 | 57.4 | 73.2 | 38.75 | 41.4 |
| 13 | 7.9 | 168.3 | 154.3 | 205.2 | 215.0 | 49.05 | 44.6 |
| 14 | 5.3 | 69.1 | 70.6 | 102.8 | 151.4 | 40.96 | 41.7 |
| 15 | 7.6 | 187.0 | 82.0 | 139.7 | 197.7 | 43.27 | 44.4 |
| 16 | 7.1 | 355.1 | 59.5 | 104.8 | 157.5 | 42.48 | 44.4 |
| 17 | 11.1 | 613.8 | 91.0 | 147.0 | 287.2 | 47.34 | 48.6 |
| 18 | 13.0 | 166.3 | 32.4 | 65.9 | 126.6 | 41.77 | 42.5 |

| District | Pop. Dens. 1958 | Pop. Dens. 1970 | Pop. Dens. 1990 | Trips per Car Trav. 1958 | Trips per Car Trav. 1970 | Trips per Car Trav. 1990 | Minutes per day (car trav.) 1958 | Minutes per day (car trav.) 1970 | Minutes per day (car trav.) 1990 |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 6.861 | 4.970 | 4.462 | 3.4 | 3.2 | 4.6 | 67.2 | 61.2 | 72.9 |
| 3 | 3.229 | 2.837 | 3.466 | 3.5 | 3.6 | 4.7 | 68.4 | 64.8 | 70.9 |
| 4 | 3.539 | 2.840 | 3.239 | 3.4 | 3.9 | 4.8 | 72.0 | 69.6 | 71.4 |
| 5 | 4.064 | 3.104 | 2.935 | 3.4 | 3.5 | 4.2 | 63.6 | 64.2 | 65.4 |
| 6 | 2.604 | 2.260 | 1.747 | 3.4 | 3.4 | 4.6 | 58.8 | 65.4 | 65.9 |
| 8 | 4.971 | 3.840 | 4.087 | 3.5 | 3.5 | 4.6 | 62.4 | 60.6 | 62.2 |
| 9 | 2.171 | 1.746 | 1.791 | 3.6 | 3.7 | 4.6 | 70.2 | 61.2 | 66.7 |
| 10 | 1.303 | 1.502 | 1.498 | 3.5 | 3.8 | 4.5 | 59.4 | 60.0 | 64.6 |
| 11 | 2.230 | 1.658 | 1.586 | 3.3 | 3.6 | 4.9 | 54.0 | 57.6 | 63.4 |
| 12 | 0.509 | 0.681 | 0.867 | 3.9 | 4.1 | 4.8 | 59.4 | 69.6 | 66.0 |
| 13 | 0.917 | 1.220 | 1.278 | 3.7 | 4.2 | 4.7 | 73.2 | 71.4 | 67.8 |
| 14 | 1.021 | 1.489 | 2.191 | 4.2 | 4.2 | 4.6 | 78.6 | 77.4 | 68.7 |
| 15 | 0.439 | 0.747 | 1.057 | 3.8 | 3.9 | 4.8 | 71.4 | 69.0 | 67.6 |
| 16 | 0.167 | 0.295 | 0.444 | 3.5 | 3.8 | 4.5 | 64.8 | 63.0 | 69.4 |
| 17 | 0.148 | 0.239 | 0.468 | 3.8 | 4.1 | 4.5 | 75.6 | 76.2 | 74.1 |
| 18 | 0.195 | 0.396 | 0.762 | 4.3 | 3.4 | 4.3 | 78.6 | 64.2 | 74.6 |

| District | Miles per day (car trav.) 1958 | Miles per day (car trav.) 1970 | Miles per day (car trav.) 1990 | Average auto speed 1958 | Average auto speed 1970 | Average auto speed 1990 |
|---|---|---|---|---|---|---|
| 2 | 10.8 | 14.2 | 24.7 | 9.6 | 14.0 | 18.6 |
| 3 | 13.2 | 16.7 | 22.6 | 11.6 | 15.4 | 19.6 |
| 4 | 13.7 | 18.3 | 23.1 | 11.4 | 15.8 | 20.9 |
| 5 | 12.5 | 15.6 | 24.8 | 11.8 | 14.6 | 20.9 |
| 6 | 11.0 | 14.4 | 22.8 | 11.2 | 13.2 | 19.4 |
| 8 | 10.6 | 13.3 | 21.3 | 10.2 | 13.2 | 19.8 |
| 9 | 12.9 | 18.4 | 20.5 | 11.0 | 18.0 | 20.1 |
| 10 | 13.0 | 15.0 | 22.3 | 13.1 | 15.0 | 21.1 |
| 11 | 10.3 | 16.0 | 22.8 | 11.4 | 16.6 | 20.5 |
| 12 | 12.9 | 19.7 | 21.7 | 13.1 | 17.0 | 23.2 |
| 13 | 16.9 | 20.3 | 25.5 | 13.9 | 17.1 | 21.9 |
| 14 | 18.4 | 22.1 | 24.7 | 14.0 | 17.1 | 22.1 |
| 15 | 18.3 | 22.3 | 25.3 | 15.3 | 19.4 | 24.3 |
| 16 | 22.1 | 24.8 | 27.4 | 20.5 | 23.6 | 25.4 |
| 17 | 24.6 | 27.6 | 29.4 | 19.5 | 21.8 | 25.4 |
| 18 | 27.2 | 25.0 | 31.4 | 20.7 | 23.4 | 25.6 |

# 1990 Travel Characteristics

The first table  Aggregate Travel Characteristics   is a summary of the travel habits of the region as a whole, broken down by employment status. Following this is a sequence of sections,  Age,   Gender,  etc., each of which breaks the population down along a different characteristic. Each section contains five tables. The first,  Work Status Summary,  simply shows the number and percentages of workers and non-workers for the different classes into which the population is divided. The next table,  Probability of Traveling,  gives the probability of *motorized* travel on a given weekday. The final three tables then give trip counts, total daily travel time, and distance traveled for that subset of the population that traveled exclusively by auto (the great majority of the total). **All of these tables include only people age 18 and over.** The column headed  Predicted  in each of the last four tables of each section is the value of the variable in question that would be predicted based on a simple hypothesis that differences between groups arise from differences in the ratio of workers to non-workers. The column  % Difference  gives the difference between the predicted and actual value of the variable in question for that group of people. As can be seen, employment status alone explains a surprising amount of the variation in travel behavior, with a few significant exceptions.

## *Aggregate Travel Characteristics by Work Status*

| | Total | Workers | Nonworkers |
|---|---|---|---|
| Total Number | 18013. | 12817. | 5196. |
| % of Total | 1. | 0.71 | 0.29 |
| # Making Trip | 15403. | 11770. | 3633. |
| % Making Trip | 0.86 | 0.92 | 0.7 |
| Ave. # of Trips | 4.68 | 4.59 | 4.99 |
| Ave. Total Time | 73.67 | 74.65 | 70.49 |
| Ave. Total Distance | 29.64 | 31.31 | 24.21 |

## *Age*

### Work Status Summary

| | Total | Workers | Nonworkers | % Workers | % Nonworkers |
|---|---|---|---|---|---|
| Total | 18013. | 12817. | 5196. | 0.71 | 0.29 |
| 18-29 | 3161. | 2645. | 516. | 0.84 | 0.16 |
| 30-39 | 5045. | 4225. | 820. | 0.84 | 0.16 |
| 40-49 | 3947. | 3333. | 614. | 0.84 | 0.16 |
| 50-64 | 3567. | 2349. | 1218. | 0.66 | 0.34 |
| 65+ | 2293. | 265. | 2028. | 0.12 | 0.88 |

**Probability of traveling**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 0.86 | 0.92 | 0.7 | 0.86 | 0 |
| 18-29 | 0.85 | 0.91 | 0.52 | 0.88 | 3.9 |
| 30-39 | 0.89 | 0.92 | 0.76 | 0.88 | -1.1 |
| 40-49 | 0.9 | 0.93 | 0.76 | 0.88 | -1.9 |
| 50-64 | 0.84 | 0.92 | 0.7 | 0.84 | -0.075 |
| 65+ | 0.72 | 0.87 | 0.7 | 0.72 | 0.87 |

**Average number of trips**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 4.7 | 4.6 | 5. | 4.7 | 0.45 |
| 18-29 | 4.6 | 4.6 | 4.8 | 4.7 | 0.75 |
| 30-39 | 4.7 | 4.7 | 5.2 | 4.7 | -1.7 |
| 40-49 | 4.9 | 4.7 | 6. | 4.7 | -4.3 |
| 50-64 | 4.5 | 4.3 | 5.1 | 4.7 | 4.4 |
| 65+ | 4.6 | 4.5 | 4.6 | 4.9 | 8.6 |

**Average total time**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 74. | 75. | 70. | 73. | -0.3 |
| 18-29 | 75. | 76. | 68. | 74. | -1.5 |
| 30-39 | 74. | 75. | 67. | 74. | 0.013 |
| 40-49 | 75. | 75. | 76. | 74. | -1.3 |
| 50-64 | 72. | 72. | 72. | 73. | 1.3 |
| 65+ | 70. | 73. | 70. | 71. | 1.1 |

**Average total distance**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 30. | 31. | 24. | 29. | -1.3 |
| 18-29 | 32. | 32. | 28. | 30. | -5.7 |
| 30-39 | 32. | 33. | 26. | 30. | -4.7 |
| 40-49 | 31. | 32. | 29. | 30. | -3.2 |
| 50-64 | 27. | 28. | 25. | 29. | 5.8 |
| 65+ | 21. | 24. | 21. | 25. | 18. |

## *Gender*

**Work Status Summary**

| | Total | Workers | Nonworkers | % Workers | % Nonworkers |
|---|---|---|---|---|---|
| Total | 18013. | 12817. | 5196. | 0.71 | 0.29 |
| Male | 8618. | 6855. | 1763. | 0.8 | 0.2 |
| Female | 9395. | 5962. | 3433. | 0.63 | 0.37 |

**Probability of traveling**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 0.86 | 0.92 | 0.7 | 0.86 | 0 |
| Male | 0.87 | 0.92 | 0.69 | 0.87 | 0.57 |
| Female | 0.84 | 0.92 | 0.71 | 0.84 | -0.54 |

### Average number of trips

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 4.7 | 4.6 | 5. | 4.7 | 0.45 |
| Male | 4.5 | 4.4 | 4.9 | 4.7 | 4.4 |
| Female | 4.9 | 4.8 | 5. | 4.7 | -3. |

### Average total time

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 74. | 75. | 70. | 73. | -0.3 |
| Male | 76. | 76. | 74. | 74. | -2.5 |
| Female | 72. | 73. | 69. | 73. | 1.9 |

### Average total distance

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 30. | 31. | 24. | 29. | -1.3 |
| Male | 32. | 33. | 26. | 30. | -6. |
| Female | 28. | 29. | 23. | 29. | 4. |

## *Household Income*

### Work Status Summary

| | Total | Workers | Nonworkers | % Workers | % Nonworkers |
|---|---|---|---|---|---|
| Total | 18013. | 12817. | 5196. | 0.71 | 0.29 |
| <15K$ | 951. | 302. | 649. | 0.32 | 0.68 |
| 15-25K$ | 1602. | 820. | 782. | 0.51 | 0.49 |
| 25-35K$ | 2253. | 1474. | 779. | 0.65 | 0.35 |
| 35-45K$ | 3215. | 2405. | 810. | 0.75 | 0.25 |
| 45-55K$ | 2965. | 2408. | 557. | 0.81 | 0.19 |
| 55-75K$ | 3132. | 2629. | 503. | 0.84 | 0.16 |
| >75K$ | 2398. | 1940. | 458. | 0.81 | 0.19 |

### Probability of traveling

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 0.86 | 0.92 | 0.7 | 0.86 | 0 |
| <15K$ | 0.7 | 0.83 | 0.63 | 0.77 | 10. |
| 15-25K$ | 0.81 | 0.92 | 0.7 | 0.81 | -0.094 |
| 25-35K$ | 0.85 | 0.92 | 0.72 | 0.84 | -0.82 |
| 35-45K$ | 0.88 | 0.92 | 0.75 | 0.86 | -1.7 |
| 45-55K$ | 0.89 | 0.93 | 0.73 | 0.88 | -1.5 |
| 55-75K$ | 0.9 | 0.93 | 0.75 | 0.88 | -1.8 |
| >75K$ | 0.88 | 0.92 | 0.71 | 0.88 | -0.3 |

**Average number of trips**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 4.7 | 4.6 | 5. | 4.7 | 0.45 |
| <15K$ | 4.1 | 3.8 | 4.2 | 4.9 | 19. |
| 15-25K$ | 4.4 | 4.2 | 4.7 | 4.8 | 7.6 |
| 25-35K$ | 4.6 | 4.5 | 4.8 | 4.7 | 3.3 |
| 35-45K$ | 4.7 | 4.6 | 5. | 4.7 | -0.036 |
| 45-55K$ | 4.8 | 4.7 | 5.6 | 4.7 | -3.8 |
| 55-75K$ | 4.8 | 4.7 | 5.5 | 4.7 | -3.1 |
| >75K$ | 4.8 | 4.7 | 5.6 | 4.7 | -3.1 |

**Average total time**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 74. | 75. | 70. | 73. | -0.3 |
| <15K$ | 67. | 65. | 68. | 72. | 7.1 |
| 15-25K$ | 69. | 71. | 66. | 73. | 5.8 |
| 25-35K$ | 71. | 72. | 71. | 73. | 2.7 |
| 35-45K$ | 73. | 74. | 70. | 74. | 0.88 |
| 45-55K$ | 76. | 76. | 75. | 74. | -2.4 |
| 55-75K$ | 76. | 77. | 72. | 74. | -3.1 |
| >75K$ | 76. | 76. | 74. | 74. | -2.9 |

**Average total distance**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 30. | 31. | 24. | 29. | -1.3 |
| <15K$ | 20. | 23. | 19. | 26. | 30. |
| 15-25K$ | 24. | 27. | 21. | 28. | 14. |
| 25-35K$ | 27. | 29. | 23. | 29. | 5.9 |
| 35-45K$ | 29. | 31. | 26. | 30. | 0.15 |
| 45-55K$ | 32. | 32. | 29. | 30. | -5.2 |
| 55-75K$ | 33. | 33. | 27. | 30. | -7.3 |
| >75K$ | 33. | 33. | 30. | 30. | -8.8 |

## *Cars per Licensed Adult*

**Work Status Summary**

| | Total | Workers | Nonworkers | % Workers | % Nonworkers |
|---|---|---|---|---|---|
| Total | 18013. | 12817. | 5196. | 0.71 | 0.29 |
| 0 | 350. | 116. | 234. | 0.33 | 0.67 |
| >0,<=0.5 | 1347. | 644. | 703. | 0.48 | 0.52 |
| >0.5,<=1 | 762. | 533. | 229. | 0.7 | 0.3 |
| >1 | 15554. | 11524. | 4030. | 0.74 | 0.26 |

**Probability of traveling**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 0.86 | 0.92 | 0.7 | 0.86 | 0 |
| 0 | 0.56 | 0.78 | 0.44 | 0.77 | 39. |
| >0,<=0.5 | 0.79 | 0.87 | 0.71 | 0.8 | 1.7 |
| >0.5,<=1 | 0.81 | 0.92 | 0.55 | 0.85 | 5.6 |
| >1 | 0.87 | 0.92 | 0.72 | 0.86 | -0.94 |

**Average number of trips**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 4.7 | 4.6 | 5. | 4.7 | 0.45 |
| 0 | 3.1 | 3.2 | 2.9 | 4.9 | 59. |
| >0,<=0.5 | 4.6 | 4.5 | 4.7 | 4.8 | 4.4 |
| >0.5,<=1 | 4.6 | 4.6 | 4.9 | 4.7 | 1.7 |
| >1 | 4.7 | 4.6 | 5.1 | 4.7 | -0.5 |

**Average total time**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 74. | 75. | 70. | 73. | -0.3 |
| 0 | 67. | 73. | 61. | 72. | 7.6 |
| >0,<=0.5 | 71. | 72. | 69. | 72. | 2.7 |
| >0.5,<=1 | 76. | 77. | 73. | 73. | -3.9 |
| >1 | 74. | 75. | 71. | 74. | -0.43 |

**Average total distance**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 30. | 31. | 24. | 29. | -1.3 |
| 0 | 14. | 16. | 13. | 27. | 84. |
| >0,<=0.5 | 23. | 25. | 21. | 28. | 19. |
| >0.5,<=1 | 29. | 30. | 26. | 29. | 0.2 |
| >1 | 30. | 32. | 25. | 29. | -3. |

## *Household Size*

**Work Status Summary**

| | Total | Workers | Nonworkers | % Workers | % Nonworkers |
|---|---|---|---|---|---|
| Total | 18013. | 12817. | 5196. | 0.71 | 0.29 |
| 1 | 1612. | 955. | 657. | 0.59 | 0.41 |
| 2 | 6028. | 3738. | 2290. | 0.62 | 0.38 |
| 3 | 3765. | 2912. | 853. | 0.77 | 0.23 |
| 4 | 4250. | 3425. | 825. | 0.81 | 0.19 |
| 5 | 1653. | 1291. | 362. | 0.78 | 0.22 |
| 6 | 535. | 379. | 156. | 0.71 | 0.29 |

**Probability of traveling**

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 0.86 | 0.92 | 0.7 | 0.86 | 0 |
| 1 | 0.83 | 0.92 | 0.7 | 0.83 | 0.1 |
| 2 | 0.83 | 0.91 | 0.7 | 0.84 | 0.52 |
| 3 | 0.87 | 0.93 | 0.67 | 0.87 | -0.2 |
| 4 | 0.88 | 0.92 | 0.69 | 0.88 | 0.028 |
| 5 | 0.88 | 0.91 | 0.78 | 0.87 | -1.5 |
| 6 | 0.85 | 0.93 | 0.67 | 0.85 | 0.025 |

### Average number of trips

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 4.7 | 4.6 | 5. | 4.7 | 0.45 |
| 1 | 4.3 | 4.3 | 4.4 | 4.8 | 10. |
| 2 | 4.4 | 4.2 | 4.7 | 4.7 | 7.6 |
| 3 | 4.6 | 4.6 | 4.9 | 4.7 | 1.3 |
| 4 | 5. | 4.9 | 5.8 | 4.7 | -6.6 |
| 5 | 5.1 | 5. | 5.5 | 4.7 | -8.5 |
| 6 | 5.1 | 4.9 | 5.8 | 4.7 | -7.7 |

### Average total time

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 74. | 75. | 70. | 73. | -0.3 |
| 1 | 70. | 71. | 69. | 73. | 4. |
| 2 | 72. | 73. | 71. | 73. | 1.1 |
| 3 | 74. | 76. | 68. | 74. | -0.89 |
| 4 | 75. | 76. | 72. | 74. | -2. |
| 5 | 75. | 76. | 69. | 74. | -1.3 |
| 6 | 75. | 77. | 70. | 73. | -2.5 |

### Average total distance

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 30. | 31. | 24. | 29. | -1.3 |
| 1 | 24. | 27. | 18. | 28. | 17. |
| 2 | 28. | 30. | 23. | 29. | 3. |
| 3 | 31. | 32. | 26. | 30. | -4.5 |
| 4 | 32. | 32. | 28. | 30. | -5.5 |
| 5 | 31. | 33. | 26. | 30. | -5.5 |
| 6 | 31. | 33. | 26. | 29. | -6.5 |

## *Home Ring*

### Work Status Summary

| | Total | Workers | Nonworkers | % Workers | % Nonworkers |
|---|---|---|---|---|---|
| Total | 18013. | 12817. | 5196. | 0.71 | 0.29 |
| Central Cities | 4100. | 2737. | 1363. | 0.67 | 0.33 |
| Suburbs <10 miles | 4216. | 2855. | 1361. | 0.68 | 0.32 |
| Suburbs >10 miles | 7206. | 5421. | 1785. | 0.75 | 0.25 |
| Rural >20 miles | 2491. | 1804. | 687. | 0.72 | 0.28 |

### Probability of traveling

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 0.86 | 0.92 | 0.7 | 0.86 | 0 |
| Central Cities | 0.82 | 0.91 | 0.65 | 0.85 | 2.9 |
| Suburbs <10 miles | 0.86 | 0.92 | 0.72 | 0.85 | -1.2 |
| Suburbs >10 miles | 0.88 | 0.93 | 0.73 | 0.86 | -1.7 |
| Rural >20 miles | 0.84 | 0.91 | 0.65 | 0.86 | 2.5 |

## Average number of trips

| | Total | Workers | Nonworkers | Predicted | % Differen |
|---|---|---|---|---|---|
| Total | 4.7 | 4.6 | 5. | 4.7 | 0.45 |
| Central Cities | 4.6 | 4.5 | 4.7 | 4.7 | 2.8 |
| Suburbs <10 miles | 4.8 | 4.7 | 4.9 | 4.7 | -1.5 |
| Suburbs >10 miles | 4.7 | 4.6 | 5.2 | 4.7 | -1.2 |
| Rural >20 miles | 4.5 | 4.3 | 4.9 | 4.7 | 5.5 |

## Average total time

| | Total | Workers | Nonworkers | Predicted | % Differen |
|---|---|---|---|---|---|
| Total | 74. | 75. | 70. | 73. | -0.3 |
| Central Cities | 70. | 70. | 71. | 73. | 4.1 |
| Suburbs <10 miles | 70. | 71. | 67. | 73. | 4.7 |
| Suburbs >10 miles | 76. | 77. | 72. | 74. | -2.9 |
| Rural >20 miles | 79. | 80. | 73. | 74. | -6.7 |

## Average total distance

| | Total | Workers | Nonworkers | Predicted | % Differen |
|---|---|---|---|---|---|
| Total | 30. | 31. | 24. | 29. | -1.3 |
| Central Cities | 22. | 24. | 19. | 29. | 29. |
| Suburbs <10 miles | 26. | 28. | 21. | 29. | 12. |
| Suburbs >10 miles | 32. | 34. | 27. | 30. | -8.7 |
| Rural >20 miles | 40. | 41. | 34. | 29. | -26. |

# *Home Distance from Center*

## Work Status Summary

| | Total | Workers | Nonworkers | % Workers | % Nonworker |
|---|---|---|---|---|---|
| Total | 18013. | 12817. | 5196. | 0.71 | 0.29 |
| 0-4 miles | 1998. | 1341. | 657. | 0.67 | 0.33 |
| 4-6 miles | 2517. | 1679. | 838. | 0.67 | 0.33 |
| 6-8 miles | 1985. | 1338. | 647. | 0.67 | 0.33 |
| 8-10 miles | 1816. | 1234. | 582. | 0.68 | 0.32 |
| 10-13 miles | 2595. | 1863. | 732. | 0.72 | 0.28 |
| 13-16 miles | 2263. | 1726. | 537. | 0.76 | 0.24 |
| 16-20 miles | 2348. | 1832. | 516. | 0.78 | 0.22 |
| 20-25 miles | 1439. | 1057. | 382. | 0.73 | 0.27 |
| >25 miles | 1052. | 747. | 305. | 0.71 | 0.29 |

## Probability of traveling

| | Total | Workers | Nonworkers | Predicted | % Differenc |
|---|---|---|---|---|---|
| Total | 0.86 | 0.92 | 0.7 | 0.86 | 0 |
| 0-4 miles | 0.82 | 0.9 | 0.65 | 0.85 | 3.2 |
| 4-6 miles | 0.83 | 0.91 | 0.67 | 0.85 | 1.4 |
| 6-8 miles | 0.85 | 0.92 | 0.72 | 0.85 | -0.82 |
| 8-10 miles | 0.85 | 0.92 | 0.72 | 0.85 | -0.7 |
| 10-13 miles | 0.87 | 0.92 | 0.74 | 0.86 | -1.3 |
| 13-16 miles | 0.89 | 0.94 | 0.74 | 0.87 | -2.8 |
| 16-20 miles | 0.88 | 0.92 | 0.72 | 0.87 | -1.1 |
| 20-25 miles | 0.85 | 0.91 | 0.69 | 0.86 | 0.71 |
| >25 miles | 0.81 | 0.89 | 0.61 | 0.85 | 5.2 |

## Average number of trips

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 4.7 | 4.6 | 5. | 4.7 | 0.45 |
| 0-4 miles | 4.5 | 4.4 | 4.6 | 4.7 | 5.4 |
| 4-6 miles | 4.7 | 4.7 | 4.9 | 4.7 | -0.26 |
| 6-8 miles | 4.8 | 4.8 | 4.9 | 4.7 | -2.4 |
| 8-10 miles | 4.7 | 4.6 | 4.9 | 4.7 | -0.077 |
| 10-13 miles | 4.8 | 4.7 | 5.5 | 4.7 | -3. |
| 13-16 miles | 4.7 | 4.6 | 5.2 | 4.7 | -0.54 |
| 16-20 miles | 4.7 | 4.6 | 5. | 4.7 | 0.17 |
| 20-25 miles | 4.6 | 4.5 | 5. | 4.7 | 2. |
| >25 miles | 4.2 | 4.1 | 4.7 | 4.7 | 11. |

## Average total time

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 74. | 75. | 70. | 73. | -0.3 |
| 0-4 miles | 68. | 68. | 67. | 73. | 8.3 |
| 4-6 miles | 72. | 72. | 71. | 73. | 2.3 |
| 6-8 miles | 71. | 72. | 67. | 73. | 4. |
| 8-10 miles | 70. | 71. | 68. | 73. | 4. |
| 10-13 miles | 75. | 75. | 75. | 73. | -1.8 |
| 13-16 miles | 76. | 76. | 74. | 74. | -2.9 |
| 16-20 miles | 77. | 79. | 67. | 74. | -4.1 |
| 20-25 miles | 78. | 80. | 71. | 74. | -5.8 |
| >25 miles | 80. | 81. | 76. | 73. | -8. |

## Average total distance

| | Total | Workers | Nonworkers | Predicted | % Difference |
|---|---|---|---|---|---|
| Total | 30. | 31. | 24. | 29. | -1.3 |
| 0-4 miles | 21. | 22. | 17. | 29. | 39. |
| 4-6 miles | 24. | 25. | 20. | 29. | 21. |
| 6-8 miles | 25. | 27. | 21. | 29. | 15. |
| 8-10 miles | 27. | 29. | 22. | 29. | 8.2 |
| 10-13 miles | 30. | 31. | 26. | 29. | -1.8 |
| 13-16 miles | 33. | 34. | 28. | 30. | -10. |
| 16-20 miles | 34. | 36. | 27. | 30. | -14. |
| 20-25 miles | 37. | 39. | 30. | 29. | -20. |
| >25 miles | 43. | 45. | 39. | 29. | -33. |

# Regression Results

Regressions are done by traffic analysis zone (TAZ). Each independent variable such as commute time is covered in a single section; all results in that section use that independent variable. The results of each regression are given in a bracketed list of the form {$R^2$, Intercept, {v1,b1,t1}, {vn,bn,tn}}, where v1 is the first regressor, b1 is its parameter estimate, and t1 is the t-statistic. A t-statistic above two is generally taken as a rough cutoff for statistical significance.

There are four general variables, then several sets of land use variables. The general variables are:

- Closest: Distance of the TAZ from the closest downtown.
- CensInc: Median TAZ household income from census data (large sample)
- TBIinc: Average household income of those TAZ residents sampled in the TBI survey (generally small sample)
- Age: Average age of TAZ residents sampled in the TBI

A unit of income here is $10,000. A unit of age is roughly ten years.

There are seven sets of land use descriptors; each set has four elements, of the form Zx, x1, x10, x20. These refer to the radius of analysis. Z. is the specific zone, 1 is all zones within a one-mile radius, 10 is all zones within a ten-minute driving distance, and 20 is all zones within a 20-minute driving distance (at congested speeds).

The seven sets are:

- TE: total employment
- TP: total population
- TR: total retail
- ED: employment density
- PD: population density
- RD: retail density
- JR: job ratio (jobs/population)

Units of total employment, population, and retail are the total divided by 1,000 for the zone and a one-mile radius, and the total divided by 100,000 for the ten and 20-minute radius. Units of density are 1,000 per square mile.

## *Commute Time*

{0.37326, 18.0056, {Closest, 0.262764, 21.7276}}
{0.0749502, 18.2945, {CensInc, 0.677462, 8.06778}}
{0.00837767, 19.5095, {TBIinc, 0.340578, 2.77177}}
{0.00581843, 22.685, {Age, -0.679828, -2.37262}}
{0.0878654, 21.8713, {ZE, -0.994609, -8.78616}}
{0.0569078, 21.3379, {TE1, -0.123556, -6.98071}}
{0.317551, 23.3222, {TE10, -3.09212, -19.2109}}

{0.368947, 24.3779, {TE20, -0.999287, -21.5281}}
{0.00219495, 21.3567, {ZP, -0.0991807, -1.6553}}
{0.0876808, 22.2991, {TP1, -0.192213, -8.77617}}
{0.288191, 24.4991, {TP10, -3.00437, -17.9235}}
{0.357527, 25.4808, {TP20, -0.873194, -21.0043}}
{0.051964, 21.5786, {ZR, -2.86395, -6.66007}}
{0.0762251, 21.5601, {TR1, -0.963208, -8.14059}}
{0.313856, 23.7827, {TR10, -20.3586, -19.0478}}
{0.337805, 24.6062, {TR20, -6.14433, -20.1125}}
{0.0757631, 21.4415, {ZED, -0.346982, -8.11426}}
{0.0558387, 21.3052, {ED1, -0.182004, -6.91235}}
{0.20231, 22.3745, {ED10, -0.710014, -14.1991}}
{0.281368, 23.3582, {ED20, -1.62185, -17.6268}}
{0.145305, 22.5223, {ZPD, -0.359829, -11.6394}}
{0.153386, 22.6824, {PD1, -0.429218, -12.0129}}
{0.208038, 23.0503, {PD10, -0.733109, -14.4494}}
{0.299934, 24.2264, {PD20, -1.50806, -18.4362}}
{0.0649483, 21.4271, {ZRD, -1.44955, -7.47947}}
{0.0766264, 21.5161, {RD1, -1.42261, -8.16341}}
{0.22871, 22.8244, {RD10, -5.45736, -15.3478}}
{0.274125, 23.6081, {RD20, -10.4979, -17.3124}}
{0.024592, 21.2335, {JRZ, -0.73153, -4.57632}}
{0.0540333, 21.4075, {JR1, -0.970509, -6.79571}}
{0.348413, 24.8793, {JR10, -6.65672, -20.5903}}
{0.386913, 27.9114, {JR20, -11.4289, -22.365}}

{0.384622, 24.9274, {{TE20, -1.23224, -6.00568}, {TP20, -0.652378, -4.39135}, {TR20, 6.1092, 3.85978}}}
{0.302184, 24.357, {{ED20, -0.380324, -0.671362}, {PD20, -2.18274, -5.05053}, {RD20, 7.51014, 1.97818}}}
{0.393778, 24.5294, {{ZE, -0.469268, -4.53426}, {TE1, 0.00842764, 0.506265}, {TE10, -0.720769, -2.42107}, {TE20, -0.769131, -9.25186}}}
{0.358724, 25.2591, {{ZP, 0.100864, 1.82987}, {TP1, -0.0364685, -1.48666}, {TP10, 0.425737, 1.04682}, {TP20, -0.949352, -9.30585}}}
{0.362132, 24.7184, {{ZR, -1.51599, -3.7446}, {TR1, 0.105789, 0.858208}, {TR10, -7.44674, -3.56909}, {TR20, -4.18398, -7.20168}}}
{0.46639, 27.9099, {{JRZ, -0.280408, -1.98846}, {JR1, -0.177546, -1.34258}, {JR10, -3.57515, -9.47281}, {JR20, -7.7095, -12.9131}}}
{0.459628, 27.8721, {{JR10, -3.81886, -10.3588}, {JR20, -7.68363, -12.7903}}}
{0.486588, 29.0768, {{ED10, 0.484097, 4.25437}, {ED20, -0.0366271, -0.132247}, {JR10, -6.00743, -11.2149}, {JR20, -9.0285, -7.54015}}}
{0.465365, 28.278, {{PD10, 0.297603, 2.54703}, {PD20, -0.253272, -1.00803}, {JR10, -3.93758, -9.82006}, {JR20, -8.72084, -9.95981}}}
{0.477471, 29.2297, {{RD10, 0.761658, 0.988034}, {RD20, 4.61284, 2.6805}, {JR10, -4.69408, -10.748}, {JR20, -11.4014, -11.0264}}}
{0.464146, 26.9305, {{CensInc, 0.187304, 2.76646}, {JR10, -3.56596, -9.42566}, {JR20, -7.60721, -12.7028}}}

# *Work Speed*

{0.390602, 21.0882, {Closest, 0.493746, 22.5389}}

{0.0508223, 22.8002, {CensInc, 1.02657, 6.58429}}
{0.0245286, 22.4227, {TBIinc, 1.04729, 4.57056}}
{0.0257919, 33.5387, {Age, -2.56999, -4.68418}}
{0.0460774, 28.2961, {ZE, -1.50538, -6.26161}}
{0.0527984, 27.8623, {TE1, -0.354319, -6.71502}}
{0.325137, 31.2824, {TE10, -6.29103, -19.5471}}
{0.398333, 33.0577, {TE20, -1.88281, -22.9059}}
{0.0223835, 28.7372, {ZP, -0.465675, -4.37158}}
{0.15211, 30.3641, {TP1, -0.537065, -11.9543}}
{0.351776, 33.7252, {TP10, -6.02496, -20.7426}}
{0.37816, 35.0139, {TP20, -1.60723, -21.9552}}
{0.0219729, 27.7977, {ZR, -3.67758, -4.33255}}
{0.0827378, 28.2536, {TR1, -2.43461, -8.50581}}
{0.319267, 31.8839, {TR10, -37.7298, -19.2869}}
{0.388167, 33.6925, {TR20, -11.8375, -22.424}}
{0.0881621, 28.1673, {ZED, -1.07059, -8.8022}}
{0.0585427, 27.8225, {ED1, -0.565442, -7.08426}}
{0.279738, 30.0676, {ED10, -1.85738, -17.556}}
{0.377063, 31.797, {ED20, -3.55942, -21.9041}}
{0.257418, 31.0638, {ZPD, -1.0846, -16.5892}}
{0.273808, 31.3943, {PD1, -1.24984, -17.2987}}
{0.35376, 31.9171, {PD10, -1.93825, -20.8328}}
{0.404583, 33.6754, {PD20, -3.30444, -23.2052}}
{0.0540604, 27.8579, {ZRD, -3.13163, -6.79747}}
{0.0913293, 28.2108, {RD1, -3.86175, -8.97231}}
{0.335252, 31.0948, {RD10, -13.7219, -19.9981}}
{0.391799, 32.5108, {RD20, -23.6798, -22.5955}}
{0.00777939, 27.3634, {JRZ, -0.739392, -2.68361}}
{0.0159737, 27.5543, {JR1, -1.1106, -3.72026}}
{0.215467, 32.5651, {JR10, -9.91518, -14.773}}
{0.359612, 38.6244, {JR20, -19.5645, -21.0995}}

# ***Non-Commute Time***

{0.00383711, 29.4198, {Closest, -0.131338, -2.01168}}
{-0.000434143, 26.5351, {CensInc, 0.302373, 0.810396}}
{0.00332216, 23.18, {TBIinc, 1.02959, 1.90698}}
{0.00066524, 23.8231, {Age, 1.60041, 1.23554}}
{-0.000681136, 27.5105, {ZE, 0.389966, 0.679403}}
{-0.000648516, 27.993, {TE1, -0.0882549, -0.698109}}
{0.000949305, 27.015, {TE10, 1.20807, 1.32349}}
{0.00657176, 25.8777, {TE20, 0.61466, 2.49653}}
{-0.000684334, 27.2256, {ZP, 0.170213, 0.677541}}
{-0.00125149, 27.7388, {TP1, 0.0121025, 0.106346}}
{0.0035012, 26.0262, {TP10, 1.63197, 1.94401}}
{0.0070461, 25.0929, {TP20, 0.554514, 2.57158}}
{-0.000872447, 27.6103, {ZR, 1.11534, 0.557222}}
{-0.00126558, 27.8072, {TR1, 0.00958967, 0.0137567}}
{0.00290259, 26.5489, {TR10, 10.0296, 1.81732}}
{0.00761335, 25.5031, {TR20, 4.16656, 2.65864}}
{-0.00116602, 27.8921, {ZED, -0.0833697, -0.280631}}

{-0.000477858, 27.9958, {ED1, -0.151289, -0.788793}}
{-0.00122981, 27.7342, {ED10, 0.0490155, 0.168573}}
{0.00256114, 26.7184, {ED20, 0.834489, 1.741}}
{-0.00111614, 28.032, {ZPD, -0.0608156, -0.34368}}
{-0.00122347, 27.6884, {PD1, 0.036149, 0.182795}}
{-0.000409102, 27.2639, {PD10, 0.221946, 0.822516}}
{0.00267774, 26.3085, {PD20, 0.759291, 1.76742}}
{-0.000814833, 27.964, {ZRD, -0.659078, -0.59665}}
{-0.00126034, 27.8309, {RD1, -0.0692455, -0.0657496}}
{-0.000706196, 27.4351, {RD10, 1.30439, 0.664675}}
{0.00320494, 26.4749, {RD20, 5.88689, 1.88235}}
{0.00310135, 27.4399, {JRZ, 1.19761, 1.86032}}
{0.000725405, 27.4785, {JR1, 0.879838, 1.25468}}
{0.00475341, 25.7018, {JR10, 3.85174, 2.18584}}
{0.0135893, 22.3773, {JR20, 9.25283, 3.44923}}

# ***Non-Worker Time***

{0.00396892, 67.6665, {Closest, 0.257596, 2.03763}}
{0.0024968, 65.6163, {CensInc, 1.21582, 1.72624}}
{0.00346066, 61.9305, {TBIinc, 1.95995, 1.93569}}
{-0.00113603, 72.4611, {Age, -0.741754, -0.320037}}
{0.000610831, 71.5866, {ZE, -1.14568, -1.21797}}
{-0.00125411, 70.6281, {TE1, -0.0160345, -0.0961409}}
{0.0000263687, 71.9021, {TE10, -1.75589, -1.01038}}
{-0.000360667, 71.9978, {TE20, -0.409059, -0.845468}}
{0.00123472, 72.9122, {ZP, -0.688522, -1.40637}}
{0.00334503, 73.2569, {TP1, -0.421458, -1.91175}}
{0.000813541, 73.0283, {TP10, -2.08785, -1.2822}}
{-0.00008365, 72.6935, {TP20, -0.405888, -0.966353}}
{0.000130709, 71.3599, {ZR, -3.96563, -1.05043}}
{-0.0011333, 70.7803, {TR1, -0.345045, -0.323384}}
{0.0000715733, 72.1152, {TR10, -10.9043, -1.02792}}
{-0.000430607, 72.0851, {TR20, -2.51337, -0.812118}}
{-0.000697511, 70.9058, {ZED, -0.262102, -0.669816}}
{-0.00121103, 70.6697, {ED1, -0.0531884, -0.207928}}
{-0.000663287, 71.2742, {ED10, -0.376314, -0.689701}}
{-0.000799254, 71.415, {ED20, -0.566437, -0.606873}}
{0.00121782, 72.4059, {ZPD, -0.471646, -1.4016}}
{0.00190485, 72.7673, {PD1, -0.601637, -1.58417}}
{-0.00074113, 71.4846, {PD10, -0.329993, -0.643584}}
{-0.000700437, 71.7782, {PD20, -0.556251, -0.668088}}
{-0.00104867, 70.7779, {ZRD, -0.68614, -0.41397}}
{-0.00104771, 70.8182, {RD1, -0.677994, -0.414885}}
{-0.000702889, 71.4018, {RD10, -2.48054, -0.666637}}
{-0.000920635, 71.3829, {RD20, -3.19532, -0.521965}}
{-0.00126005, 70.5621, {JRZ, 0.063, 0.0675128}}
{-0.000292844, 70.1756, {JR1, 0.864314, 0.8766}}
{-0.000322629, 72.3522, {JR10, -3.00407, -0.863066}}
{-0.000202841, 73.663, {JR20, -5.02801, -0.916289}}

## *Non-Worker Speed*

{0.318193, 13.8967, {Closest, 0.595576, 19.2394}}
{0.0682314, 14.3255, {CensInc, 1.54649, 7.67614}}
{0.015095, 15.8807, {TBIinc, 1.07923, 3.62258}}
{0.00470103, 24.4094, {Age, -1.48846, -2.17625}}
{0.024748, 21.7494, {ZE, -1.26244, -4.59047}}
{0.0296934, 21.2865, {TE1, -0.243961, -5.02058}}
{0.237631, 25.9429, {TE10, -7.06606, -15.7339}}
{0.264448, 27.8059, {TE20, -2.07429, -16.8933}}
{0.0266323, 22.9464, {ZP, -0.680653, -4.75842}}
{0.172234, 25.4957, {TP1, -0.765157, -12.8679}}
{0.302912, 29.389, {TP10, -7.4737, -18.5666}}
{0.278983, 30.2501, {TP20, -1.84959, -17.5232}}
{0.0357908, 21.8266, {ZR, -6.04585, -5.51012}}
{0.0682752, 21.9635, {TR1, -2.33929, -7.67875}}
{0.242976, 26.7628, {TR10, -43.6129, -15.965}}
{0.257507, 28.4561, {TR20, -13.0934, -16.5931}}
{0.0392835, 21.4462, {ZED, -0.655249, -5.77441}}
{0.0323638, 21.2603, {ED1, -0.38999, -5.23984}}
{0.195908, 24.3313, {ED10, -2.01475, -13.9183}}
{0.244226, 26.2743, {ED20, -3.84547, -16.019}}
{0.235719, 25.908, {ZPD, -1.36355, -15.6512}}
{0.25468, 26.4469, {PD1, -1.59982, -16.4709}}
{0.263229, 26.6177, {PD10, -2.1928, -16.8405}}
{0.284224, 28.5756, {PD20, -3.6994, -17.7509}}
{0.0516332, 21.5332, {ZRD, -3.16951, -6.63819}}
{0.0698922, 21.8878, {RD1, -3.62439, -7.77426}}
{0.230018, 25.5403, {RD10, -14.8809, -15.4044}}
{0.252345, 27.0394, {RD20, -25.6335, -16.3699}}
{0.000250093, 20.7615, {JRZ, -0.302044, -1.09447}}
{0.00399997, 20.9294, {JR1, -0.595099, -2.04369}}
{0.145096, 27.1583, {JR10, -11.0754, -11.6297}}
{0.230344, 34.0893, {JR20, -21.9659, -15.4185}}

## *Transit Share*

{0.409045, 11.7913, {Closest, -0.543214, -23.4203}}
{0.35547, 17.1611, {CensInc, -2.89484, -20.9105}}
{0.131135, 16.5074, {TBIinc, -2.49249, -10.9719}}
{0.0200976, 11.3825, {Age, -2.33172, -4.15009}}
{0.0731276, 4.02891, {ZE, 1.79471, 7.96289}}
{0.149463, 4.52634, {TE1, 0.392816, 11.8322}}
{0.561975, -0.495392, {TE10, 8.11749, 31.8721}}
{0.422096, -1.53351, {TE20, 2.11061, 24.057}}
{0.0942466, 1.89637, {ZP, 1.02911, 9.12722}}
{0.473233, -0.3262, {TP1, 0.876848, 26.6761}}
{0.378187, -2.31184, {TP10, 6.79406, 21.9565}}
{0.342828, -3.06577, {TP20, 1.68895, 20.3382}}
{0.0760491, 4.22364, {ZR, 6.81722, 8.13057}}
{0.247644, 3.61763, {TR1, 3.40961, 16.1668}}

{0.360425, -0.287188, {TR10, 43.0791, 21.1366}}
{0.357701, -1.72764, {TR20, 12.4866, 21.0122}}
{0.187376, 4.23595, {ZED, 1.07248, 13.5422}}
{0.157175, 4.59657, {ED1, 0.59878, 12.1865}}
{0.727344, 0.464335, {ED10, 2.65302, 45.9466}}
{0.553619, -0.925466, {ED20, 4.48838, 31.3374}}
{0.685599, -0.908684, {ZPD, 1.5385, 41.5439}}
{0.687344, -1.41156, {PD1, 1.78886, 41.7125}}
{0.69677, -1.79498, {PD10, 2.64428, 42.6448}}
{0.570095, -3.17598, {PD20, 4.10236, 32.4028}}
{0.226608, 4.03533, {ZRD, 5.31122, 15.2567}}
{0.252216, 3.7614, {RD1, 5.06874, 16.3644}}
{0.667526, -0.544534, {RD10, 18.3813, 39.8639}}
{0.536254, -1.59585, {RD20, 28.9677, 30.2601}}
{0.000660087, 5.47577, {JRZ, 0.394315, 1.23389}}
{0.0183794, 5.12164, {JR1, 1.1425, 3.97622}}
{0.329398, -1.8496, {JR10, 12.7852, 19.7367}}
{0.294998, -6.32435, {JR20, 19.7205, 18.2204}}

{0.729274, 0.137523, {{ED10, 2.42115, 22.6622}, {ED20, 0.533476, 2.57573}}}
{0.667133, -0.581648, {{RD10, 18.141, 17.6527}, {RD20, 0.472775, 0.26171}}}
{0.766096, -1.81303, {{ZPD, 0.693349, 7.7595}, {PD1, 0.194308, 1.66507}, {PD10, 1.73177, 9.47741}, {PD20, -0.525895, -2.04002}}}
{0.798582, -1.34451, {{ZPD, 0.461068, 5.40339}, {PD1, 0.325822, 3.00476}, {PD10, 0.436367, 3.37377}, {ED10, 1.28954, 11.4788}}}
{0.79919, -2.13674, {{ZPD, 0.469512, 5.5027}, {PD1, 0.321155, 2.9654}, {PD10, 0.554915, 3.84493}, {ED10, 1.28203, 11.4217}, {Closest, 0.0401724, 1.84005}}}
{0.809583, 1.80033, {{ZPD, 0.37883, 4.51855}, {PD1, 0.269401, 2.54737}, {PD10, 0.465722, 3.70111}, {ED10, 1.22933, 11.2178}, {CensInc, -0.636389, -6.81688}}}

# *Walk, Bike Share*

{0.100915, 5.7336, {Closest, -0.21571, -9.47542}}
{0.184574, 9.91466, {CensInc, -1.66261, -13.4181}}
{0.0600041, 9.17911, {TBIinc, -1.34922, -7.17586}}
{0.0137119, 7.12729, {Age, -1.55358, -3.46365}}
{0.114515, 1.71432, {ZE, 1.78162, 10.1634}}
{0.389234, 1.89829, {TE1, 0.503119, 22.4743}}
{0.290052, -0.213533, {TE10, 4.64545, 18.0046}}
{0.14886, -0.105327, {TE20, 1.00012, 11.8043}}
{-0.0000721792, 2.94614, {ZP, 0.0915455, 0.971036}}
{0.164421, 0.488316, {TP1, 0.412307, 12.516}}
{0.110598, -0.14335, {TP10, 2.93539, 9.96803}}
{0.108401, -0.617987, {TP20, 0.758727, 9.8575}}
{0.0464509, 2.41421, {ZR, 4.26169, 6.28749}}
{0.315421, 1.49483, {TR1, 3.06033, 19.1169}}
{0.139444, 0.352914, {TR10, 21.3812, 11.3654}}
{0.111034, 0.0136143, {TR20, 5.55747, 9.98986}}
{0.370992, 1.74897, {ZED, 1.19884, 21.6226}}

{0.386489, 2.02438, {ED1, 0.745388, 22.345}}
{0.343877, 0.462095, {ED10, 1.45299, 20.3855}}
{0.208713, 0.0806302, {ED20, 2.19708, 14.4789}}
{0.285589, -0.0721986, {ZPD, 0.791157, 17.8103}}
{0.207683, 0.201565, {PD1, 0.784115, 14.4339}}
{0.221171, -0.046838, {PD10, 1.1878, 15.0209}}
{0.207259, -0.943923, {PD20, 1.9721, 14.4154}}
{0.201809, 2.09903, {ZRD, 3.98974, 14.1771}}
{0.313346, 1.64421, {RD1, 4.49349, 19.0253}}
{0.25517, 0.247235, {RD10, 9.05711, 16.492}}
{0.186477, -0.109139, {RD20, 13.6228, 13.5024}}
{0.0251032, 2.90462, {JRZ, 1.16103, 4.62255}}
{0.159677, 2.18211, {JR1, 2.60217, 12.3006}}
{0.192181, -1.25944, {JR10, 7.78153, 13.7543}}
{0.0848102, -1.83956, {JR20, 8.45841, 8.61984}}

{0.456201, 0.0816791, {{ZED, 0.874792, 13.4771}, {ZPD, 0.467063, 10.2214}, {ZRD, 0.350916, 1.17204}}}
{0.451365, 0.367119, {{ED1, 0.647091, 11.8667}, {PD1, 0.477995, 9.09277}, {RD1, -0.142478, -0.360444}}}
{0.424657, 1.72985, {{ZED, 0.622595, 7.30816}, {ED1, 0.448527, 8.64222}}}
{0.299021, 0.224812, {{ZPD, 1.25155, 10.195}, {PD1, -0.572686, -4.01723}}}
{0.324843, 1.53989, {{ZRD, 1.29984, 3.80166}, {RD1, 3.72496, 12.04}}}
{0.48578, 0.274961, {{ZED, 0.506086, 6.21546}, {ED1, 0.343589, 6.83959}, {ZPD, 0.4205, 9.73573}}}
{0.436172, 1.57201, {{ZED, 0.481828, 5.29824}, {ED1, 0.438752, 8.53076}, {ZRD, 1.19863, 4.13682}}}
{0.485488, 0.316798, {{ZED, 0.514957, 6.25586}, {ED1, 0.331602, 6.28369}, {ZPD, 0.501683, 4.2727}, {PD1, -0.0960456, -0.743581}}}
{0.496269, 2.78504, {{ZED, 0.451375, 5.52824}, {ED1, 0.362206, 7.25572}, {ZPD, 0.314926, 6.33957}, {CensInc, -0.507104, -4.17225}}}