



STATEWIDE CONGESTION OVERVIEW FOR OREGON

Prepared by

OREGON DEPARTMENT OF TRANSPORTATION
Transportation Planning Analysis Unit

February 2004



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EXECUTIVE SUMMARY

BACKGROUND

The Oregon Department of Transportation (ODOT) traffic congestion management system (CMS) provides general information regarding roadway congestion trends. It also provides specific information regarding traffic congestion trends on state highways. The objectives of the program are to estimate and forecast the location and average severity of congestion on the state highway system, estimate the effect of congestion on highway mobility, and identify significant attributes of the highway system and highway travel affecting traffic congestion. Transportation engineers, planners and managers can use this information to help develop plans and projects for managing traffic congestion. There are two main products from the CMS. One is an inventory of congestion on state highways. The other is a report to provide background information on statewide congestion trends and the major factors influencing those trends. This *Statewide Congestion Overview for Oregon-2003* is an update to the report prepared in 1998.

FINDINGS

Vehicle travel in Oregon has grown almost continuously since 1980. Average vehicle miles traveled (VMT) per capita increased by almost 35 percent from 1980 to 2002. Rapid growth occurred after 1982 as the state recovered from economic recession. The rate of per capita VMT growth slowed after 1990, but population continued to grow steadily. As a result, per capita VMT grew continuously, increasing by 80 percent overall between 1980 and 2002.

Traffic growth, particularly in urban areas, was not matched by growth of roadway infrastructure. From 1982 to 2002, traffic on major roads in urban areas grew about four times faster than the number of roadway lane-miles. On urban freeways and expressways alone, traffic grew about six times faster than lane-miles. On average, urban freeway lanes in 2002 were carrying almost double the amount of traffic they carried in 1982.

In the most congested state highway corridors (located primarily in the Portland metropolitan area), the state highways cannot handle the peak traffic demands so the duration of peak congestion has increased. On several of these corridors, about a third of the traffic normally expected to occur in the peak hour spills over to adjacent times.

Travel speeds have decreased as congestion has increased. In the Portland-Vancouver metropolitan area, for example, the 2003 Urban Mobility Report (UMR) of the Texas Transportation Institute estimated that in 2001, peak-period trips took an average of 24 percent more time per mile of travel than off-peak trips due to ordinary congestion. When the effects of traffic accidents and other incidents are included, peak-period trips were estimated to take 44 percent more time per mile of travel than off-peak trips. The Portland area had among the lowest peak period travel speeds of large urban areas in the country (1-3 million population). In the

Eugene and Salem areas peak period trips were estimated to take 10 percent more time than off-peak trips considering the effects of incident congestion as well as recurring congestion. This is about average for small urban areas (less than 500,000 population).

Although average peak period travel speed in the Portland area is lower than the average for urban areas of its size, the average travel time is lower than average as well. In 2001, the average peak period traveler in the Portland area spent about 148 annual hours traveling during peak periods. The large urban area average was about 177 annual hours. Travel times in the Portland area are shorter than the large area average despite slower than average travel speeds because average travel distances on major roads in the Portland area are shorter. In other words, while the major road system is more congested in Portland, people do not travel on it as far. In 2001, there were 10.8 VMT per peak period traveler in the Portland area. In comparison, the 2001 large urban area average was 12.2 VMT per peak period traveler.

Oregonians are reporting that it takes longer to commute to work than it used to. According to the Oregon Population Survey responses, the average commute time in the Portland metropolitan area increased from 19 minutes in 1990 to 21 minutes in 2000. It increased for commuters in other places in the Willamette Valley from 15 minutes in 1990 to 19 minutes in 2000. Commute times are lower in other places in the state.

Public concerns about congestion are increasing. In 1990 almost half of the respondents to the Oregon Population Survey thought that traffic congestion was a small problem and less than a quarter thought that it was a serious problem. By 2002, a third thought that congestion was only a small problem and 29 percent thought it was a serious problem.

ASSESSMENT

Long-term trends (1970 to 2002) demonstrate that growth of VMT in Oregon is strongly associated with economic growth. Although average per capita VMT has grown substantially over the past three decades, the average amount of VMT per job in Oregon and the ratio of VMT to total statewide personal income have not. The ratio between VMT and total statewide personal income has stayed almost constant at about 360 miles per \$1,000 of income (in year 2000 dollars). That ratio has varied by no more than 8 percent over a period of more than 30 years.

The constancy of the relationship between travel and the economy can also be seen by comparing the estimated cost of peak-period travel in the Portland area with the size of the Portland area economy. Although peak-period travel speeds in the Portland area have declined markedly since 1982 and travel times have increased, the ratio of peak-period travel costs to total personal income has shown almost no change.

The growth of travel and the economy since 1970 are linked to demographic, social and economic changes that increased the amount of specialization, trade and economic output. The population of the state grew by 63 percent from 1970 to 2002. Job growth was even greater (128 percent) due to the entry of baby boomers and an increased percentage of women into the labor force as well as to economic factors. Households put more time into paid labor to compensate for

declining hourly wages as the country lost higher paid manufacturing jobs overseas and other economic and political pressures drove hourly wages down. Households adjusted to these changes by putting a larger share of their time into specialized paid labor and buying more household products and services. This resulted in more travel by households and freight carriers.

Since the rates of growth of VMT and the state's economy were nearly identical, one would expect that congestion growth might have been avoided if a constant proportion of the state's economy were invested in highway expansion. The capital investment in highways since the 1960s, however, was a shrinking proportion of the state economy. During the 1960s, an average of 2.5 percent of total state personal income was spent on highway capital outlay. By the 1990s, the average dropped to 0.8 percent.

In large part, the mobility that Oregonians' enjoyed during the past several decades was a result of the relatively high level of highway capital investments made from the late 1950s through the early 1970s. Congestion increased because the excess capacity created by those investments was used up and not replaced.

While the gap between travel growth and the growth of the road system is at the root of the state's congestion problems, the solution to congestion is not simply building more roads. There are several reasons, aside from funding, that road construction does not keep up with travel demand in urban areas. Roads become more costly to build as urban areas grow because property values increase, buildings must be purchased and torn down to make room for construction, and more expensive construction techniques must be used to reduce neighborhood or environmental impacts.

A number of other strategies in addition to road-building can help in the management of congestion. Operational treatments such as ramp metering, traffic signal coordination, incident management programs and high-occupancy vehicle lanes can substantially reduce congestion delay. Public transportation plays an important role in reducing delay by reducing the numbers of vehicles on congested roadways. Land development and how it is managed also has a significant effect. Coordinating the location of development and its layout with the transportation system can help to avoid creating future traffic bottlenecks. Still other land use strategies can reduce the impact of congestion on the public by reducing the length of travel in congestion. Congestion can also be reduced through value pricing and other pricing approaches which replace some of the fixed costs of driving with costs that vary with congestion levels or the number of miles driven. In the longer run, automated vehicle and highway systems may substantially increase highway capacities.

CONCLUSIONS AND RECOMMENDATIONS

It is important to understand the economic underpinnings of travel and congestion. This can help with targeting policies and limited resources towards actions that do the most good. Perhaps just as important, it can help avoid policies and actions that are counterproductive or that do not act in the best interests of Oregonians. This study only addresses the economic connections at a

general level. However, the following findings provide useful guidance for transportation and land use planners and decision-makers:

- ***Travel in the future is likely to grow as the state's economy grows, but the nature of economic growth may change.*** On average, every new job in Oregon adds about 15,500 vehicle miles annually. Every \$1,000 increase in total state personal income adds about 360 VMT annually.
- ***Congestion is expected to get much worse if economic growth continues to greatly exceed capital investment in the road system.*** To a large extent, the levels of mobility and accessibility enjoyed by Oregonians over the past three decades is a result of highway investments made previously. Congestion increased as the capacity of the system was used up and not replaced.
- ***It is possible to increase the capacity of existing road space with traffic operations programs and improvements.*** Evidence is showing that operations programs such as ramp metering, incident management and traffic signal coordination can greatly reduce travel delay due to congestion and can improve travel time reliability.
- ***Public transportation services can significantly reduce the impacts of congestion.*** Public transportation offers the greatest congestion relief where it is provided on exclusive rights-of-way in congested corridors. The benefits of public transportation are increased when land development is coordinated with public transportation services.
- ***Land use policies can reduce the impacts of congestion.*** Some land use policies can help reduce congestion by making the road system work more efficiently. In addition, maintaining compact urban areas can reduce trip lengths so that shorter distances offset declining travel speeds.
- ***Since congestion is most likely to get worse in the future, it is important to recognize how people cope with congestion and take actions that improve their ability to cope.*** Helping people reduce the impacts of congestion on their lives requires knowledge about how people manage the conflicting time demands of their jobs, households and travel. The experience of the past several decades shows that people substantially limit the effects of rising congestion on their travel time budgets through their own actions. Failure to recognize the significance of these coping strategies could result in policies that ultimately harm people.
- ***Congestion relief should be directed towards activities that provide the most benefits to Oregonians.*** Different activities are affected to varying degrees by congestion. With limited dollars available to address congestion problems, it is important to do analysis that goes beyond simply estimating how vehicles are affected by a proposed improvement. It is also necessary to estimate how different households and businesses will be affected.
- ***Directing congestion relief requires the use of integrated transportation, economic and land use analysis tools.*** Targeting congestion relief to get the most benefit requires analysis that identifies who is likely to benefit from potential improvements and how much they will benefit. This is a complex undertaking requiring the use of integrated economic, transportation and land use analysis tools.

- ***Better data is needed to improve understanding of congestion and how to address it.*** Understanding congestion and its effects on Oregonians depends on having good data about the transportation system and how people and businesses use it.

Although the statistics on the growth of congestion on Oregon's freeways and other major roads look grim, the ability of the Portland area to avoid increased travel costs relative to income is promising. Oregon cannot avoid rising congestion without substantially increasing its investment in its major road system. Even without such an investment, things can be done to limit the impact of congestion on the lives and economic well-being of Oregonians.

Policy-makers must make careful choices about how and where resources are spent. Effective choices requires an understanding of how travel affects people's lives and the economy, how people respond to different public policy actions, improved data collection and analysis, and using tools that enable the evaluation of public-policy choices.

STATEWIDE CONGESTION OVERVIEW

BACKGROUND

The Statewide Congestion Overview is one of the products of the state congestion management system (CMS). The CMS provides information on transportation system performance related to traffic congestion. This information is intended to help transportation engineers, planners and managers develop plans and projects for managing traffic congestion.

The purpose of this report is to provide background information on statewide congestion trends and the major factors influencing those trends. Information is drawn primarily from published data sources and ODOT databases. Because the information presented is of a general nature, it is most applicable to the development of statewide policy.

This report should not be used for identifying site specific congestion problems or solutions to those problems. Detailed analysis is usually required in such situations. This report condenses a large amount of research. Questions about sources or methods supporting the points made in the report are referred to the appendixes.

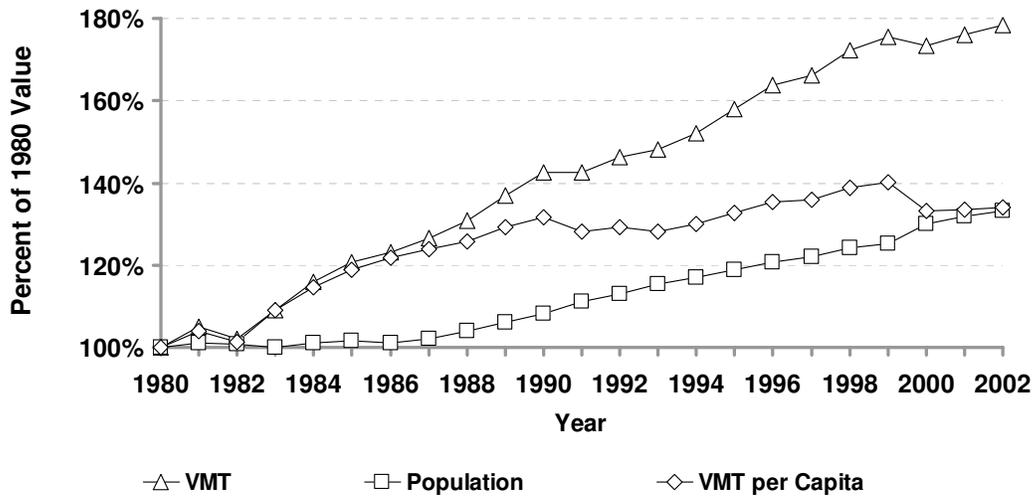
TRAVEL AND CONGESTION TRENDS

Public Perception

Public concerns about congestion are increasing. In 1990 almost 50 percent of the respondents to the Oregon Population Survey thought that traffic congestion was a small problem and less than 25 percent thought that it was a serious problem. By 2002, a third of the respondents thought that congestion was only a small problem and 29 percent thought it was a serious problem. Public attitudes reflect the growth of traffic and crowding on the road system.

Vehicle Miles Traveled

Vehicle travel in Oregon has grown almost continuously since 1980. Average vehicle miles traveled (VMT) per capita increased by about 35 percent from 1980 to 2002. Rapid growth occurred after 1982 as the state recovered from economic recession. The rate of per capita VMT growth slowed after 1990, but population continued to grow steadily. As a result, total VMT grew almost continuously, increasing almost 80 percent between 1980 and 2002 (Figure 1).



Note: Indexed to 1980 Values

Sources: VMT - ODOT Finance Section; Population - Portland State University Center of Population Research & Census.

Figure 1. Statewide Vehicle Miles Traveled, Population and Vehicle Miles Traveled per Capita 1980-2002

Traffic Growth vs. Lane-Miles

Traffic growth was not matched by growth in lane-miles of the major road system (freeways and other principal arterials). From 1982 to 2002, traffic on major roads in urban areas grew about 4 times faster than the number of roadway lane-miles. On urban freeways and expressways alone, traffic grew about 6 times faster than lane-miles. On average, urban freeway lanes in 2002 were carrying almost double the amount of traffic they carried in 1982. The gap between the growth of traffic and expansion of the major road system grew faster in the Portland area than in most other large metropolitan areas in the country (populations of 1 to 3 million).⁹ By 2001, peak period traffic on the major road system in the Portland area was almost enough to consume 4 hours of capacity.¹⁰

Travel Speeds

Peak period travel speeds on major urban roads declined as traffic densities increased. In 2001 for the Portland-Vancouver urban area, it took on average 24 percent more time per mile of travel during the peak period than during the off-peak period. Peak period travel speeds were therefore about 20 percent lower than off-peak speeds. In comparison, in Portland in 1982, it was

⁹ David Schrank and Tim Lomax, *The 2003 Annual Urban Mobility Report*, Texas Transportation Institute, September 2003, Exhibit A-18, p. 80. The Roadway Congestion Index (RCI) compares daily traffic volumes to lane-miles of the major road system.

¹⁰ Appendix A, p. A-16.

estimated to take only 3 percent more time per mile of travel during the peak period than during the off-peak period. These estimates consider the effects of everyday recurring congestion but do not include the effects of congestion due to incidents.¹¹

The increase in demand on major roadways is not limited to the Portland area. Traffic congestion on major roads also increased in the Salem and Eugene-Springfield areas, although by much less than in Portland. It is estimated that it takes about 5 percent more travel time during peak times than during off-peak times, not counting the effects of traffic incidents.¹² Congestion increased in the Medford and other urbanized areas, but congestion trend measures for these areas are not currently estimated.

As congestion increases, the variability of travel speeds increases. When traffic volumes approach the capacity of a roadway, traffic flows become more chaotic and travel speeds decrease and become more variable. The potential for disruptions caused by traffic accidents or other incidents increases and the effects of incidents on delay increases. The effects can be substantial. As congestion becomes more severe, travel time becomes more unreliable and the amount of delay due to unexpected events increases.

Adding the average effects of incident congestion to the effects of recurring congestion, an estimate can be made of the total effects of congestion delay on peak period travel speeds. In the Portland area in 2001, travel during the peak period took about 44 percent more time per mile traveled if all the recurring and incident-caused delays were averaged together. This compares to the 1982 value of 5 percent more time in the peak period than the off-peak period in Portland.¹³

Incident delays are usually unpredictable and that makes peak period travel times unreliable. Travel reliability can be measured by estimating the percentage increase in the average congested travel time required to have a 95 percent confidence of on-time arrival. For Portland area freeways in 2001, this increase was estimated to be about 40 percent.¹⁴

Travel Time

Although average peak period travel speed in the Portland area is lower than the average for all large urban areas, the average travel time is shorter. The Portland area has among the lowest peak period travel speeds of cities in its size class. In 2001, the estimated average peak period

¹¹ Texas Transportation Institute, *2003 Urban Mobility Report: Methodology*, pp. 16-18. The Travel Rate Index (TRI) estimates of how much slower travel is on the major road system during peak times versus off-peak times. The TRI for the Portland-Vancouver urban area in 2001 was estimated to be about 1.24. The Portland area TRI in 1982 was estimated as 1.03.

¹² *ibid.* The TRI values reported for the Eugene and Salem areas were 1.06 and 1.05 respectively.

¹³ The *2003 Annual Urban Mobility Report* (Exhibit A-2, p. 64) includes a measure that adds the average effects of incident congestion to the effects of recurring congestion. The resulting Travel Time Index (TTI) estimates the total effects of congestion delay on peak period travel speeds. The estimated TTI for the Portland area in 2001 was 1.44. In comparison, the TTI for the Portland area in 1982 was estimated to be 1.05.

¹⁴ Texas Transportation Institute, *Monitoring Urban Roadways in 2001: Examining Reliability and Mobility with Archived Data*, June 2003, Appendix PDX, p. PDX-9. Report is available at http://mobility.tamu.edu/mmp/reports/monitoring_urban_roadways/appendices/PDFs/portland.pdf.

speed in the Portland area was about 70 percent of the off-peak speed, while the estimated average peak period speed for all large urban areas was about 78 percent of the average off-peak speed. Peak period speeds in the Portland area were therefore about 90 percent of the large urban area average.¹⁵ On the other hand, average peak period travel times show that Portland area travelers spend relatively less time traveling. In 2001, the average peak period traveler in the Portland area spent about 148 annual hours traveling on the major road system during peak periods. The large urban area average was about 177 annual hours. Peak period travel times in the Portland area were 83 percent of the large urban area average.¹⁶

Travel times in the Portland area are shorter than the large area average despite slower than average travel speeds because average travel distances on major roads in the Portland area are shorter. In other words, while the major road system is more congested in Portland, people do not travel on it as far. In 2001, there were 10.8 VMT per peak period traveler in the Portland area. In comparison, the 2001 large urban area average was 12.2 VMT per peak period traveler. The average distance in Portland was therefore 88 percent of the average distance for large urban areas as a whole.

Data from the Census also show the average Portland area commute time to be shorter than the large urban area average. The average journey to work time for Portland area residents in 2000 was 24.4 minutes. This is 96 percent of the overall large urban area average of 25.3 minutes.¹⁷

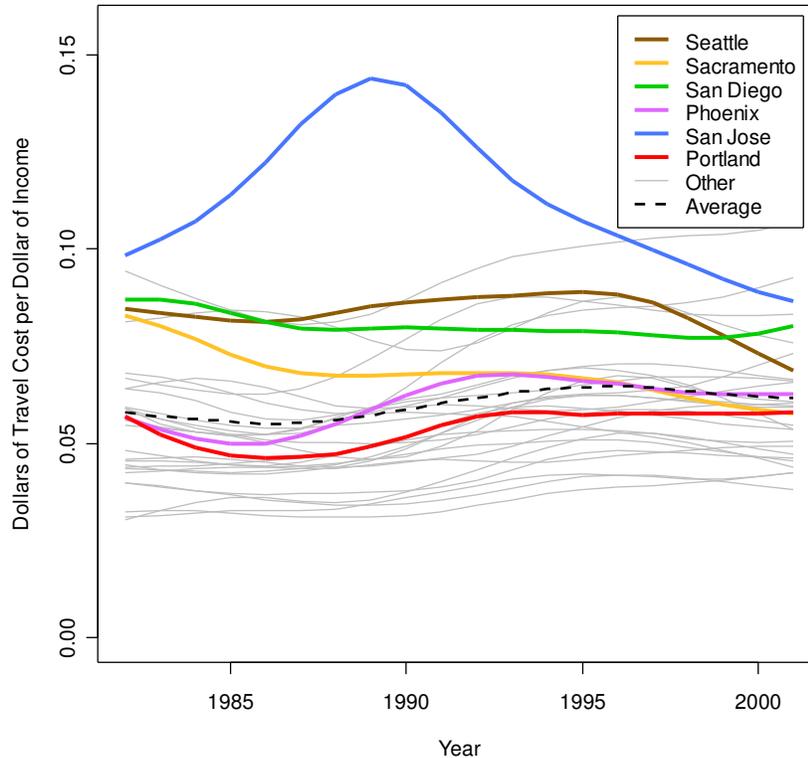
Travel Cost

The limited increases in travel time help to limit the impacts of congestion on the Portland area economy. This can be seen by comparing estimated travel costs during peak periods with total personal income for each urban area, adjusting for inflation and cost-of-living differences. This produces a relative cost of travel. While travel time for the Portland area increased by a small amount from 1982 to 2001, relative peak period travel cost declined by a small amount. The large urban area average increased by a small amount during the same time period but the trends for urban areas in general show that relative travel costs for most urban areas have changed little over time. This is shown in Figure 2.

¹⁵ From the *2003 Annual Urban Mobility Report*. The ratio of peak to off-peak speeds is $1/TTI$. Since the 2001 TTI for the Portland area was 1.44, the speed ratio was 0.694. Similarly the average TTI and speed ratios for all large urban areas were 1.29 and 0.776, respectively. Since the UMR assumes the same off-peak speeds for all urban areas (60 mph freeway and 35 mph for other major roads), the ratio of average peak period speeds in Portland and all large urban areas is 0.894 (0.694/0.776).

¹⁶ The *2003 Annual Urban Mobility Report* reports delay rather than travel time. The formula for calculating travel time from delay and the TTI is as follows: Since congested travel time-freeflow travel time=delay, and congested travel time= freeflow travel time* travel time index, therefore congested travel time = delay* travel time index/(travel time index-1).

¹⁷ Appendix A, Table A-5, p. A-28. The difference between the Portland and large area commute time averages is not as great as travel time difference computed from the *2003 Annual Urban Mobility Report*, but that may be due to differences in what is measured in each case. The Census journey-to-work data only addresses commutes. Also, the Census includes a larger area and reports all work trips, not just work trips on major roads in the urbanized area.



Sources: Delay costs - 2003 Urban Mobility Report; CPI - Bureau of Labor Statistics (Portland area CPI); Cost of Living Index - *Sperling's Best Places*, <http://www.bestplaces.net/>

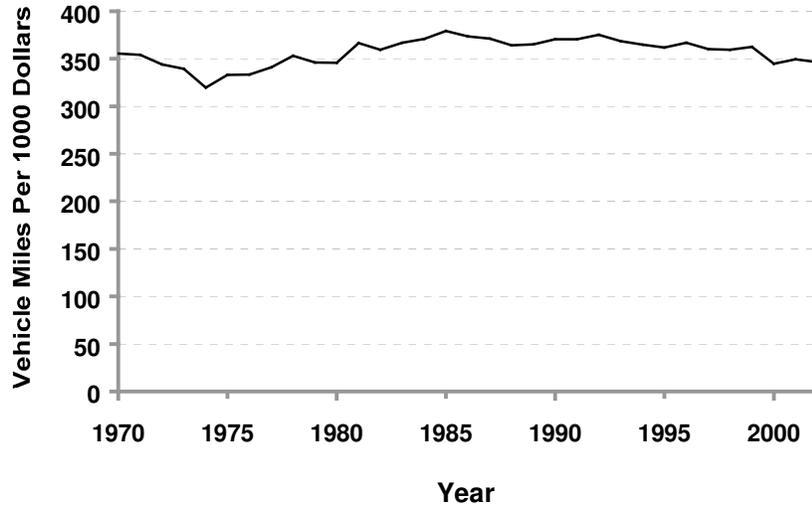
Figure 2. Trends in Travel Cost for Large Urbanized Areas

The cost of peak period travel relative to income for large metropolitan areas has not changed much despite large increases in congestion for most areas. This suggests that changes in congestion interact with other urban forces to maintain some equilibrium between the cost of transportation and economic output. This leads to a conclusion that travel and congestion need to be evaluated in an economic context.

ECONOMIC BASIS OF TRAVEL AND CONGESTION

Relationship of VMT and the Economy

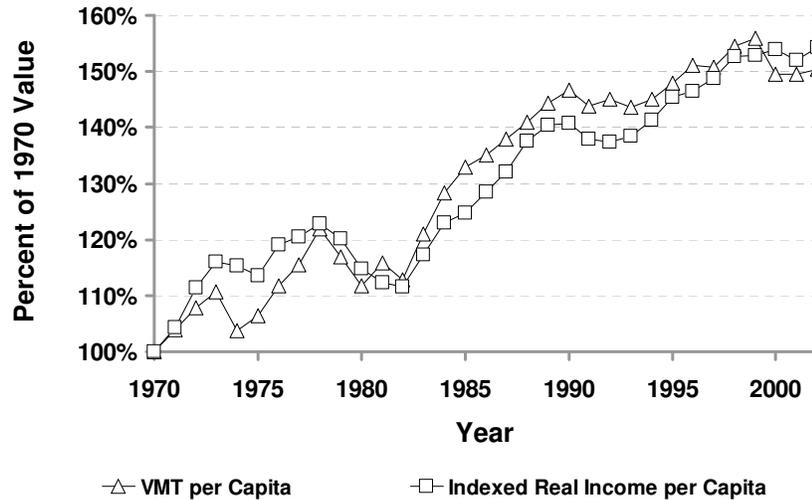
Over the long run (30+ years) changes in per capita VMT have closely followed changes in Oregon's economy. Although per capita VMT has grown substantially over the past 3 decades, the average amount of VMT per job in Oregon and the ratio of VMT to total statewide personal income have not. Each job added to Oregon's economy has on average added about 15,500 VMT to Oregon's roads and highways. The ratio of total statewide income to VMT is fairly constant at about 360 miles per \$1,000 (year 2000 dollars). This is shown in Figure 3.



Note: Year 2000 dollars.
 Source: VMT - ODOT Finance Section; Personal Income - US Bureau of Economic Analysis.

Figure 3. Average Vehicle Miles Traveled per \$1,000 of Real Personal Income in Oregon: 1970-2002

The constancy of the relationship between VMT and the economy seems remarkable given the many changes that have occurred in the state. Increases in population account for much of the growth of the economy and travel, but increases in per capita travel also track increases in per capita incomes fairly closely (Figure 4). This relationship is not coincidental. Economic and social changes in the United States have been responsible for the growth of both the economy and travel.



Sources: VMT - ODOT Finance Section; Income - Bureau of Economic Analysis; CPI-Bureau of Labor Statistics (Portland area CPI).

Figure 4. Comparison of Per Capita Vehicle Travel and Real Personal Income in Oregon: 1970-2002

Specialization, Trade and Transportation

The connection between travel and the economy is explained by the fundamental economic principle of comparative advantage. People gain economically when they specialize in producing goods and services they can produce most efficiently and trade with others for the things that they are less efficient at producing. It is the benefits of comparative advantage that encourage people, businesses and regions to specialize. This is also why most travel and goods transport occurs. Travel and communication are necessary for trade to occur, and trade is necessary for specialization to occur.

While trade produces travel, changes to the transportation system may in turn induce trade by lowering travel costs and expanding market areas. Several researchers have estimated that past investments in highways stimulated a substantial amount of economic growth and a sizable return on investment.¹⁸ Figure 5 illustrates the connections between specialization, trade and transportation.

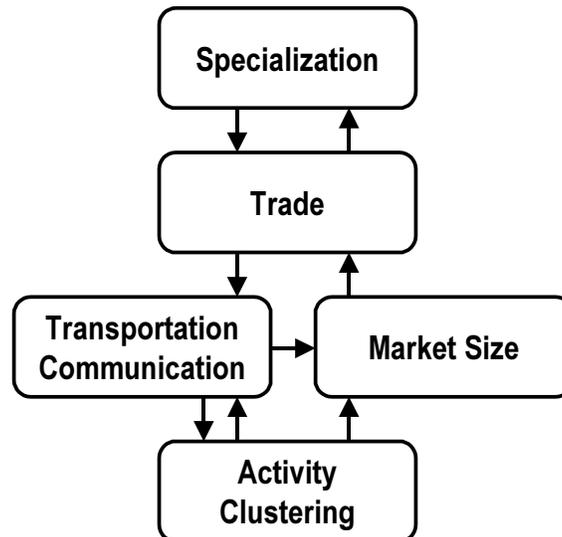


Figure 5. Connection between Specialization, Trade and Transportation

¹⁸ David Alan Aschauer, *Public Investment and Private Sector Growth: The Economic Benefits of Reducing America's "Third Deficit"*, Washington, D.C: Economic Policy Institute, 1990. Kazem Attaran and Philippe Auclair, *Highway Stock and Private-Sector Productivity*, Transportation Research Record 1274, pp. 119-124. Arthur C. Jacoby, *Recent Advances in Understanding the Effects of Highway Investment on the U.S. Economy*, Transportation Quarterly, Vol. 53, No. 3 (Summer 1999), pp. 27-34.

The transportation system also affects the clustering of activities and that in turn affects market areas. Urbanization occurs primarily because people and businesses cluster geographically to reduce their transportation and communication costs. This increases the size of the market for a given transportation cost and thereby increases the economic benefits of specialization and trade.

Activity Clustering and Travel

While clustering reduces transportation costs, it also increases the competition for space as space becomes a scarcer commodity. This is true for both the space available for development and the space on transportation facilities available to travelers. Increased demand for space increases the price of space for development and the travel time cost for transportation. These costs act in opposition to the benefits of clustering, so urban densities achieve a balance at the point where the benefits of additional clustering are offset by the additional costs. Changes to the transportation system influence the relative costs and thereby influence the degree of clustering that occurs.

The costs of clustering are also mitigated by a number of ways people have available to minimize the effects of congestion on travel time. These include:

- Use less congested routes.
- Travel during less congested times.
- Chain trips to accomplish more with each trip (e.g. shop on the way home from work).
- Travel to a destination requiring less travel on congested routes.
- Use a transportation mode that is less affected by congestion.
- Substitute communications for travel.
- Move to a location that requires less travel time to accomplish desired activities.

Perhaps it should not be surprising that the ratio of peak period travel costs to income for the Portland area did not change appreciably over time despite rising congestion. Increases in congestion were probably offset by the economic benefits of increased clustering and by the various strategies people used to limit the effects of congestion on travel time.

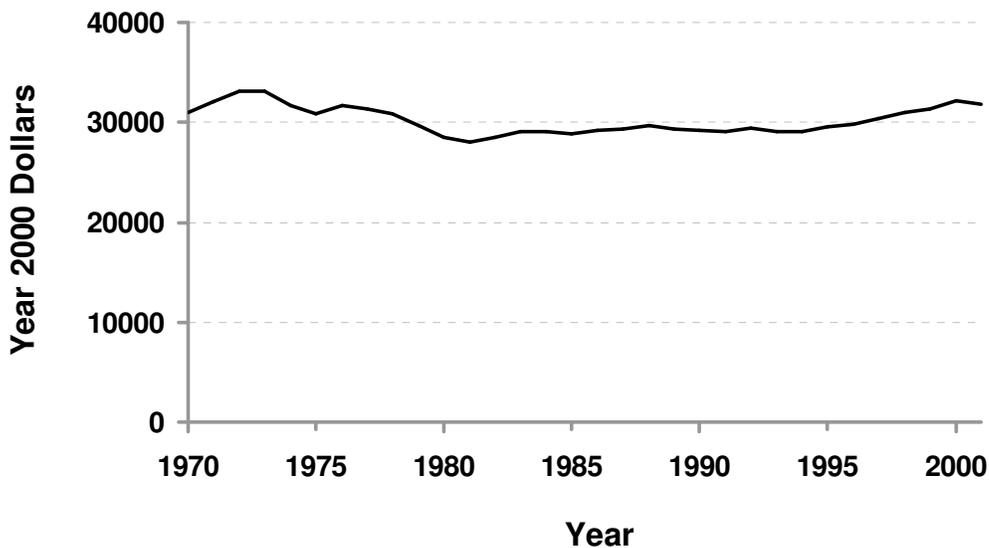
Effect of the Economy on VMT Growth

The growth of travel and the economy since 1970 are linked to demographic, social and economic changes that increased the amount of specialization, trade and economic output. The population of the state grew by 63 percent from 1970 to 2002. Job growth was even greater (128 percent) due to the entry of baby boomers and an increased percentage of women into the labor force as well as to economic factors. Households put more time into paid labor to compensate for declining hourly wages as the country lost higher paid manufacturing jobs overseas and other economic and political pressures drove hourly wages down. Households adjusted to these changes by putting a larger share of their time into specialized paid labor and buying more household products and services. This trend was also encouraged by increasing foreign trade

which lowered consumer goods prices and encouraged greater substitution of purchases for household activities.¹⁹

Not only are more people working today, but many are working more hours, a trend that is contrary to what has occurred in the rest of the industrialized world. According to the Harris Poll, the average number of hours spent working per week in the United States increased from 41 in 1973 to 50 in 1998 where it remained until 2002, when it dropped to 47 hours because of the recession. Workers in the United States worked an average of 171 more hours in 1998 than they worked in 1960, the equivalent of about a month's worth of work. This was accompanied by a relative decline in hourly wages in the United States compared to wages in Europe and Japan.

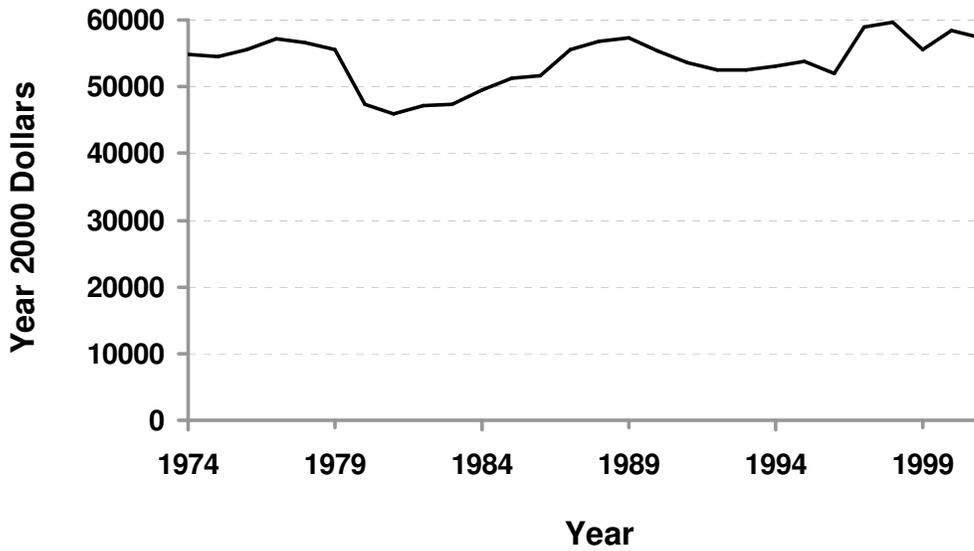
Households increased their working hours in part because of declining hourly wages. Average wage and salary income in Oregon has remained almost constant despite growth in working hours (see Figure 6). Moreover, the trend for most households is somewhat worse because an increased share of income goes to people in the highest income brackets. Since the 1970s, most households experienced little or no economic gain despite increasing the number of paid workers. Figure 7 shows that the median income for 4-person households in Oregon has seen no improvement over the past 30 years.



Sources: Income - Bureau of Economic Analysis; CPI - Bureau of Labor Statistics (Portland area CPI).

Figure 6. Average Annual Wages in Oregon: 1970-2001

¹⁹ As an example, consider two different household responses to declining wages. One household decides to make more household goods to substitute for goods they formerly bought. Another household decides to work more hours to maintain household purchasing power. In general, the household that spends more time in paid labor should be better off economically because they can purchase more goods and services with their wages than they could produce themselves, i.e., most people can buy more clothes with a day's worth of wages than they can sew in a day.



Sources: Income - U.S. Census Bureau, Median Income for 4-Person Families by State; CPI - Bureau of Labor Statistics (Portland area CPI).

Figure 7. Median Income for 4-Person Families in Oregon: 1974-2001

Households in Oregon maintain their standard of living by working more. Of course, more people working more days results in more commuting. But that is only one of the effects of increased work on travel. The larger effects result from increasing specialization and trade as households put more hours into paid labor and fewer into household labor and leisure. This has a chain of effects on travel (Figure 8).

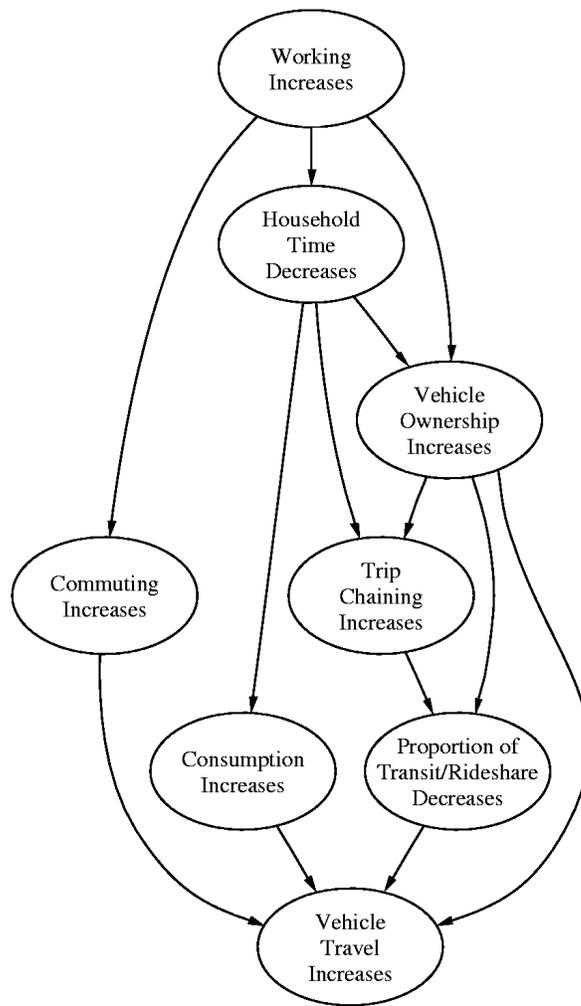


Figure 8. Effects of Changes in Work and Consumption on Travel

Increased work hours result in less time available to do household activities such as caring for children, cooking and cleaning. From 1969 to 1987, the average time that women spent annually on household work declined by 249 hours while men’s household work time increased by 151 hours, resulting in an overall decline of about 70 hours per year per adult.²⁰ As the average time spent on household work declined, purchases towards household services increased. Workers hire others to assume some of the care for their children, purchase more prepared foods, and purchase more cleaning and household maintenance services, among other things. For example, the number of paid childcare employees increased nationally from 190,000 to 468,000 from 1977

²⁰ Juliet B. Schor, *The Overworked American: The Unexpected Decline of Leisure*, Basic Books, New York, 1992, p. 36.

to 1992.²¹ The proportion of household food expenditures spent on eating out increased from 26 percent in 1970 to 38 percent in 1997.²² Nationally, per capita personal consumption expenditures doubled between 1970 and 2000.²³ More purchases resulted in more travel by households and the commercial transport sector. Truck VMT in Oregon grew at a faster rate than overall VMT. From 1980 to 2002, truck VMT doubled while overall VMT grew by 78 percent.

The increase in work and decline of household time has also increased the ownership and use of automobiles and other personal vehicles.²⁴ The increase in travel necessary to maintain households makes it necessary for people to economize on travel time. They do this by increasingly using private vehicles for transportation and by linking other trips with work trips. Using a personal vehicle offers considerable time savings for many people. For example, people who drive or ride in private vehicles spend, on average, half the time on their commutes as people who use public transit.²⁵ By using private vehicles, they can more easily combine other activities with their trips to and from work. Women workers in particular chain together work and non-work trips.²⁶ The increase in the number of vehicles and the increase in trip chaining has an adverse effect on the proportion of trips that involve shared rides or public transportation. All of this increases the amount of vehicle travel.

Comparison of Highway Investment and Economic Growth

Since the rates of growth of VMT and the state's economy are nearly identical, one would expect that congestion growth might have been avoided if a constant proportion of the state's economy were invested in highway expansion. This assumes that the relative costs of expansion remained constant and that expansion was done in a way that supported comprehensive plans and avoided induced travel.

The capital investment in highways since the 1960s was a shrinking proportion of the state economy (Figure 9). During the 1960s, an average of 2.5 percent of total state personal income was spent on highway capital outlay. By the 1990s, the average dropped to 0.8 percent.

²¹ Lynne M. Casper and Martin O'Connell, *State Estimates of Organized Child Care Facilities*, Population Division, U.S. Bureau of the Census, Population Division Working Paper No. 21, March 1998, Washington, D.C.

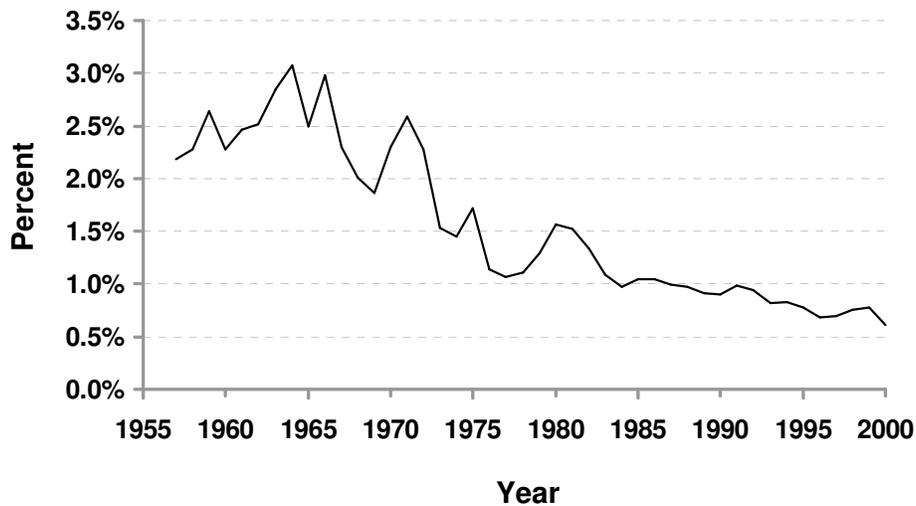
²² Judith Jones Putnam and Jane E. Allshouse, *Food Consumption, Prices, and Expenditures, 1970-1997*, Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture, Statistical Bulletin No. 965, Table 99 – Food expenditures by families and individuals as a share of disposable personal income, 1970-97.

²³ Personal consumption expenditures in 1970 were \$2,317.5 billion in 1996 dollars and population was 205,052,000. In 2000, personal consumption expenditures were \$6,257.8 billion in 1996 dollars and population was 275,372,000. This equals an increase of 2.01. Source: *Economic Report of the President*, Council of Economic Advisors, February 2002, Tables B-2 and B-34.

²⁴ From 1975 to 2001, the number of vehicles per driving-age person in Oregon increased by about 18 percent. In 1975, there were about 1,628,000 motor vehicles registered in Oregon, and in 2001 there were about 3,039,000 registered motor vehicles in Oregon (Source: *Highway Statistics*). The population 16 years and older in Oregon grew from about 1,666,000 in 1975 to about 2,633,000 in 2001 (Source: Oregon Employment Department).

²⁵ Patricia S. Hu and Jennifer R. Young, *Summary of Travel Trends*, 1995 Nationwide Personal Transportation Survey, U.S. Department of Transportation, Federal Highway Administration, December 1999, Figure 11, page 43.

²⁶ Nancy McGuckin and Elaine Murakami, *Examining Trip-Chaining Behavior: A Comparison of Travel by Men and Women*, Federal Highway Administration, one of a series of papers published on the 1995 NPTS, npts.ornl.gov/npts/1995/Doc/Chain2.pdf.



Sources: Personal Income – US Bureau of Economic Analysis; Capital Expenditures - *Highway Statistics Summary to 1995*, Table HF-202C, *Highway Statistics* reports for years 1996-1999, Table HF2.

Figure 9. Percentage of Total State Personal Income Spent on Highway Capital Outlay in Oregon: 1957-2000

The significance of the declining investment rate is seen in the deficit between the increase in major road system VMT and lane-miles. In general, the greater the deficit, the greater the increase in congestion.²⁷ Daily VMT on the major road systems of Eugene, Portland and Salem grew by 43 percent from the year 1990 to the year 2000. Over that same time period, lane-miles grew by 20 percent or 37.5 lane-miles per year. If lane-miles had grown at the same rate as VMT, an annual rate of 80.6 lane-miles per year would have been added, just over twice the actual increase. However, the investment rate in the 1990s was a third of the rate during the 1960s. If spending on capacity in the 1990s had equaled the 1960 rates, the lane-mile deficit probably would not have occurred during that time period.

Contribution of Induced Travel to VMT Growth

These findings raise questions about some popular notions regarding the causes of per capita VMT growth. Some assert that highway construction and suburban sprawl are the principal causes of rising vehicle travel. Induced travel arguments suggest that adding capacity is ineffective because it causes sprawl and induces travel growth that negates the benefits of highway expansion. This is important because transportation policies based on the assumption that highways and sprawl cause travel growth could be very different than policies based on the belief that economic changes are primarily responsible.

²⁷ Schrank and Lomax, *2003 Annual Urban Mobility Report*, pp. 31-33.

The induced travel theory is that demand for travel behaves like demand for most other goods and services - if the cost goes down, people will travel more and if the cost goes up, people will travel less. Declining travel costs may increase travel by encouraging people to make more vehicle trips, make longer vehicle trips, substitute vehicle travel for riding public transportation or walking, or to spread out (sprawl) where they build their homes or businesses. This is consistent with the model shown in Figure 5.

There is no doubt among most researchers of the subject that the induced travel phenomenon is real, but there is little consensus on the magnitude of the effects of adding road capacity.²⁸ Research results vary widely because of varying definitions of induced travel, methods of calculating induced travel, assumptions regarding causal relationships, and limitations in the quality of the data used. Consequently, the research results cannot be directly applied to general transportation policy development or to specific transportation projects. Oregon's unique land use planning laws also make it difficult to apply research results from other areas of the country.

No induced travel studies have been done in Oregon. However, related studies and information cast doubt on the notion that induced travel and sprawl are significant causes of the growth of travel in Oregon over the past 30 years. It is expected, for example, that Oregon's strong land use planning laws have had an influence on curbing sprawl and associated increases in travel. This is borne out by an Oregon study of the effects of highway expansion on land use changes.²⁹

The study compared urbanization trends in 20 Oregon cities with state highway improvements in those cities. It included in-depth case studies of highway projects and changes in land use patterns in six Oregon cities. The case studies examined land use changes using a variety of data and interviews with local focus groups of city and county planning staff, ODOT staff, developers and realtors. The study found that:

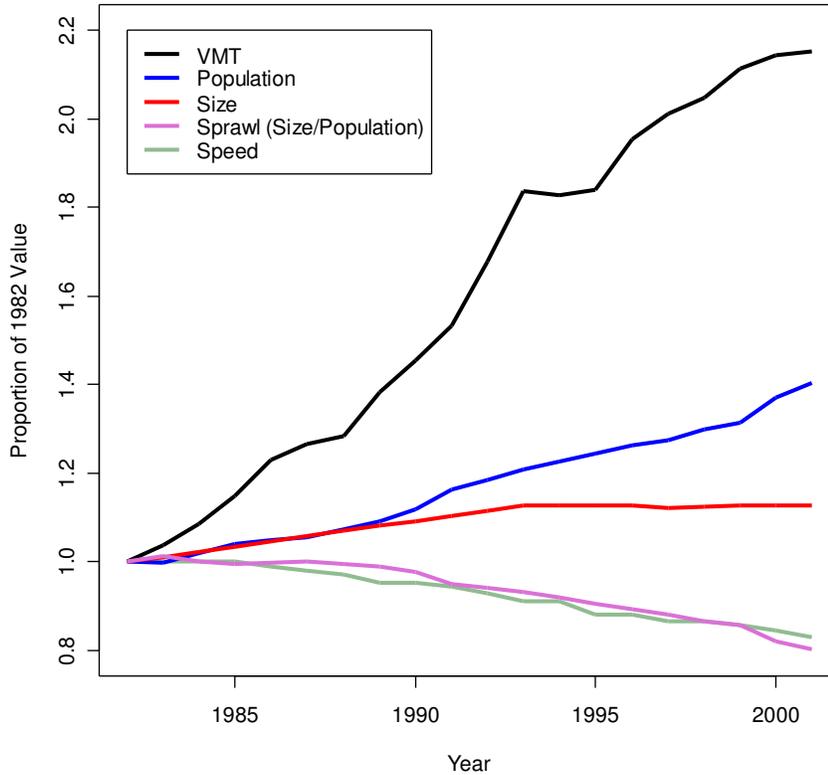
- Developments occurring after highway improvements were generally consistent with the comprehensive plans established before the highway improvements were made.
- None of the highway improvements appeared to be associated with annexations or urban growth boundary (UGB) expansions.
- Development of all types occurring after highway construction was dispersed throughout the communities and was not concentrated around the highway projects.
- No cases were found of major new developments occurring outside UGBs along highways that were expanded.

The sprawl and induced travel explanation of rising VMT in Oregon is also inconsistent with the theory of induced travel. The theory says that induced travel occurs when transportation system improvements reduce the cost of travel. Therefore, if induced travel occurred, evidence of increasing highway speeds would be expected. Although the number of lane-miles of the major road system in the Portland area increased by 58 percent between 1982 and 2001, travel speeds

²⁸ For a good current overview of induced travel research findings see *Working Together to Address Induced Demand*, ENO Transportation Foundation, Washington, D.C., 2002.

²⁹ ECONorthwest and Portland State University, *A Guidebook for Evaluating the Indirect Land Use and Growth Impacts of Highway Improvements*, Oregon Department of Transportation, SPR Project 327, April 2001.

on the major road system decreased continually during that time period. The declining speed trend is shown in Figure 10.



Sources: VMT & Speed - 2003 Urban Mobility Report; Size - FHWA Highway Performance Monitoring System database; Population - Portland State University Center for Population Research & Census and FHWA Highway Performance Monitoring System database.

Figure 10. Portland Area Vehicle Miles Traveled, Speed and Sprawl Trends 1982-2002

If sprawl were a cause of rising VMT, then evidence should show that the population of the Portland area became more dispersed, but instead it became more concentrated. This is also shown in Figure 10. It does not appear likely that sprawl and induced travel due to road widening were responsible for the growth of travel in Oregon. It is more likely that the combination of population growth and increasing amounts of work were responsible.

WHAT TO DO ABOUT CONGESTION

Highway Capacity Expansion

Increasing investment in highway capacity helps to reduce congestion. Urban areas with smaller lane-mile deficits have experienced less growth in traveler delay.³⁰ Congestion on major roads in Oregon has grown, in large part, because traffic has grown as the state's economy has grown, but the portion of the economy reinvested in road system expansion has declined substantially. To a large extent, the mobility that Oregonians have enjoyed has been a result of decisions made decades ago to plan for and build roads to serve future needs. Mobility has declined as surplus capacity has been used up.

The future of congestion in Oregon depends on how Oregonians plan and build road systems for tomorrow. This is not just an issue for the Portland area. It is also an issue for the smaller metropolitan areas and other urban areas that are growing rapidly. These areas need to plan for road systems that will serve the needs of future growth or they will experience future undesirable levels of congestion. They may find their economies are not large enough to offer agglomeration benefits to offset rising congestion levels.

Roadway expansion, however, is unlikely to succeed as the only approach to congestion relief. Only five of 75 urban areas in the country were able to keep the difference between traffic growth and lane-mile growth to less than 10 percent.³¹

There are several reasons why the lane-mile deficit is likely to continue. It is unlikely that investment levels in roadway modernization will approach past levels. This is because the public is unlikely to approve large tax increases and because a large share of future highway expenditures will go towards replacing existing aging roads and bridges. The public has also chosen to limit road expansions because of the amount of land they consume and their impacts on neighborhoods and the environment. Roads become more costly to build as urban areas grow because property values increase, more buildings must be purchased and torn down, and more expensive construction techniques must be used to reduce neighborhood or environmental impacts. Therefore, successful approaches to alleviating congestion are likely to involve the combination of roadway expansion and other complementary actions.

Operational Treatments

A variety of operational treatments can improve roadway performance and reduce congestion and its effects. The effects of five of these were evaluated: ramp metering, traffic signal coordination, incident management programs, high occupancy vehicle (HOV) lanes and public transportation services.³²

³⁰ Schrank and Lomax, *2003 Annual Urban Mobility Report*, pp. 31-33.

³¹ *ibid*, pp. 31-33.

³² *ibid*, pp. 36-50.

The evaluation found that ramp metering, which helps to maintain freeway speeds under heavy traffic loads, reduced delay by an average of about four percent in the 26 urban areas in the country with ramp metering.³³ Traffic signal coordination is estimated to produce an average of about a 1.5 percent reduction in arterial delay in the study areas.³⁴ Incident management programs are estimated to reduce freeway delay an average of five percent in the 56 areas that have incident management programs.³⁵ HOV lanes are estimated to lower delay by about one percent in the eight areas that have them.³⁶ Public transportation services in large urban areas reduced delay by over 16 percent.³⁷ The total annual delay savings for the Portland area was estimated to be over 15,000 hours in 2001. That is about 40 percent of the estimated delay in the area.³⁸

The effectiveness of operational treatments in reducing congestion delay depends on the extent of deployment. It is estimated that full deployment of ramp metering could reduce congestion delay by over 11 percent. Full deployment of traffic signal coordination could reduce delay by about three percent more. Full deployment of incident management could reduce delay by about nine percent. The combined potential reduction from these operational strategies is about 23 percent.³⁹ In comparison, the 2001 level of deployment in the Portland area was estimated to produce about seven percent reduction in delay.⁴⁰

Rail and bus lines on separate rights-of-way reduce travel demand on highways and permit travelers to avoid congestion delays and travel with greater reliability. The Portland metropolitan area is building light-rail lines to relieve congestion in capacity-constrained highway corridors including the I-84, I-5 and US 26 corridors. Investments in public transportation in Portland appear to be successful in the growth of transit ridership and reduction of congestion delay. The last decade has seen passenger miles of travel on public transportation grow faster than VMT on the major road system (Table 1). It is estimated that public transportation services alone in the Portland area reduced congestion delay by an amount equal to about a third of the area's annual delay.⁴¹

³³ David Schrank and Tim Lomax, *The 2003 Annual Urban Mobility Report: Volume 2, Five Congestion Reduction Strategies and Their Effects on Mobility*, Texas Transportation Institute, September 2003. p. 8.

³⁴ *ibid*, p. 11.

³⁵ *ibid*, p. 16.

³⁶ *ibid*, p. 18.

³⁷ *ibid*, p. 22.

³⁸ *The 2003 Annual Urban Mobility Report*. Exhibit A-5, page 67. Annual hours of delay are estimated to be 37,975. Delay reductions due to public transportation are estimated to be 12,820 hours annually. Delay reductions due to other operations programs are estimated to be 2,935 hours annually.

³⁹ *The 2003 Annual Urban Mobility Report: Volume 2, Five Congestion Reduction Strategies and Their Effects on Mobility*. pp. 24-25.

⁴⁰ See note 30.

⁴¹ See note 30.

| Mode | 1990 (thousands) | 2000 (thousands) | Change (percent) |
|---|-----------------------------|-----------------------------|-----------------------------|
| Public Transport (units are passenger miles traveled) | 547 | 952 | 74 |
| Bus | 437 | 624 | 43 |
| Light Rail | 110 | 328 | 198 |
| Roads (units are vehicle miles traveled) | 19,398 | 26,254 | 35 |
| Freeway | 7,490 | 9,974 | 33 |
| Other Principal Arterial | 3,177 | 5,328 | 67 |
| Other Road | 8,197 | 10,952 | 34 |

Source: Daily passenger miles traveled computed from annual data provided by Tri-Met at <http://www.trimet.org/inside/ridership.htm>. Highway and road VMT from ODOT HPMS databases.

Table 1. Daily Portland Area Travel by Private and Public Transportation

Regulatory and Policy Tools

Land use planning provides other tools for managing the effects of congestion. Zoning and other land use regulations can improve travel speeds by:

- Managing the distribution of development so that development patterns more closely match the capabilities of the transportation system to serve them.
- Facilitating the construction of collector-distributor roads to serve development and facilitate circulation between nearby land uses and reducing traffic on arterials.
- Managing the locations of access points to arterials and interchange areas to reduce the effects of driveway traffic on congestion.
- Encouraging higher density development in areas where high capacity public transportation exists or is planned.
- Planning and preserving corridors for future major road construction to improve the likelihood that roads can be built in the future when they are needed.

Still other land use policies can reduce the impact of congestion on the public by reducing the length of travel in congestion. Compact urban areas and planning that places destinations near each other can reduce trip lengths and this can help offset the effects of rising congestion on travel time and delay. This appears to be happening in the Portland-Vancouver area. Although roadway congestion in the area has grown much faster than average for an area of its size, congested travel distances have grown more moderately, with the result that traveler delay is about average and travel times are below average.

Value pricing (also known as congestion pricing) offers another approach to managing congestion. With value pricing, special highways or highway lanes are available to road users who pay a toll which varies with the congestion level. When demand is low, the price is low and when the demand is high the price is high. By adjusting price in this way, the level of use is managed to keep traffic flowing smoothly. Value pricing offers people in a hurry the option of spending money to save travel time. For example, a parent who is rushing to the daycare provider to avoid paying a dollar a minute late fee might welcome such an option. The price is set at a level that optimizes road performance. One value pricing approach tries to alleviate fairness concerns by compensating those who travel in the unpriced highway lanes with revenues generated from the priced lanes.

Another pricing approach is to replace some of the fixed costs of driving with costs that vary with the number of miles driven. For example, automobile insurance can be paid on a per mile basis rather than on an annual basis. Unlike value pricing, such programs do not vary the cost with congestion. Instead they reduce congestion by reducing vehicle travel. It is estimated that a national system of mileage-based automobile insurance could reduce driving by about nine percent.⁴² An Oregon law adopted in 2003 encourages insurance companies to offer pay-as-you-drive insurance as an option.

Alternative approaches to congestion relief are to increase highway throughput by changing the characteristics of highways in more fundamental ways. Car-only highways can be built with narrower lanes and lower clearances to increase the number of automobiles and other light vehicles that can occupy the space. This is particularly beneficial in tunnels or on structures to reduce construction costs. For example, the Cofiroute tunnels under construction in Paris double-deck six lanes for passenger vehicles with 10-foot wide lanes and 8.5-foot high clearances.⁴³ Separate truck and passenger vehicle highway lanes can also make automated highways safer and more effective. In the longer run, automated vehicle and highway systems might substantially increase highway capacities. Although the benefits could be substantial, the technical and institutional challenges are substantial as well. This is a growing area of investigation and may yield some surprising results in the next several decades.

CONCLUSIONS AND RECOMMENDATIONS

The causes of congestion on Oregon roadways are complex. There is no single action that will reduce congestion to acceptable levels. Understanding the effects of the economy on travel and congestion is important to help target policies and limited resources towards actions that do the most good. This is also important to help avoid policies and actions that are counterproductive or that do not act in the best interests of Oregonians.

This study only addresses the economic connections at a general level. However, the following findings provide useful guidance for transportation and land use planners and decision-makers:

⁴² Aaron S. Edlin, *Per-Mile Premiums for Auto Insurance*, Institute of Business and Economic Research Economics Department Working Papers, University of California, Berkeley, CA, Paper E02'318.

⁴³ Peter Samuel, *How to 'Build Our Way Out of Congestion': Innovative Approaches to Expanding Urban Highway Capacity*, RPPI Policy Study 20, Reason Foundation, 1999.

- ***Travel in the future is likely to grow as the state's economy grows, but the nature of economic growth may change.*** On average, every new job in Oregon adds about 15,500 vehicle miles annually. Every \$1,000 increase in total state personal income adds about 360 VMT annually. As the economy grows in the future, similar changes can probably be expected. How the economy will grow may be different, however, and the social and economic changes that resulted in the shift of household time into paid labor may not continue to the same degree in the future. For example, there has been very little change in the female labor force participation rate since 1993.
- ***Congestion is expected to get much worse if economic growth continues to greatly exceed capital investment in the road system.*** To a large extent, the levels of mobility and accessibility enjoyed by Oregonians over the past three decades is a result of highway investments made at the beginning of that time. Since then, the rate of investment dropped and lagged growth of the economy and VMT significantly. Congestion increased as the capacity of the system was used up and not replaced.
- ***It is possible to increase the capacity of existing road space with traffic operations programs and improvements.*** Evidence is showing that operations programs such as ramp metering, incident management and traffic signal coordination can greatly reduce travel delay due to congestion and can improve travel time reliability. It is estimated that full deployment of operation programs in large urban areas can reduce delay by about 23 percent. These programs are cost effective means of reducing the impacts of congestion.
- ***Public transportation services can significantly reduce the impacts of congestion.*** It is estimated that public transportation services alone reduce delay in the Portland area by an amount equal to about a third of the area's annual delay. Public transportation offers the greatest congestion relief where it is provided on exclusive rights-of-way in congested corridors. The benefits of public transportation are increased when land development is coordinated with public transportation services.
- ***Land use policies can reduce the impacts of congestion.*** Some land use policies can help reduce congestion by making the road system work more efficiently. An example is managing the location of activities so that the distribution and routing of trips more closely matches the availability of transportation services. Other examples include developing collector-distributor roads in conjunction with land developments so that traffic can be directed to enter the arterial system where disruptions of flow will be least impacted, and managing accesses to help reduce disruptions to arterial flow. In addition, maintaining compact urban areas can reduce trip lengths so that shorter distances offset declining travel speeds.
- ***Since congestion is most likely to get worse in the future, it is important to recognize how people cope with congestion and take actions that improve their ability to cope.*** Helping people reduce the impacts of congestion on their lives requires knowledge about how people manage the conflicting time demands of their jobs, households and travel. The experience of the past several decades shows that people substantially limit the effects of rising congestion on their travel time budgets through their own actions. The availability of choices allows them to shift routes, change travel times, chain trips, change how they travel, and change where they live or work. Failure to recognize the significance of these coping strategies

could result in policies that are counterproductive. For example, efforts to reduce automobile commuting need to recognize that many people (particularly working women) combine commuting and household trips to help balance the time demands of work, home, children and travel.

- ***Congestion relief should be directed towards activities that provide the most benefits to Oregonians.*** Different activities are affected to varying degrees by congestion. Congestion levels that shoppers and retail storeowners are willing to tolerate may be unacceptable to some manufacturers and other businesses. With limited dollars available to address congestion problems, it is important to do analysis that goes beyond simply estimating how vehicles are affected by a proposed improvement. It is also necessary to estimate how different households and businesses will be affected. The ability to direct congestion relief would also be improved by offering value pricing options in congested freeway corridors.
- ***Directing congestion relief requires the use of integrated transportation, economic and land use analysis tools.*** Targeting congestion relief to get the most benefit requires analysis that identifies who is likely to benefit from potential improvements and how much they will benefit. This is a significant undertaking because of the complex relationships between the economy, transportation and land use. ODOT has worked for several years to develop integrated models to be used for this type of analysis. The first generation statewide integrated model was used to analyze the economic implications of Oregon's cracked bridge problem. A second-generation statewide model permits more detailed analysis and will soon be tested for use. The regional planning agency for the Portland area (Metro) is also using a land use model in conjunction with its economic and transportation models to evaluate the effects of transportation and land use policies for the Portland metro area. It is important to continue to develop and refine better analysis tools.
- ***Better data is needed to improve our understanding of congestion and how to address it.*** Much of what can be analyzed about congestion comes from traffic counts and roadway inventory data. The understanding of congestion and its effects can be improved by improving the quality and frequency of traffic counts, and by consolidating traffic count and traffic flow information from sources such as the traffic operations center in Portland and urban traffic signal controllers. Periodic commercial and household travel surveys are needed to understand how households and businesses are responding to changes in congestion. It is also important to gather and analyze data on traffic incidents and the effects on travel delay since these are estimated to be responsible for a large portion of congestion delay.

Although the statistics on the growth of congestion on Oregon's freeways and other major roads look grim, the ability of the Portland area to avoid increased travel costs relative to income is promising. Oregon cannot avoid large increases in congestion without substantially increasing investment in its major road system. However, congestion is not going to be managed successfully by road building only. Improving efficiency through operations improvements and providing alternative travel options such as public transportation are important as well.

Success will depend on how well the transportation system is planned today and whether land use and transportation systems are planned and managed to reinforce each other. Policy-makers must make careful choices about how and where resources are spent. Making effective choices

requires an understanding of how travel affects people's lives and the economy and how people respond to different public policy actions, improved data collection and analysis, and using tools that enable the evaluation of public-policy choices.

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APPENDIX A CONGESTION TRENDS

This appendix presents an overview of various indicators of congestion in Oregon. These indicators are based on information drawn from published sources such as the Federal Highway Administration's (FHWA) *Highway Statistics* reports and the Texas Transportation Institute's *Urban Mobility Report* (UMR). It also draws from various published and unpublished databases compiled by ODOT and other state and local agencies including:

- Estimates of total statewide vehicle miles traveled
- Inventories of state highway traffic volumes and vehicle miles traveled
- Inventories of state highway mileage and features such as the number of travel lanes
- Inventories of a sampling of state and local roads used for the Highway Performance Monitoring System (HPMS)⁴⁴
- The Oregon Population Survey, a multi-agency biennial survey of Oregon Households
- Estimates of congestion on state highways calculated from data on state highway traffic volumes and characteristics for the congestion monitoring program

Several measures related to traffic congestion were developed based on these information sources and are presented in this chapter. They include:

- Public Perceptions of Traffic Congestion
- Vehicle Miles Traveled
- Traffic Flow Density
- Volume-to-Capacity Ratio
- Peak Hour Spreading
- Travel Time
- Urban Mobility Report Measures
- State Highway Congestion Inventory and Oregon Highway Plan Mobility Measures

PUBLIC PERCEPTIONS OF TRAFFIC CONGESTION

Public perceptions of congestion often have more influence on public decisions than do more objective measures, but the subjective nature of public opinion makes comparisons across geography and time difficult. For example, nearly the same proportions of people in Central Oregon view congestion to be a serious problem as do those in the Portland metropolitan area (34 percent vs. 36 percent). Yet objective measurements of traffic volumes and volume-to-capacity ratios indicate greater stresses on the Portland metropolitan area highways and streets

⁴⁴ The Highway Performance Monitoring System is a Federal Highway Administration program initiated in 1978 to provide a national highway database. The federal government uses information from the database for strategic planning, reporting to Congress and apportioning highway trust funds. Much of the data published in FHWA's *Highway Statistics* series of reports comes from the HPMS.

than those in Central Oregon. Similarly, a higher percentage of long-term residents think congestion is a serious problem (34 percent) than do people who recently moved to Oregon (26 percent).⁴⁵ Often these emigrants from larger metropolitan areas have experienced much more dramatic congestion in the cities and regions they left behind than native or long-term Oregonians have witnessed in this state.

Despite differences in perception, Oregonians think that traffic congestion has gotten worse over the past decade (Table A-1). In 1990, about half of Oregonians thought congestion was a moderate or serious problem and less than a quarter thought that traffic congestion was a serious problem. Now about two-thirds believe traffic congestion is a moderate or serious problem and 29 percent believe that it is a serious problem. Portions of the report which follow support these perceptions with objective measurements of congestion.

| Magnitude of Problem | Percentage of Respondents Agreeing | | | | |
|----------------------|------------------------------------|------|------|------|------|
| | 1990 | 1996 | 1998 | 2000 | 2002 |
| Serious Problem | 22 | 26 | 25 | 33 | 29 |
| Moderate Problem | 32 | 37 | 32 | 34 | 36 |
| Small Problem | 46 | 37 | 44 | 33 | 35 |

Source: Northwest Research Group, Inc. *Oregon Progress Board 2002 Oregon Population Survey*, PowerPoint presentation. Oregon Office of Economic Analysis, January 2002, Slide 17, http://www.oea.das.state.or.us/ops/presentation_05.ppt

Table A-1. Oregonians' Perceptions of Traffic Congestion

These statistics are from the Oregon Population Survey, a statewide telephone survey of a randomly selected sample of Oregon households done every two years. The Oregon Progress Board, ODOT and other state agencies collectively participate in developing the survey. Survey respondents are asked questions on a number of different topics related to services that the state provides such as health care, employment, children's services, education, land use and transportation. The first survey was administered in 1990 and the most recent one in 2002, although the . Information on the Oregon Population Survey is available at the following Internet address: <http://www.oea.das.state.or.us/ops/ops.htm>

A survey was conducted of over 1800 shippers and motor carriers in the state to gauge their satisfaction with Oregon's freight transportation system.⁴⁶ They were asked to identify problems that they experience such as infrastructure problems (e.g. rough roads, ruts), congestion, regulations (e.g. speed limits, weight restrictions), other drivers, and other problems (e.g. weather-related safety problems, road construction). Overall, 14 percent of the identified

⁴⁵ Kanhaiya L Vaidya, *2000 Oregon Population Survey Summary of Findings* (Oregon Department of Administrative Services, January 12, 2001).

⁴⁶ Oregon Department of Transportation, *Preliminary Results: Statewide Shipper/Motor Carrier Survey*. 2001.

problems were congestion related. For the largest firms having 200 or more trucks, 32 percent of the identified problems were congestion related.

VEHICLE MILES TRAVELED

Vehicle miles traveled (VMT) is a common measure of total travel demand by motorists. VMT is typically defined as the total number of miles traveled by all vehicles on roadways during a given period. It is commonly reported on an annual or daily basis. Daily vehicle miles traveled are commonly referred to as DVMT. ODOT prepares several estimates of VMT for various purposes. Annual total VMT on all roads in the state is estimated from motor fuel sales and weight-mile tax records and is used to estimate and project revenues. Annual VMT on state highways is developed from traffic counts at over 5,000 locations on the state highway system and is used for estimating and projecting travel demand on the state highway system. Estimates of travel on state highways and local roads are also prepared from the HPMS sample data. These data are reported in the FHWA annual *Highway Statistics* reports. Finally, VMT for various types of travel (e.g. commuting) is estimated using urban and statewide travel models.

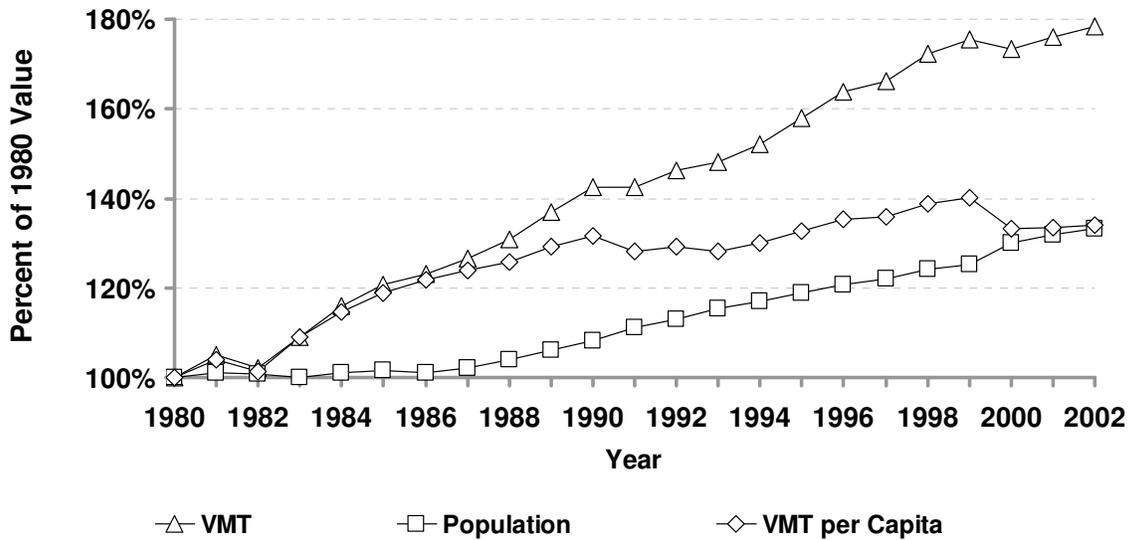
VMT is often presented in terms of the average number of vehicle miles traveled per person (VMT per capita). This is calculated by dividing total VMT by total population. Note that when VMT per capita is calculated this way, it does not measure how much the average person travels because the VMT estimates include all travel in and through an area, not just the passenger travel of people living in the area. Rural counties tend to have higher rates of VMT per capita in part because through traffic to and from more populous urban counties is often a significant proportion of total VMT.

Figure A-1 shows changes in population, VMT and VMT per capita in Oregon since 1980. Population and vehicle travel changed little from 1980 to 1982 due to an economic recession. From 1982 to 1987, VMT grew as the state's economy recovered but population remained stable. This resulted in a high rate of growth of per capita VMT for that period compared to the average for the entire period between 1980 and 2002.

After 1987, Oregon's population began to grow at a fairly constant rate of 1.7 percent per year while VMT continued to grow at a steady pace. Consequently, per capita VMT continued to grow but at a declining rate compared to the previous five years. Between 1990 and 1993, the rate of VMT growth slowed to about the rate of population growth so per capita VMT changed little over that time period. Per capita VMT began growing again after 1993 as VMT grew faster than population. In 2000, VMT dropped and per capita VMT dropped even more. This may have been a response to large increases in gas prices and a slowing economy.

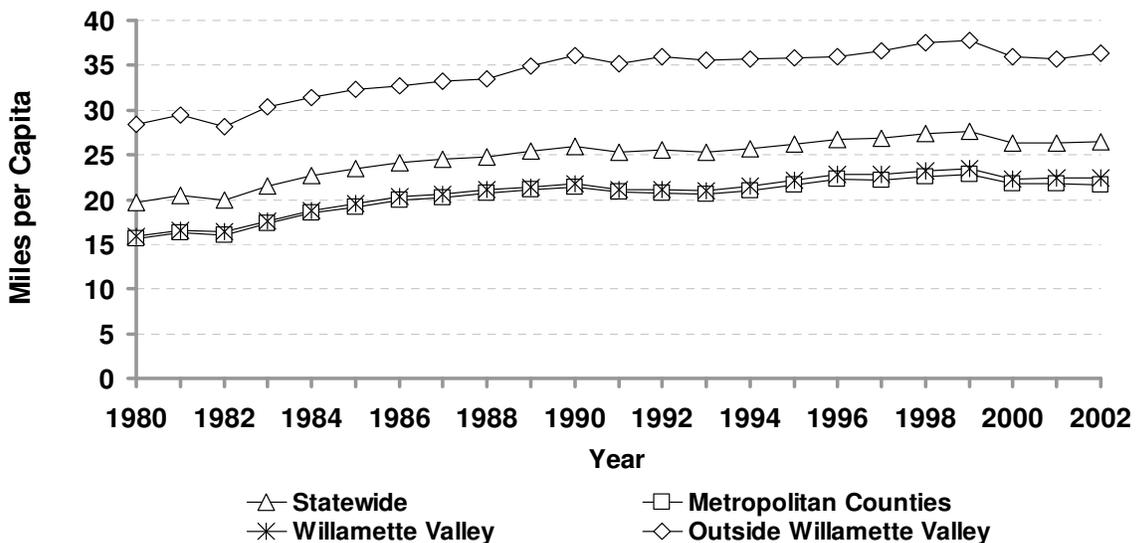
Figure A-2 shows changes in daily per capita VMT for different regions of the state. Per capita VMT is highest outside of the Willamette Valley because the population is more dispersed in those areas and because much of the travel in and through these areas comes from or is destined for the Willamette Valley. Per capita VMT in the Willamette Valley and in metropolitan counties is almost the same because most of the metropolitan population in the state is within the Willamette Valley and most of the Willamette Valley's population is located within metropolitan

counties. The statewide average is more like that of the Willamette Valley than the rest of the state because about 70 percent of the state's population and 60 percent of the VMT are in the Willamette Valley.



Source: VMT-ODOT Finance Section; Population-Portland State University Center for Population Research & Census

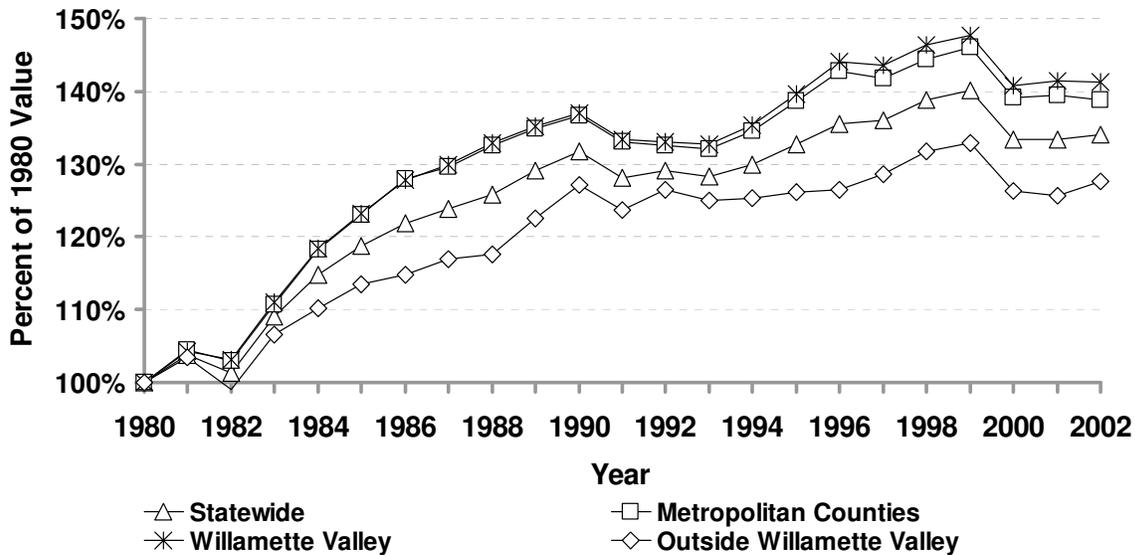
Figure A-1. Statewide VMT, Population and VMT per Capita 1980-2002, Indexed to 1980 Values



Sources: VMT – ODOT Finance Section and Transportation Data Section; Population – Portland State University, Center for Population Research and Census.

Figure A-2. Daily VMT per Capita, State and by Selected Regions: 1980-2020

Figure A-3 shows the growth of VMT in the state by region where VMT after 1980 is compared to a base value of 100 percent for 1980. Although Figure A-2 shows that per capita VMT outside is greater than it is inside the Willamette Valley, Figure A-3 shows that per capita VMT has been growing at a faster rate within the Willamette Valley. The graph also shows that the per capita VMT grew more slowly outside the Willamette Valley after 1990. These changes were probably due to the greater rate of economic growth within the Willamette Valley.



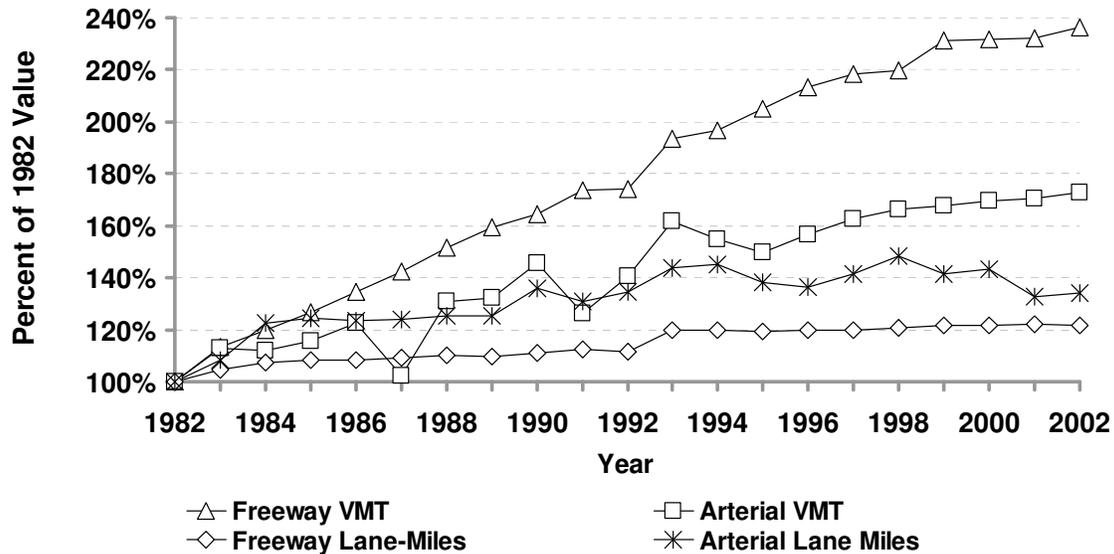
Source: VMT – ODOT Finance Section and Transportation Data Section; Population – Portland State University, Center for Population Research and Census.

Figure A-3. VMT per Capita: 1980-2002, Indexed to 1980 Values

TRAFFIC FLOW DENSITY

VMT and per capita VMT are measures of roadway use, not congestion. VMT can, however, be used as part of a simple congestion indicator by comparing it with roadway lane-miles. These data are collected for a statistical sample of all roadway types (e.g. interstate highway, other freeways and expressways, other principal arterials, minor arterials) as part of the HPMS inventory process. The sample data are expanded based on the sampling frequency to provide estimates of conditions for each roadway type. This sampling approach to roadway data gathering is a cost-effective way of estimating roadway conditions compared to the expensive alternative of inventorying the entire road system. However, the sampling process increases the uncertainty of the estimates as annual fluctuations which stand out from the longer-term trends.

Figure A-4 compares changes in VMT and lane-miles for freeways and other arterial roads.⁴⁷ Over the period from 1982⁴⁸ to 2002, the rate of VMT growth on urban freeways was over six times greater than rate of growth of urban freeway lane-miles. Growth in VMT on other urban arterials also outpaced growth in urban arterial lane-miles but by a modest amount.



Sources: ODOT Finance Section and Transportation Data Section

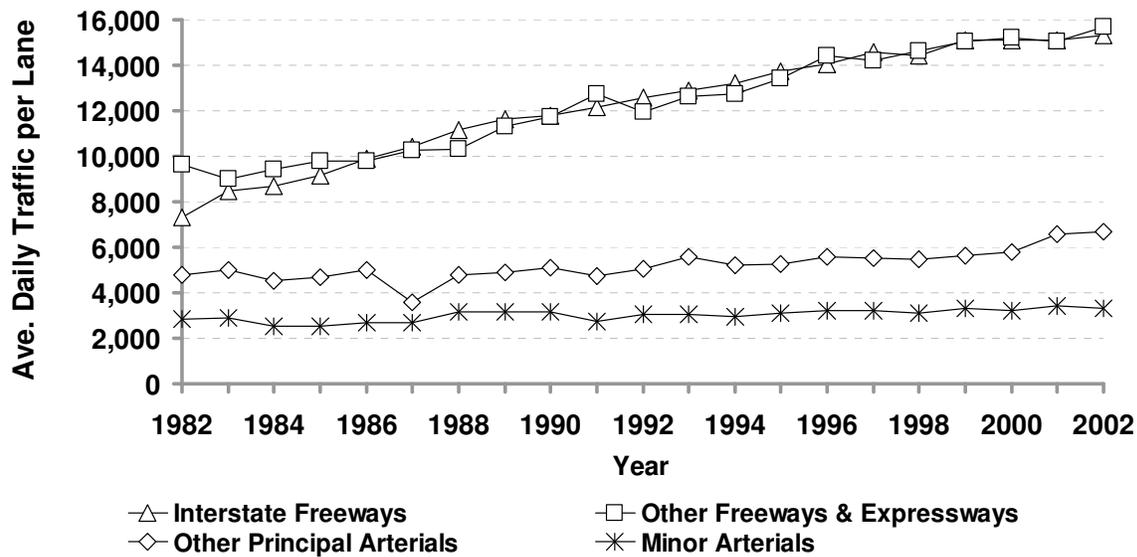
Figure A-4. Urban Freeway & Arterial VMT and Lane Miles in Oregon: 1982-2002, Indexed to 1982 Values

Average daily traffic per lane, a measure of traffic flow density, is determined by dividing daily VMT by lane-miles. Figure A-5 shows the average daily traffic per lane for urban freeways and for other urban arterials. The rates for urban freeways and expressways are much higher than for other urban arterials because a freeway lane can carry more than twice as much traffic as an urban arterial.⁴⁹ More importantly, freeway and expressway traffic density has grown at a rapid and sustained rate since 1982 - 3.4 percent per year vs. 1.7 percent per year for other principal arterials. This is a consequence of the greater rate of traffic growth on freeways than other arterials as well as the larger gap between traffic growth and added capacity for freeways than other arterials.

⁴⁷ Lane-miles measures the miles of traffic lanes. For example, four miles of a four-lane highway is sixteen lane-miles.

⁴⁸ The analysis period starts in 1982 because lane-mile data is not available for prior years.

⁴⁹ The *2000 Highway Capacity Manual* identifies the ideal capacity of a freeway lane as 2300 passenger cars per hour per lane. The ideal capacity of an arterial lane is 1900 passenger cars per hour of green time per lane, but since the green time under good circumstances might only be half the time, the capacity is more like 950 passenger cars per hour or about 40 percent of the capacity of a freeway lane.



Source: ODOT Finance Section and Transportation Data Section

Figure A-5. Density of Traffic on Urban Freeways and Arterials in Oregon: 1982-2002

VOLUME-TO-CAPACITY RATIO

The measure of daily traffic flow density just presented has some limitations. First, it does not recognize that roadway sections having the same number of lanes can have different capabilities (capacities) for carrying traffic. Differences can be caused by topography, roadway geometry or types of traffic using the roadway. The capacity of a road segment is the maximum volume of traffic that can pass through the section on a sustained basis and is typically reported in terms of vehicles per hour. The second limitation is that daily traffic flow density does not reflect the variations in traffic flows and congestion that occur on different days of the year and at different times of the day.

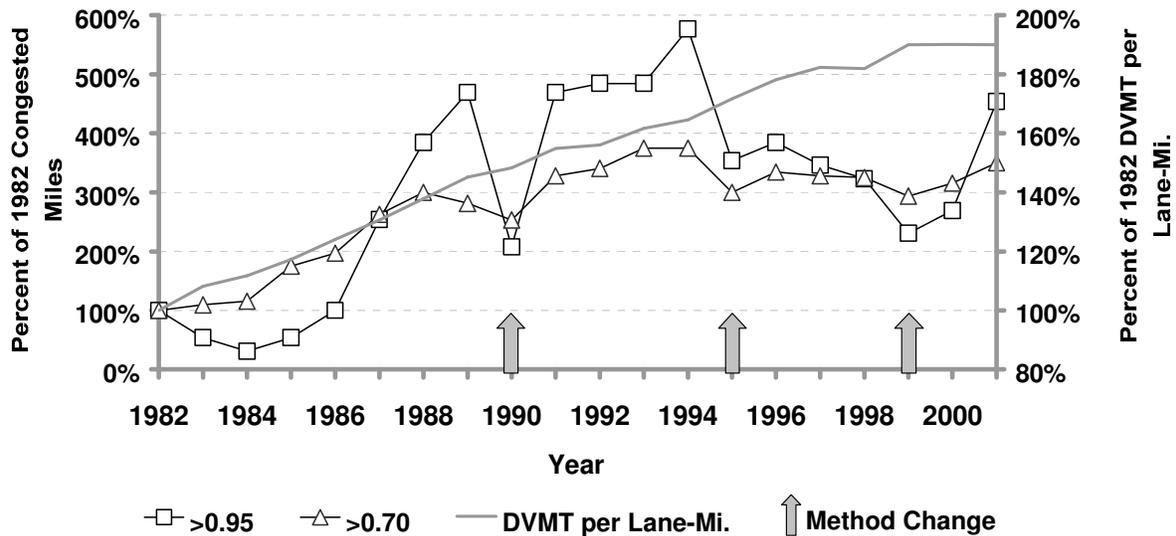
These limitations are overcome by comparing peak-hour traffic volumes to roadway capacities. This measure is called the volume-to-capacity ratio, or v/c. The v/c indicates how close a roadway is operating to the threshold between smooth traffic flow and chaotic (stop-and-go) traffic flow during ordinary peak-hour traffic conditions. For example, a v/c ratio of 0.8 indicates that the road has a reserve of about 20 percent of its capacity to handle more extreme traffic fluctuations.

Volume-to-capacity ratios are typically reported for the weekday peak-hour volume or the 30th-highest hourly volume of the year. In urban areas, where the highest average hourly volumes occur during the afternoon peak commute times (around 4 p.m. to 6 p.m.), the peak-hour volume and the 30th hour volume are about the same. They are typically about 11 percent of the average

daily traffic volume when congestion is slight. In most rural areas, peak (30th hour) volumes occur on weekends (including Friday evenings) and are typically about 15 percent of the average daily traffic volume.⁵⁰

HPMS-derived v/c data are reported as miles of roadways of each functional class that fall within several v/c ranges.⁵¹ For the purpose of this report, data are presented for the number of highway miles at v/c above 0.70 and the number of miles at v/c above 0.95. The 0.70 ratio generally corresponds to the point where travel speeds begin to drop noticeably below free flow speeds. The 0.95 ratio identifies roadway sections that are approaching capacity and experience significant queuing and delay.

Figure A-6 shows v/c trends for urban freeways in Oregon using HPMS data reported in FHWA *Highway Statistics* publications. Caution needs to be applied in interpreting this graph. The HPMS methods for calculating v/c have changed over time so the measures are not comparable before and after each change in calculation methods.



Source: ODOT Transportation Data Section

Figure A-6. Freeway Volume/Capacity Ratio Trends Showing Effects of Changes in Calculation Methods

The effects of the methodological changes can be seen in Figure A-6. In each year a change was made (1990, 1995, 1999) there is a marked drop in v/c. It is unlikely that these drops were due to

⁵⁰ Institute of Transportation Engineers, *Traffic Engineering Handbook*, 4th ed., (Prentice Hall, Englewood Cliffs, 1992) 51.

⁵¹ The v/c data have been reported consistently for many years in five categories: <0.21, 0.21-0.40, 0.41-0.70, 0.71-0.95, >0.95. In 1989, the 0.71-0.95 category was split at 0.80.

reduced demand or increases in physical capacity because the trend in urban freeway traffic density (DVMT/lane-mile) rose during those years. Instead, what happened in 1995 and 1999 is that changes in the methods of estimating freeway capacity had the effect of increasing capacity estimates. This then lowered the estimates of volumes exceeding the v/c thresholds. The drop in 1990 corresponds to a change in the software used to calculate capacities but it is unknown how that might have affected v/c calculations. The net effect of these changes was to depress the apparent increases in v/c over time. If a consistent methodology had been applied over time, the percentage increase in congested mileage would be much greater than the 300 to 400 percent increase shown in Figure A-6.

PEAK HOUR CONGESTION AND PEAK PERIOD SPREADING

As metropolitan areas grow and become more congested, peak periods of congestion last longer. This peak-period spreading occurs because traffic queues form and take time to dissipate. People also adjust their departure times to avoid the worst of the congestion

The extent of peak-period spreading can be estimated from traffic data collected at automatic traffic recorders (ATRs) located around the state. The percentage of the average daily traffic occurring during the peak hour is estimated from the hourly traffic counts made continuously at the ATRs. An estimate of peak-period spreading can be calculated by comparing the percentage of traffic occurring during the peak hour with the percentage that might be expected to occur during the peak hour if congestion were slight or nonexistent.⁵² The difference provides a proxy for the amount of traffic that is shifted out of the peak hour. Table A-2 shows the percentage of peak-period traffic demand that is not accommodated in the peak hour for fifteen ATRs located in or near the state's metropolitan areas.

Table A-2 suggests that the peak period has been getting longer over the last five years on interstate highways in the Portland metropolitan area as increasing proportions of peak period demand cannot be accommodated during the peak hour. Greater amounts of spreading are occurring on freeways leading into the central city area. By the year 2000, about a third of the peak period travel on I-84 shifted out of the peak hour.

It is also notable that a significantly greater amount of peak period shifting is occurring at the ATRs in the Medford area than in Salem or Eugene. This probably reflects the heavy reliance on I-5 for intraurban north-south travel and the concentration of the metropolitan area's commercial activities along Crater Lake Highway.

⁵² Eleven percent, see previous section.

| ATR # | Route | Location | 1998 | 1999 | 2000 | 2001 | 2002 |
|--------|-------|--|------|------|------|------|------|
| 03-011 | I-5 | 0.6 mile north of Baldock Rest Area | 15 | 17 | 16 | 17 | 18 |
| 03-016 | I-205 | 1.3 miles east of I-5 | 20 | 22 | 22 | 23 | 24 |
| 26-002 | US-26 | US 26 at Vista Ridge Tunnels, in Portland | 28 | 28 | 29 | 31 | 29 |
| 26-004 | I-5 | I-5 on Interstate Bridge, north of Portland | 26 | 28 | 29 | 30 | 28 |
| 26-005 | I-405 | I-405 at southerly junction on I-5, in Portland | 24 | 26 | 27 | 25 | 28 |
| 26-015 | I-84 | I-84, 0.9 mile E. of I-5 | - | 34 | 34 | 34 | 34 |
| 26-014 | I-84 | I-84, at N.E. 53rd Avenue Undercrossing | 30 | 32 | 32 | 32 | 32 |
| 26-016 | I-5 | 1.1 miles north of S.W. Terwilliger Blvd., in Portland | 22 | 24 | 25 | 23 | 24 |
| 26-018 | I-205 | 0.2 mile S. of S.E. Washington St. undercrossing | 25 | 28 | 30 | 29 | 30 |
| 26-019 | I-5 | 0.03 mile south of N. Ainsworth Street undercrossing, | 28 | 28 | 29 | 29 | 29 |
| 26-022 | I-205 | 0.9 mile south of US 26 | 23 | 25 | 26 | 26 | 28 |
| 26-024 | I-205 | Government Island | 13 | 15 | 15 | 16 | 17 |
| 26-026 | I-5 | Marquam Bridge, in Portland | 24 | 25 | 27 | 26 | 27 |
| 26-027 | I-405 | Near West Fremont Bridge Interchange, in Portland | 15 | 17 | 20 | 22 | 23 |
| 24-004 | OR-22 | 0.9 mile east of Salem | 5 | 7 | 7 | 7 | 8 |
| 20-008 | I-105 | 0.70 mile west of I-5, in Eugene | 7 | 8 | 8 | 8 | 8 |
| 15-017 | OR-62 | 0.1 mile northeast of Biddle Road Overcrossing | 8 | 10 | 12 | 12 | 14 |
| 15-019 | I-5 | South approach of Medford Viaduct | 14 | 15 | 15 | 14 | 17 |

Note: In 1998, ATR #26-015 replaced another ATR (#26-013) located about 0.4 miles to the east

Source: Data from ODOT Transportation Data section, analysis by Transportation Planning Analysis Unit

Table A-2. Percentage of Peak Period Traffic Not Accommodated in the Peak Hour

URBAN MOBILITY REPORT FINDINGS

The Texas Transportation Institute publishes an annual Urban Mobility Report (UMR) report of congestion trends in 75 U.S. urban areas. The latest report covers the period between 1982 and 2001. Three urban areas in Oregon are included in the study: Portland (including Vancouver, WA), Salem-Keizer and Eugene-Springfield. (Hereafter these areas are referred to as Portland, Salem and Eugene for simplicity.)

The UMR estimates a number of congestion measures from data collected for the Federal Highway Administration HPMS. The HPMS data is an inventory of traffic volumes and roadway characteristics for public roads in each state. Some characteristics are inventoried for all roadway sections and some are inventoried for a sample chosen using statistical methods to represent conditions on the entire public roadway system. In Oregon, 2,200 roadway sections are sampled on state highways, local roads and federal roads. A third of the roadway sections are inventoried each year so that the entire sample is inventoried every three years.

By its nature, the HPMS data is subject to sampling errors as well as measurement errors. These errors are not very important when the results are aggregated over many places, but they become quite apparent when looking at the data for individual urban areas. This can be seen in Figure A-7 which shows the estimates of annual per capita delay for large urban areas.

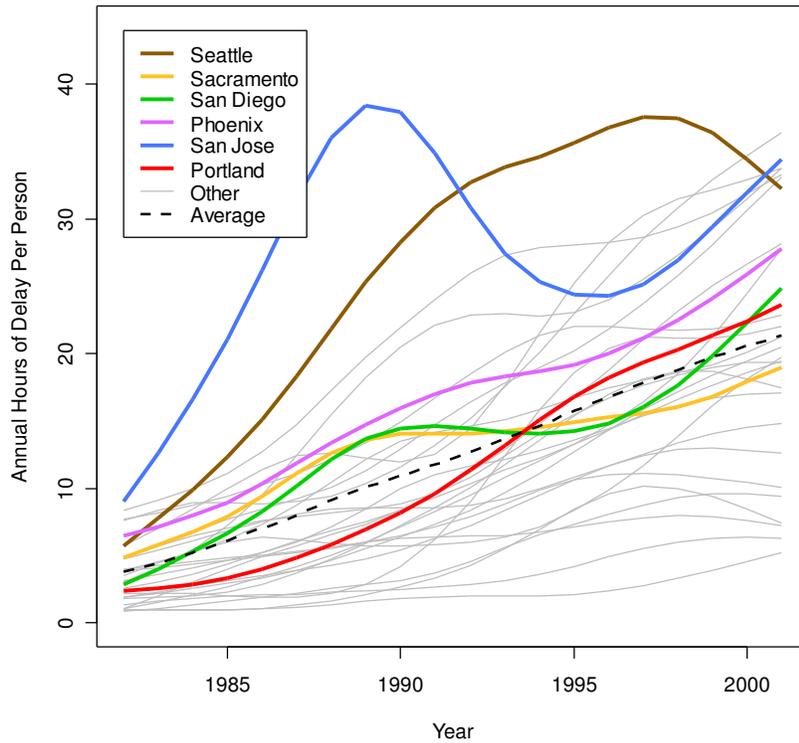
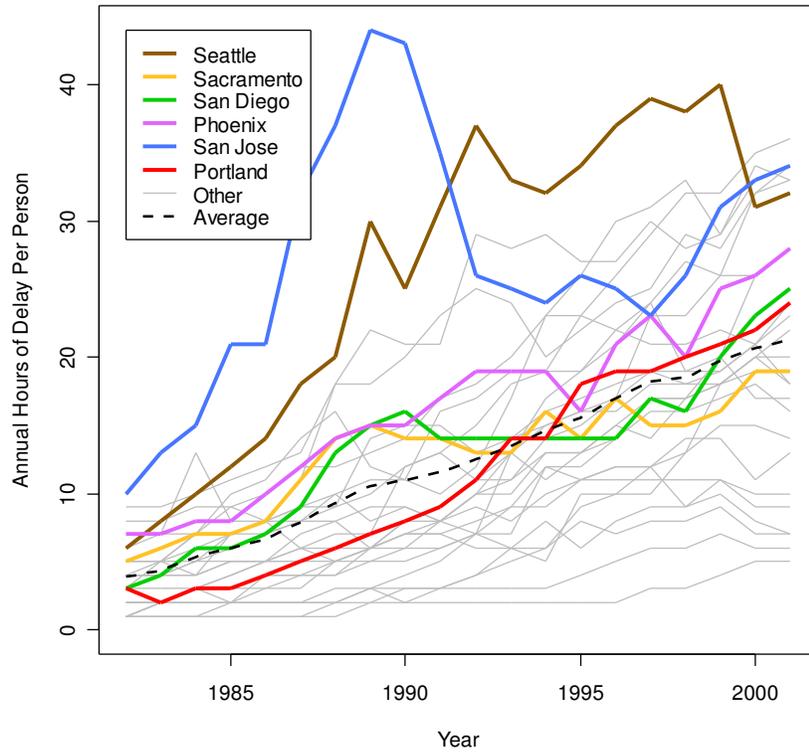


Figure A-7. Illustration of Variability in Urban Mobility Report Data and the Results of Smoothing Out the Variations

Because of these errors, care needs to be taken in how the congestion estimates are interpreted. The errors can be reduced by aggregating the results over several areas and smoothing out the trends as the second graph in Figure A-7 shows.⁵³

The UMR methods also limit the effect of data errors by only analyzing congestion on roads classified as freeways and other principal arterials (the major road system.) These road classifications are sampled at higher rates than other classified roads and the majority of urban travel occurs on them as well. It should be recognized, however, that while this approach limits the effects of sampling errors, it may also introduce other errors because the influences of other roads on urban congestion are not considered.

The UMR supplements HPMS data with data from a number of sources such as public transit databases. It also uses a number of constants and functional relationships derived from national studies. This is necessary because the HPMS data, in most cases, is not adequate by itself to estimate congestion. The use of national averages and relationships introduces errors in the congestion estimates.

Uncertainties in the data do not preclude congestion comparisons for individual urban areas, but it needs to be recognized that estimates and rankings for individual years are approximate. Comparisons should be based on overall trends in the data and rankings. As long as these data limitations are recognized, the wealth of information collected by the UMR can be used to gain a better understanding of congestion, ways of measuring it, the meaning of measures, the effects of congestion on society, and the effects of public policies.

The UMR estimates several measures of the extent and effect of peak period congestion on the major road system. Peak period congestion includes congestion that occurs regularly during peak hours as well as congestion due to unpredictable traffic incidents (e.g. accidents, disabled vehicles), which add to peak period congestion. The UMR definition of the peak period is broad. It includes the morning and evening peak hours and other times when congestion regularly occurs on some portions of the major road system.

The remainder of this section looks at several of the key UMR congestion measures along with several other measures calculated from UMR data and economic data from other sources. The discussion focuses on large urban areas like Portland and shows how the measures relate to one another and how their differences affect the interpretation of congestion. A discussion on congestion measures for small urban areas including the Eugene and Salem areas is included at the end of the section.

The figures of congestion-related data are composed of two graphs. The first graph shows trends in the data for the 30 large urban areas. The data for most of these areas are shown as light gray lines and the trends for six western cities are highlighted in color: Portland, Seattle, Sacramento,

⁵³ The technique used for smoothing was to fit cubic splines to the data using the R language function `smooth.spline` with six degrees of freedom. For documentation see the help page for `smooth.spline`. R documentation can be found at <http://www.r-project.org/>.

San Diego, Phoenix and San Jose. The graph also shows the average value for all large metropolitan areas.

The second graph shows the rankings of these areas according to the data relative to all 75 metropolitan areas included in the UMR. The ranking approach follows the general convention used in the UMR where the lowest ranks correspond to highest data values.⁵⁴ Figure A-8, for example, shows how the large urban areas compare with respect to their population size. It can be seen that the Portland area has a slightly lower than average population size. Its growth lagged relative to the average during the 1980s, dropping its ranking, but accelerated in the 1990s bringing its ranking back to about where it was in 1982.

To understand congestion measures, peak period usage of the major road system must be examined. Usage measures show the relationship between the amount of use and the capacity available to accommodate the use. Traffic flow density and volume-to-capacity ratios are usage measures.

Usage measures are key inputs to the UMR congestion estimation procedures. All usage measurements in the UMR methodology are based on the ratio of average daily traffic (ADT) per lane. Speed estimation procedures relate speed equations to this ratio for each type of facility, direction of travel, and range of usage. In addition, a single system usage index, the Roadway Congestion Index (RCI) indicates the extent of roadway congestion based on the comparison of ADT per lane on freeways and other principal arterials to threshold values representing the onset of congestion. The threshold for freeways is 14,000 vehicles per lane per day and the threshold for other principal arterials is 5,500 vehicles per lane per day.

The Roadway Congestion Index is not a particularly easy measure to understand, either how it is calculated or what it means. However, a compatible and more understandable measure easily derived from the UMR data is shown in Figure A-9. The first graph shows how many vehicles would be traveling on each lane of the major road system during the peak period if travel were evenly spread over the major road system. To compute this measure, the freeway and principal arterial DVMT are multiplied by the proportion of travel occurring during the peak period and divided by the total lane-miles. The computation of total lane-miles accounts for the differences in capacity of freeways and other principal arterials by converting the other principal arterial lane-miles into equivalent freeway lane-miles using the UMR study congestion threshold values (5,500/14,000).

⁵⁴ The rankings differ from those in the Urban Mobility Report with respect to how ties are treated. In the Urban Mobility Report, ties are given the same ranking value. In these figures, ranks for ties are given in order of their positions in the list so that each has a unique value. This difference in ranking methods is unimportant because the rankings are approximate and shown as approximate trends.

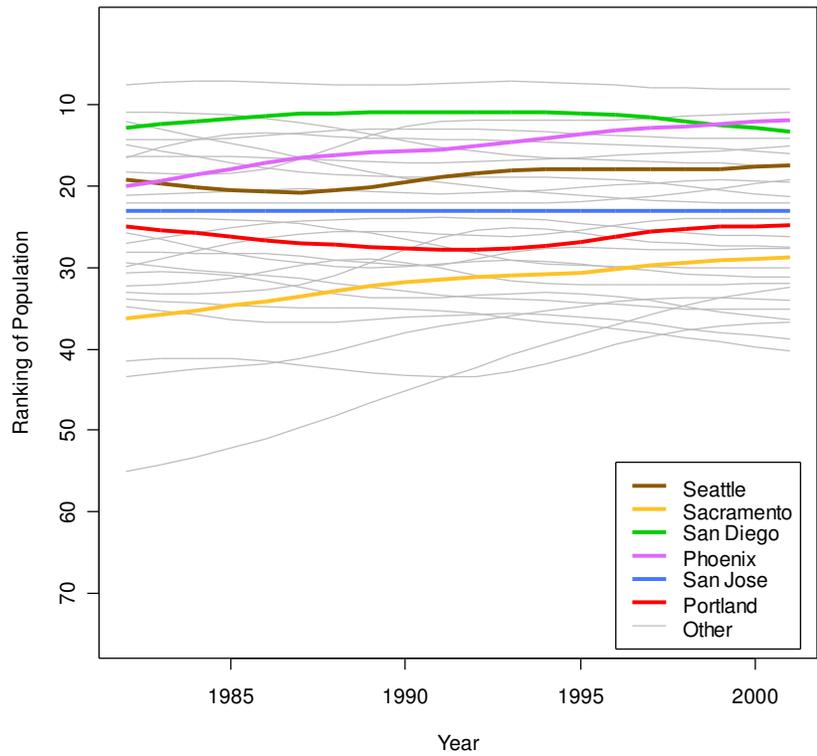
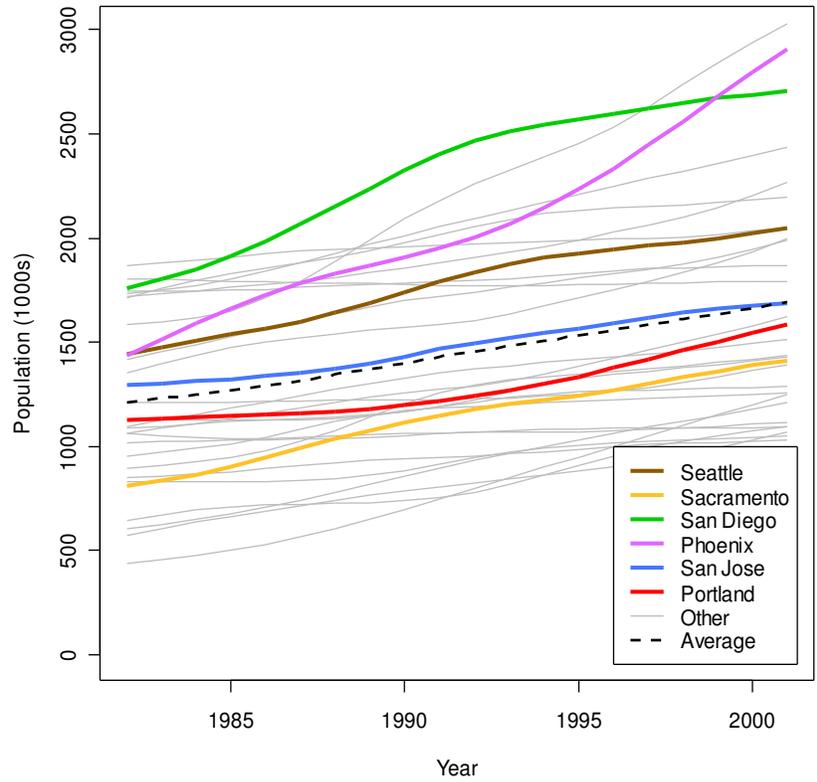


Figure A-8. Population and Ranking of Large Urbanized Areas

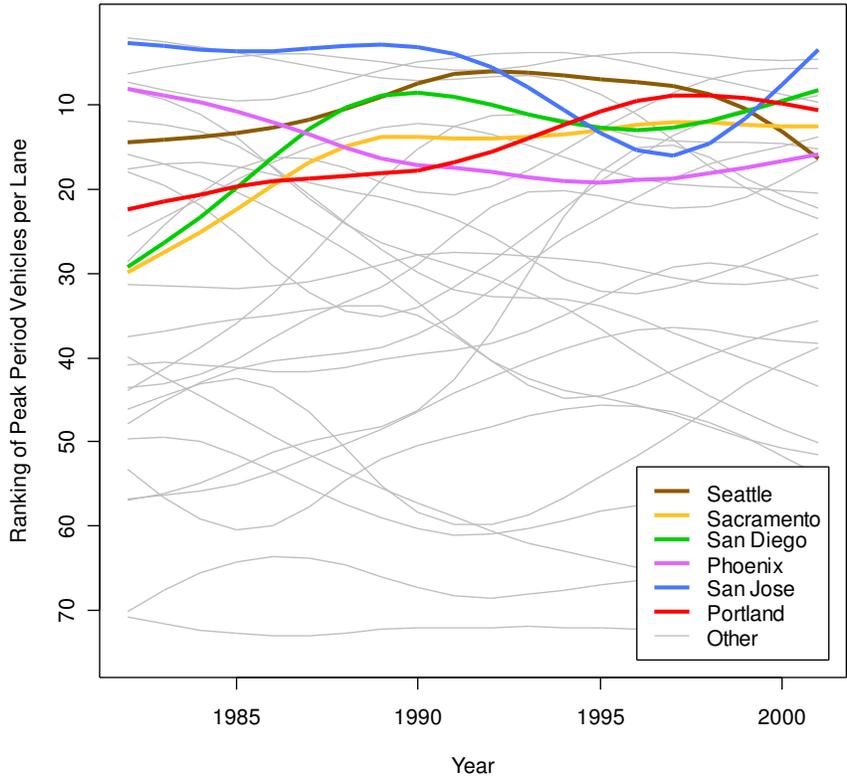
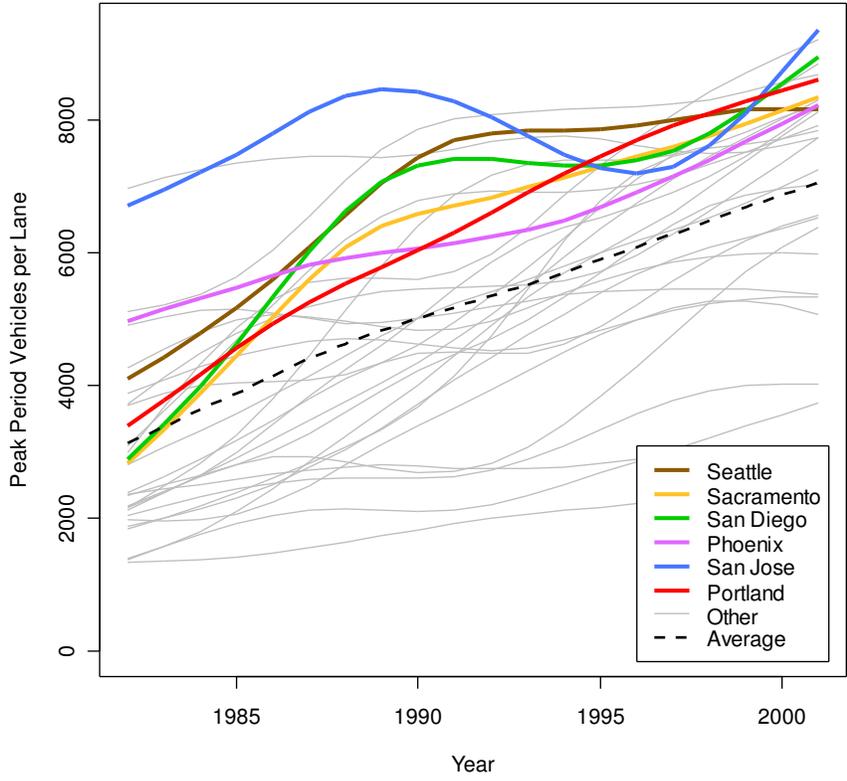


Figure A-9. Peak Period Major Road System Usage and Ranking in Large Urbanized Areas

The implications of the usage values shown in Figure A-9 can be seen by considering that the average freeway lane has enough capacity to carry about 2,200 vehicles per hour under ideal conditions (e.g. straight, level, non-merge, etc.). By 2001, peak period usage of the major road system in the Portland area was almost enough to consume four hours of capacity. Figure A-9 shows that usage in Portland started off higher than average for large cities and grew at a higher than average rate. This places Portland high in the rankings of urban areas with the most heavily used major road systems.

Given the high peak period usage and rapid growth in usage of the Portland area major road system, it should not be surprising that congestion is growing rapidly as well. The growth of congestion is indicated by increasing traffic densities (vehicles are traveling closer to one another) and declining traffic speeds. By the year 2001, Portland had a relatively high level of principal arterial congestion compared to other large urban areas. This is what is shown by the Travel Time Index (TTI) measures in Figure A-10. The TTI is an estimate of how much longer it takes on average to travel on the major road system during peak times vs. off-peak times considering the effects of everyday recurring congestion and the effects of congestion due to incidents. For example, a TTI of 1.4 means that on average, it takes 40 percent more time to travel on the major road system during peak times than during off-peak times.

The TTI has grown in all large urban areas and grew faster than average in the highlighted areas. It grew in Portland at one of the fastest rates. By 2001, Portland's major road system was among the most congested in the nation.

The high TTI values do not mean, however, that Portland area residents have experienced particularly high levels of delay due to congestion. That is because the delay travelers experience in making trips depends not only on how slowly they travel because of congestion, but also on how far they travel. The same amount of delay can be experienced by a traveler who makes a short trip on very congested roads and another traveler who makes a long trip on less congested roads. Thus, it is important to consider how far people travel as well as how fast they to determine how much delay they experience as a result of congestion.

Figure A-11 shows average travel distances per peak period traveler on the major road system. This measure is computed by dividing the total VMT during the peak period by the estimated number of peak period travelers. It can be seen that the Portland area's relative position in these graphs is very different than in the previous two figures. The average travel distance in the Portland area has been lower than the large area average for most of the period between 1982 and 2001. The Portland average started out lower in 1982 but grew at a faster rate until 1993, when it exceeded the large area average by a small amount. It then declined and by 1997 was again below the large area average. This, along with increases in other urban areas, resulted in a decline in the Portland area's ranking to about 40th.

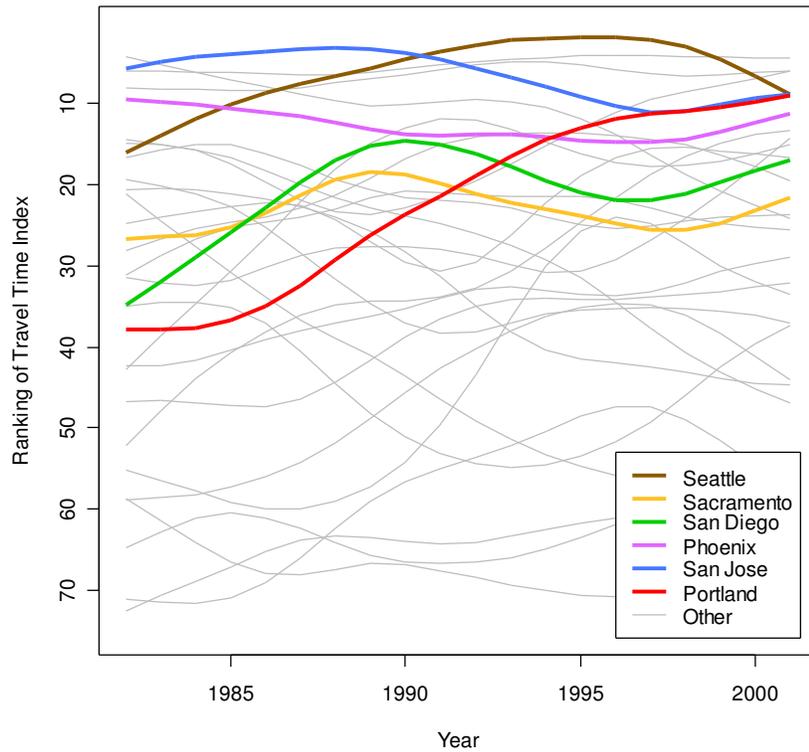
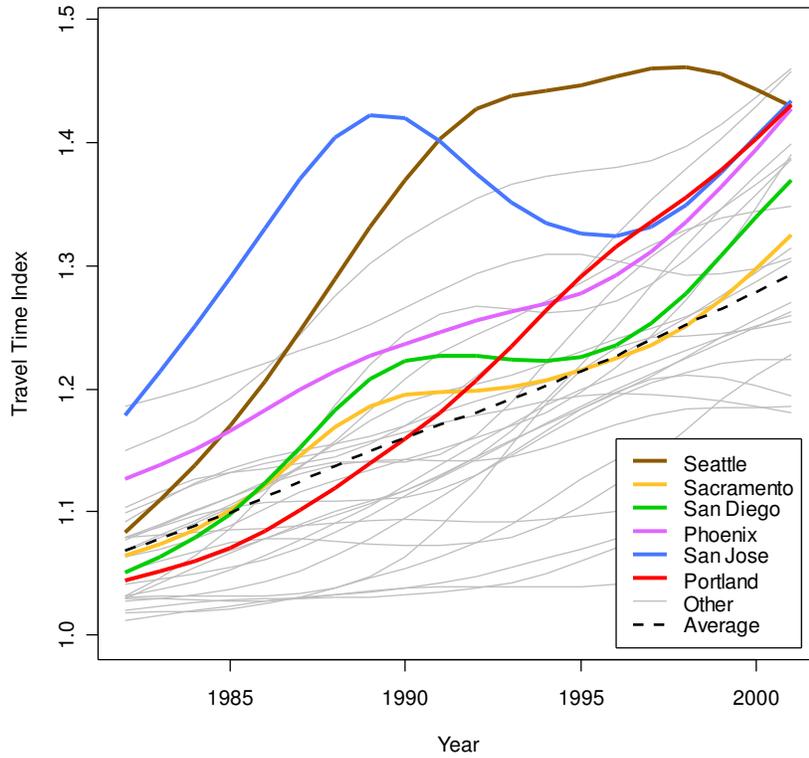


Figure A-10. Travel Time Index Values and Ranking for Large Urbanized Areas

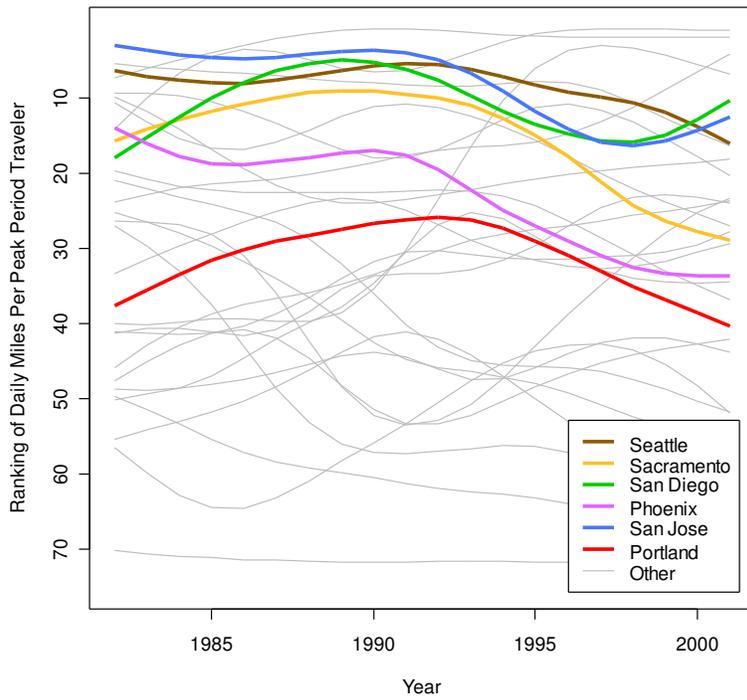
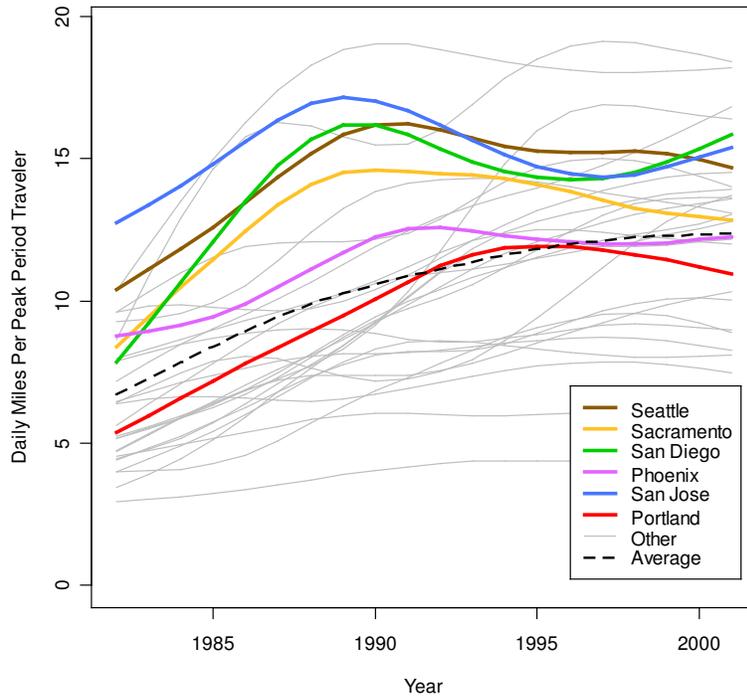


Figure A-11. Peak Period Vehicle Travel Distances on Congested Major Roads and Rankings in Large Urbanized Areas

The higher intensity of congestion in the Portland area, as indicated by the TTI, is offset by shorter travel distances. Consequently, the increases in delay for peak period travelers in the Portland area were much closer to the large urban area average than the change in the TTI suggests. This is shown in Figure A-12. Peak traveler delay in the Portland area started out below the average for large areas during the early 1980s, grew more rapidly during the late 1980s and early 1990s, and then leveled off at the large metropolitan area average growth rate from 1995 on. The Portland area ranked 20th or higher for delay during the last six years of the study timeframe despite ranking 13th or lower for TTI during that same period. The difference in ranking is the result of moderate congested travel distances. The Phoenix and Sacramento areas had similar patterns where moderation of congested distances helped to offset the effects of rising congestion. Peak travel delay in Sacramento dropped from above to below average due to the combined effect of less rapid growth of both congestion and congested travel distances. For Seattle and San Jose, however, long congested travel distances reinforced high congestion levels to result in greater amounts of delay.

Although travel delay is a better measure than TTI of the effects of congestion, it still has an important limitation. Both delay and the TTI are based on somewhat arbitrary assumptions about the speeds that travelers would choose if there were no congestion - 60 miles per hour (mph) on freeways and 35 mph on other principal arterials. These assumptions are reasonable for low-density suburban settings. However, travelers do not expect to drive as fast in high-density settings like downtowns because the closer spacing of attractions makes faster driving uncomfortable and unnecessary. Therefore, the UMR estimate of delay tends to overstate the delay in more densely developed areas where people tend to travel more slowly.

The problems caused by uncongested speed assumptions and varying urban densities can be reduced by comparing congestion effects on the basis of peak period travel time rather than peak period travel delay. The significance of uncongested speed assumptions is reduced because they no longer serve as a baseline in the calculations.

Travel time provides a more complete and unbiased measure of the effects of congestion on people's daily lives. For example, shoppers in a less dense urban area may face less congestion but longer travel distances than shoppers in a denser urban area. If it takes the same amount of travel time for both sets of shoppers, it does not matter that the shoppers in the denser urban area have higher estimated delay (according to the uncongested speed assumptions). People in different urban areas generally carry out the same types and numbers of activities during the peak period. Using peak period travel time as a congestion measure indicates the total cost in time necessary to do those activities.

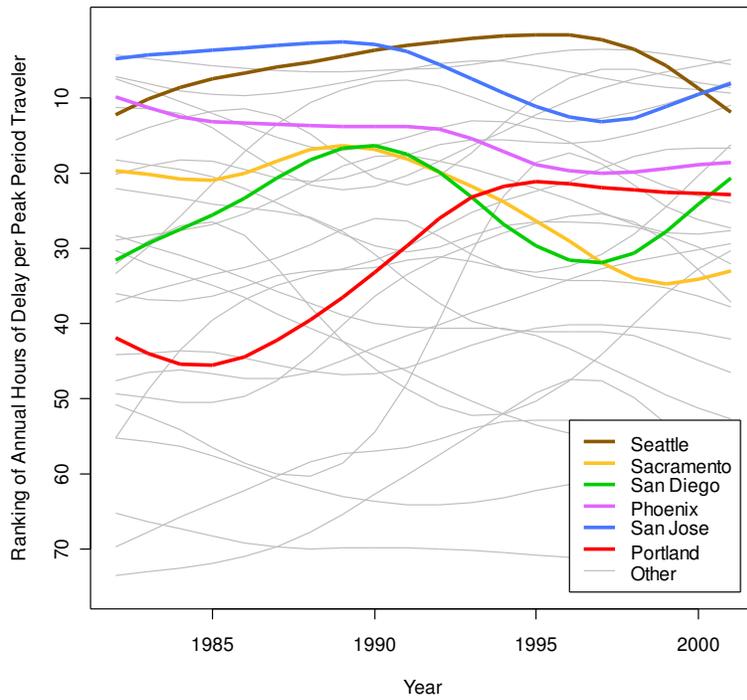
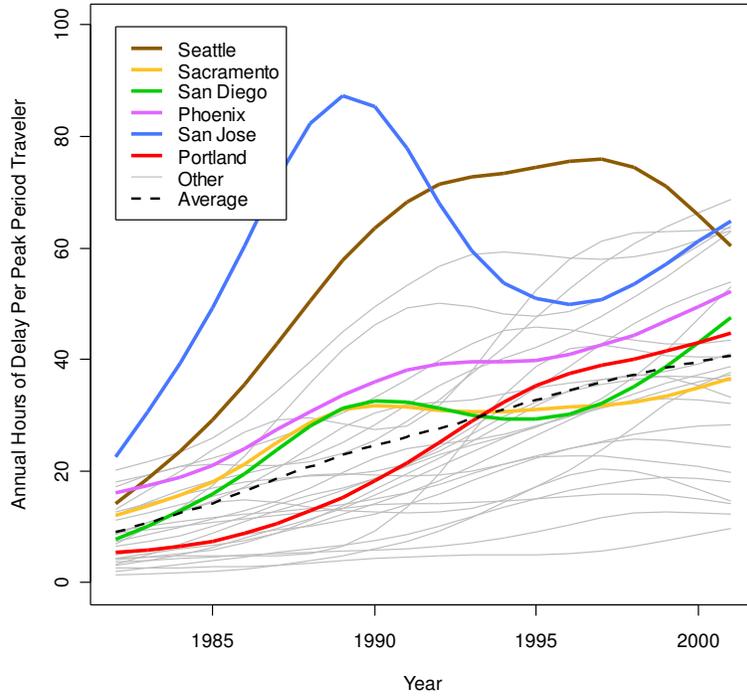


Figure A-12. Major Road Congestion Delay and Ranking in Large Urbanized Areas

The UMR data set does not include congested travel time estimates, but such estimates can be easily calculated from the UMR estimates of total delay and TTI.⁵⁵ The results of this computation are shown in Figure A-13. The first chart shows the average annual hours of travel on the major road system per peak period traveler. Comparing this chart with Figure A-12 shows that looking at peak period travel times presents a very different picture of the effects of congestion. Whereas peak traveler delay in the Portland area increased about seven times from 1982 to 2001, the average travel times of peak travelers increased by less than 10 percent. Travel times in the Portland area remained below the large urban area average throughout the entire study period. In ranking terms, the Portland area has remained in the group of cities with the shortest peak period travel times. Clearly, shorter congested travel distances in the Portland area have helped to moderate the impact of congestion on Portland area travelers.

It is also useful to examine the trends for the other highlighted large urban areas. Seattle and San Jose have much higher peak period travel times and have had more growth in travel time. As with delay, this is the consequence of combining substantial growth of congestion with growth of congested trip lengths. The other areas have much lower peak period travel times and have had much less growth in travel time. Sacramento, in particular, is noteworthy because it is one of the few places where peak period travel times declined. This decline, along with increases in travel times elsewhere, resulted in a dramatic drop in Sacramento's ranking.

Although peak period travel time does a better job than delay in representing the effects of congestion, it does not present a complete picture. This is because comparisons based on travel time assume the peak period trips in all urban areas are equally productive. However, urban areas vary in their production levels. One would expect an urban area with a booming economy to have more hours of travel during the peak period than an urban area with a sagging economy because more workers and products are being moved.

⁵⁵ The formula is as follows:

since: congested travel time – freeflow travel time = delay

and: congested travel time = freeflow travel time * travel time index

therefore: congested travel time = delay * travel time index / (travel time index – 1)

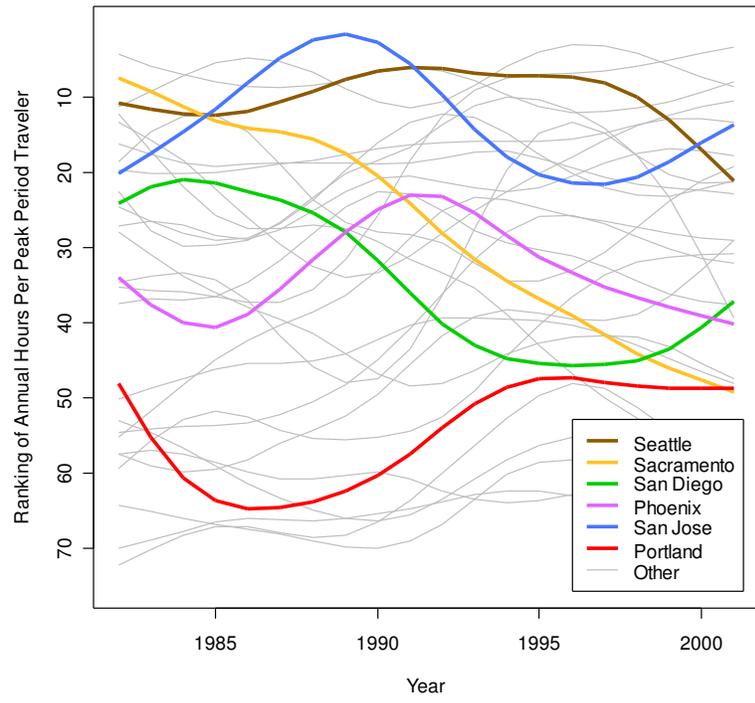
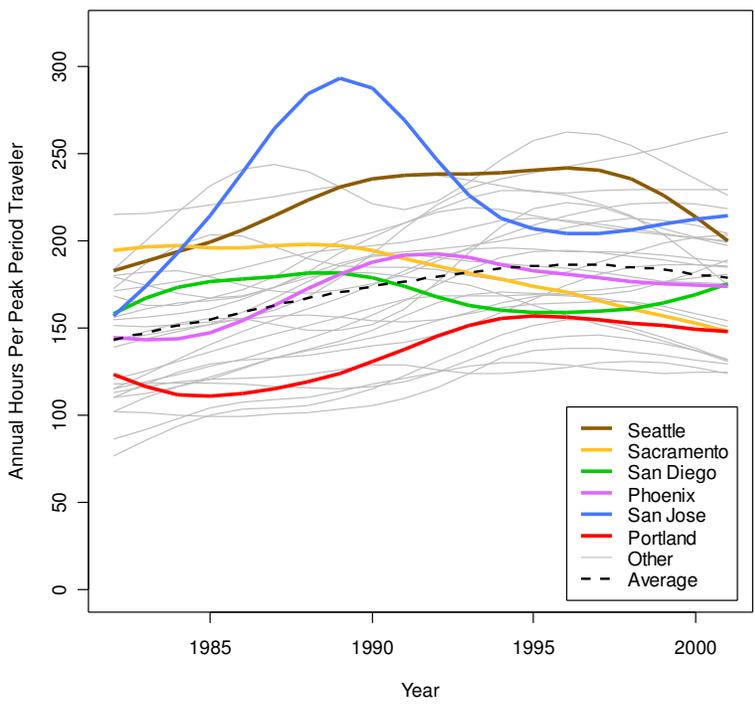


Figure A-13. Trends in Travel Time and Ranking for Large Urbanized Areas

To look at the full impact of congestion, peak period travel costs must be compared with economic output. Such a measure can be calculated by dividing annual peak period travel cost by annual income for each urban area.⁵⁶ This measure shows relative peak period travel costs required to produce each dollar of income. It is important to account for differences in the cost of living and inflation among urban areas, but that is straightforward to do.⁵⁷ Figure A-14 shows the results of these calculations.

In Figure A-14, the unit cost of peak period travel has changed much less than congestion over time for all large urban areas. For example, although the travel cost for San Jose grew dramatically from 1982 to 1990, it fell to its 1982 level by 2001. This happened despite increases in peak period travel time from 1995 to 2001. Growth of incomes must have offset growth in travel time. For the large urban areas as a whole, the travel time for peak travelers increased 25 percent, while the unit cost of travel increased by only 9 percent. Unit travel costs in the Portland area remained below the large urban area average and changed little over the 20-year period. In 2001, Portland's unit costs were a little lower than they were in 1982 and have remained fairly constant since 1994. The Portland area ranked in the lower half of UMR study areas in terms of unit travel costs.

Only the UMR congestion TTI trends are shown for Salem and Eugene. The other measures presented for the large urbanized area are not discussed because they are confounded by the effects of through traffic - traffic that has origins and destinations outside of the area. Through traffic is not much of a consideration in most large urbanized areas because this traffic is a very small fraction of total traffic. In small urbanized areas, it can be a substantial portion of major road system traffic. Therefore, measures that are denominated by area population, travelers or income will be overstated as a result of incorporating through traveler delay.

⁵⁶ The UMR includes estimates of peak period delay cost (UMR Exhibit A-7). The delay cost calculation methodology is a function of the hours of peak period delay. (See pages 22-24 of the UMR methodology, http://mobility.tamu.edu/ums/report/methodology_appB.pdf). The peak period travel cost is computed from this by dividing by the total hours of delay and multiplying by the total travel time. Per capita incomes are taken from the Bureau of Economic Analysis (BEA) for each metropolitan area. Although the per capita income average is for the entire metropolitan boundary area whereas the UMR data is for the urbanized area (an area smaller than the metropolitan area), the use of per capita incomes from BEA rather than total incomes adjusts adequately for this geographical difference. The BEA data is in nominal dollars.

⁵⁷ Travel costs and area incomes are converted to real (inflation adjusted) dollars using the consumer price index (CPI) from the Bureau of Labor Statistics (BLS). The base period for the CPI is 1982-1984. The BLS provides CPI values for a few of the metropolitan areas and general CPI values for different regions of the country. Where a specific CPI is available for an urban area, it is used. Otherwise, the general regional index for the urban area is used. Adjustments to income are also made to account for urban area differences in the cost of living. Information on the cost of living for different urban areas is from *Sperling's Best Places* at <http://www.bestplaces.net/>.

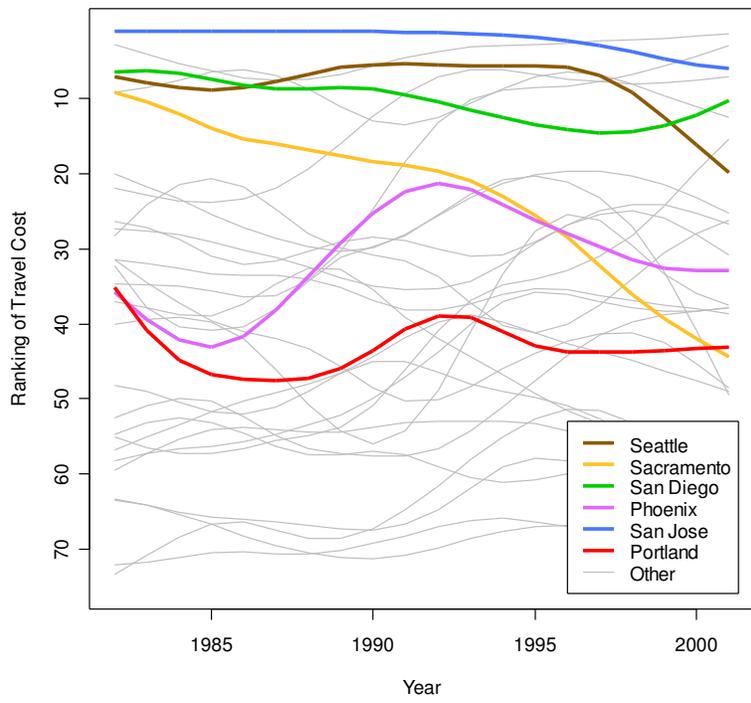
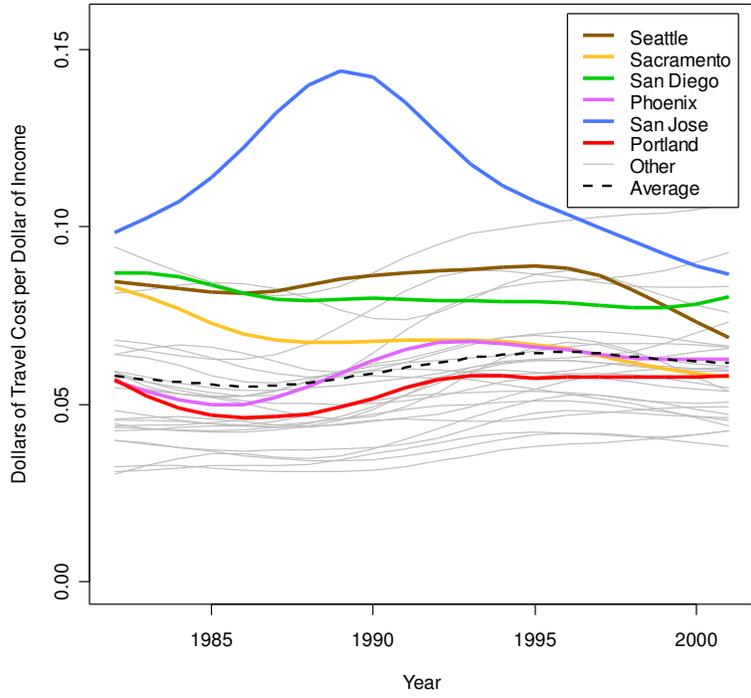


Figure A-14. Trends in Travel Cost and Ranking for Large Urbanized Areas

Figure A-15 shows TTI trends for small urbanized areas including Salem OR, Eugene OR, Bakersfield CA, Boulder CO, Spokane WA, and Beaumont TX. All of the highlighted areas are either close to or below the small urban area average for most of the period between 1982 and 2001. The Salem area TTI climbed slightly above the average in 1993 and the Eugene area TTI climbed above in 1999. Salem's trend relative to Eugene reflects the greater effect of through traffic. Salem, which is in the middle of the Willamette Valley and closer to Portland, has more through traffic than Eugene, which is located at the southern end of the Willamette Valley and far from Portland. The contribution of through traffic to Salem's trend has not been estimated.

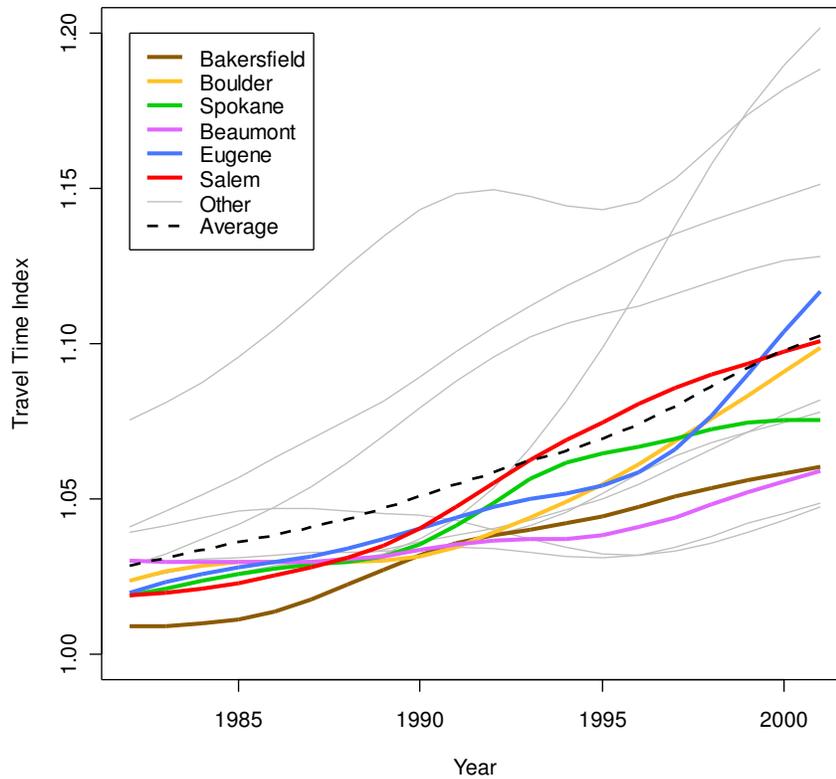


Figure A-15. Travel Time Index Values for Small Urbanized Areas

TRAVEL TIME AND TRAVEL TIME RELIABILITY

As the previous section illustrates, travel time is one of the best measures of congestion. As people drive along a road, they are not aware of the average traffic volume per lane or volume-to-capacity ratio. They are, however, aware of how much time their trips take. They are also aware of the uncertainty of their travel.

Travel time data are among the most difficult data to collect or estimate correctly, particularly under congested conditions. Travel time varies considerably over space and time and therefore requires an extensive number of measurements to get an accurate estimate. These data can be

collected by test driving roads at prevailing speeds many times during various hours of the day, monitoring traffic speeds through an extensive system of speed sensors, using geographic positioning systems (GPS) or other technology to track vehicles, and surveys which ask people to keep track of their travel time. This section looks at data gathered from two of these methods - commute time data gathered by the Census Bureau and by the Oregon Population Survey, and travel time data gathered from speed sensors in the Portland area as part of the Advanced Transportation Monitoring System (ATMS).

The Census of Population, the Oregon Population Survey, and the National Personal Transportation Survey (NPTS) provide sources of travel time data in their periodic household surveys. The first two provide data on average commute travel times in Oregon. The NPTS provides data on travel times for other trip purposes as well but does not have a large enough sample of Oregon households to provide a statistically valid representation for Oregon.

Both the Census of Population and the Oregon Population Survey show that commute travel times have been increasing. According to the Census, the statewide average travel time to work was 20.6 minutes in 1990 and 21.4 minutes in 2000. The average travel time in the Portland Consolidated Metropolitan Statistical Area (CMSA)⁵⁸ increased from 21.7 minutes in 1990 to 24.4 minutes in 2000⁵⁹.

Table A-3 shows average travel times in Oregon counties that contain the state's urbanized areas. Between 1990 and 2000, the journey to work travel times for residents of these counties increased in the range of 1.4 minutes (Benton County) to 4 minutes (Marion County).

| County | 1990 Average | 2000 Average | Difference |
|---------------|---------------------|---------------------|-------------------|
| Benton | 16.4 | 17.8 | 1.4 |
| Clackamas | 23.5 | 26.2 | 2.7 |
| Deschutes | 16.3 | 18.7 | 2.5 |
| Jackson | 16.7 | 18.9 | 2.2 |
| Lane | 18.1 | 19.9 | 1.8 |
| Marion | 19.4 | 23.5 | 4.0 |
| Multnomah | 21.1 | 23.8 | 2.7 |
| Polk | 20.3 | 23.4 | 3.1 |
| Washington | 21.7 | 23.7 | 2.0 |

Table A-3. Average Journey to Work Times Reported by the Census

⁵⁸ This includes Multnomah, Washington, Clackamas, Columbia, Yamhill, Polk, Marion Counties and Clark County, Washington.

⁵⁹ Nancy A. McGuckin and Nanda Srinivasan, *Journey to Work Trends in the United States and its Major Metropolitan Areas: 1960-2000*, FHWA-EP-03-058 (U.S. Department of Transportation, Federal Highway Administration, June 30, 2003).

Table A-4 shows trends in average commute times gathered by the Oregon Population Survey. This survey has been taken every two years since 1990. The trends indicate that average commute times have increased from around 2 to 4 minutes between 1990 and 2000.

| Region | 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | Average Error |
|-------------------------|-------------|-------------|-------------|-------------|-------------|-------------|----------------------|
| Portland Metro | 19 | 19 | 20 | 20 | 19 | 21 | +/- 1 |
| Other Willamette Valley | 15 | 17 | 17 | 16 | 16 | 19 | +/- 1 |
| North Coast | 15 | 14 | 15 | 17 | 14 | 17 | +/- 3 |
| Southwest Oregon | 13 | 14 | 16 | 16 | 15 | 17 | +/- 2 |
| Central Oregon | 12 | 16 | 13 | 15 | 14 | 16 | +/- 3 |
| Eastern Oregon | 11 | 13 | 13 | 14 | 13 | 15 | +/- 2 |

Table A-4. Average Commute Times in Minutes Reported by Respondents to the Oregon Population Survey by Area of the State

Table A-5 compares mean journey to work travel times for the Portland CMSA with those of other large metropolitan areas for 1980, 1990 and 2000. This list includes all of the large areas studied in the UMR except for the West Palm Beach area which was not included in the sources researched for this paper.⁶⁰

It is important to recognize that changes in reported travel times are not solely the result of increased congestion. As urban areas grow in population, they also spread out geographically and this contributes to increases in the length and time of trips. Also, as larger urban areas grow, their housing prices tend to increase. More people move to satellite cities where they can get less expensive housing in return for a longer commute.

⁶⁰ The definition of the areas included in the journey to work data is also different than the definitions used in the Urban Mobility Report. In many, if not most cases, the areas are larger than the areas used in the Urban Mobility Report. In the case of the Miami and Ft. Lauderdale areas, one Census area includes both of these areas. Sources: U.S. Department of Transportation, *Journey-To-Work Trends in the United States and its Metropolitan Areas 1960-1990*, Table 4-13; U.S. Department of Transportation, *Journey-To-Work Trends in the United States and its Metropolitan Areas 1960-2000*, Exhibit 3.5; Wendell Cox Consultancy, *US Metropolitan Journey to Work Travel Times: 1980-2000 - Areas over 1,000,000*.

| Area | 1980 | 1990 | 2000 |
|----------------|-------------|-------------|-------------|
| Atlanta | 24.9 | 26.0 | 31.2 |
| San Jose | 23.9 | 25.6 | 29.3 |
| Miami | 22.6 | 24.1 | 28.9 |
| Ft. Lauderdale | 22.6 | 24.1 | 28.9 |
| Seattle | 22.8 | 24.3 | 27.7 |
| Orlando | 20.3 | 22.9 | 27.0 |
| New Orleans | 24.5 | 24.4 | 26.7 |
| Phoenix | 21.6 | 23.0 | 26.1 |
| Denver | 22.0 | 22.4 | 25.9 |
| Tampa | 20.2 | 21.8 | 25.6 |
| Sacramento | 19.5 | 21.8 | 25.6 |
| St. Louis | 22.6 | 23.1 | 25.5 |
| Baltimore | 25.3 | 26.0 | 25.5 |
| San Diego | 19.5 | 22.2 | 25.3 |
| Pittsburgh | 22.8 | 22.6 | 25.3 |
| San Antonio | 20.2 | 21.9 | 24.5 |
| Cincinnati | 21.8 | 22.1 | 24.5 |
| Portland | 21.4 | 21.7 | 24.4 |
| Norfolk | 21.0 | 21.6 | 24.1 |
| Las Vegas | 18.9 | 20.4 | 24.1 |
| Cleveland | 21.6 | 22.0 | 24.0 |
| Indianapolis | 20.8 | 21.9 | 23.8 |
| Minneapolis | 20.1 | 21.1 | 23.7 |
| Columbus | 20.1 | 21.2 | 23.2 |
| Kansas City | 20.7 | 21.4 | 22.9 |
| Milwaukee | 18.8 | 20.0 | 22.1 |
| Oklahoma City | 20.2 | 20.3 | 22.0 |
| Buffalo | 19.3 | 19.4 | 21.1 |
| Average | 21.4 | 22.4 | 25.3 |

Table A-5. Mean Journey to Work Travel Times for Large Areas

Increased instrumentation of roads and vehicles is providing another source of travel time information. Increasingly, new technologies are being deployed to collect traffic flow and speed information continuously over large portions of the freeway and arterial system. These are components of Advanced Transportation Management Systems (ATMS) which are put into place to better manage traffic flows and reduce traffic disruptions. The Mobility Monitoring Program collected and analyzed data from 21 cities with ATMS, including the Portland metropolitan

area.⁶¹ The study identifies the potential for using archived traffic speed and volume data to measure performance and points out current data limitations.

One of the biggest benefits of archived ATMS data is that it can be used to compute better estimates of travel time reliability. While TTI includes the effects of incident-related delay, it does not convey how variable the travel times may be. The uncertainty of travel times is becoming more recognized as an important congestion management issue.

The Mobility Monitoring Program developed two measures of travel reliability to communicate travel time uncertainty. The Planning Time Index is a measure of the additional time that travelers need to budget during the peak period to assure a 95 percent probability of on-time arrival. It is expressed in the same way as the TTI. The Buffer Time Index is the percentage difference between the Planning Time Index and the TTI. It measures the additional time that needs to be budgeted to account for travel time uncertainty. Table A-6 shows the estimated TTI and Buffer Time Index values for a selection of freeways in the Portland area.

| Section | Travel Time Index (Average Peak) | Buffer Time Index (Average Peak) |
|---|---|---|
| ORE-217 NB: 72 nd Ave. to Walker Rd. | 1.15 | 36% |
| ORE-217 SB: Walker Rd. to 72 nd Ave. | 1.22 | 51% |
| I-205 NB: ORE 99E to Division | 1.21 | 33% |
| I-205 SB: Airport Way to ORE 43 | 1.28 | 35% |
| I-5 NB: Stafford Rd. to Jantzen Beach | 1.50 | 43% |
| I-5 SB: Jantzen Beach to Nyberg Rd. | 1.31 | 32% |
| I-84 WB: 39 th St. to I-5 | 1.52 | 42% |
| I-84 EB: 33 rd St. to 202 nd Ave. | 1.72 | 53% |
| US 26 EB: Helvetia Rd. to Skyline Blvd. | 1.29 | 68% |
| US 26 WB: Skyline Blvd. to Murray Blvd. | 1.49 | 39% |
| Average for sections | 1.37 | 42% |

Table A-6. Estimated Travel Time Index and Buffer Time Index for Selected Locations in the Portland Area in 2001

⁶¹Tim Lomax, Shawn Turner and Richard Margiotta, *Monitoring Urban Roadways in 2001: Examining Reliability and Mobility with Archived Data*, FHWA-OP-03-141 (U.S. Department of Transportation, Federal Highway Administration, June 2003).

APPENDIX B THE ECONOMICS OF CONGESTION

Why has roadway congestion grown so much in Oregon's urban areas? The simple answer is that traffic grew much faster than the roads that carry it were expanded. Between 1982 and 2002, urban freeway travel grew almost six times faster than freeway capacity. The capacity increases for other arterials also lagged travel growth on those roads, but not by as much as for freeways (see Appendix A).

This simple answer might not be the correct one, however, because congestion, travel, urbanization, and economic development are dynamic and interact with each other. As congestion changes, so do people's attitudes about when, where and how to travel.⁶² Congestion also affects employers' attitudes about whether and where they should move their businesses.⁶³

CAUSE AND EFFECT

Determining what is a cause and what is a consequence is difficult due to the complexity of economic, land use and transportation interactions. For example, some people believe that road building causes congestion by increasing suburban sprawl, thus increasing driving⁶⁴. Others believe that high population and employment densities and inadequate roads cause congestion.⁶⁵ Although there are disagreements about cause and effect, most agree that it is important to understand the linkages between congestion, travel, land use and economic development. Failure to do so can result in unintended consequences such as those described in the following account of how one city tried to solve its downtown congestion problem.

Everybody had agreed on the proposed plan. The mayor had the support of both the citizens and the city council. Because the volume of traffic downtown and the resultant noise and air pollution had become intolerable, the speed limit was lowered to twenty miles per hour and concrete "speed bumps" were installed to prevent cars from exceeding it.

But the results were hardly what the planners anticipated. The lower speeds forced cars to travel in second rather than third gear, so they were noisier and produced more exhaust. Shopping trips that used to take only twenty minutes now took thirty, so the number of cars in the downtown area at any given time increased markedly.

⁶² Richard G. Dowling and Steven B. Colman, *Effects of Increased Highway Capacity: Results of a Household Travel Behavior Survey*, Paper presented at the Transportation Research Board Annual Conference (January 1997).

⁶³ Peter Gordon, Harry W. Richardson, and Myung-Jin Jun, *The Commuting Paradox: Evidence from the Top Twenty*, *Journal of the American Planning Association*, Vol. 57, No. 4 (Autumn 1991) 416-420.

⁶⁴ Surface Transportation Policy Project, *Why Are The Roads So Congested? A Companion Analysis of the Texas Transportation Institute's Data On Metropolitan Congestion* (November 1999).

⁶⁵ See, for example, the Thoreau Institute web site <http://www.ti.org/>

A disaster? No – shopping downtown became so nerve-racking that fewer and fewer people went there. So the desired result was achieved after all? Not really, for even though the volume of traffic gradually went back to its original level, the noise and air pollution remained significant. To make matters worse, during the period of increased traffic, word had gotten around that once-a-week shopping expeditions to a nearby mall on the outskirts of a neighboring town were practical and saved time. More and more people started shopping that way.

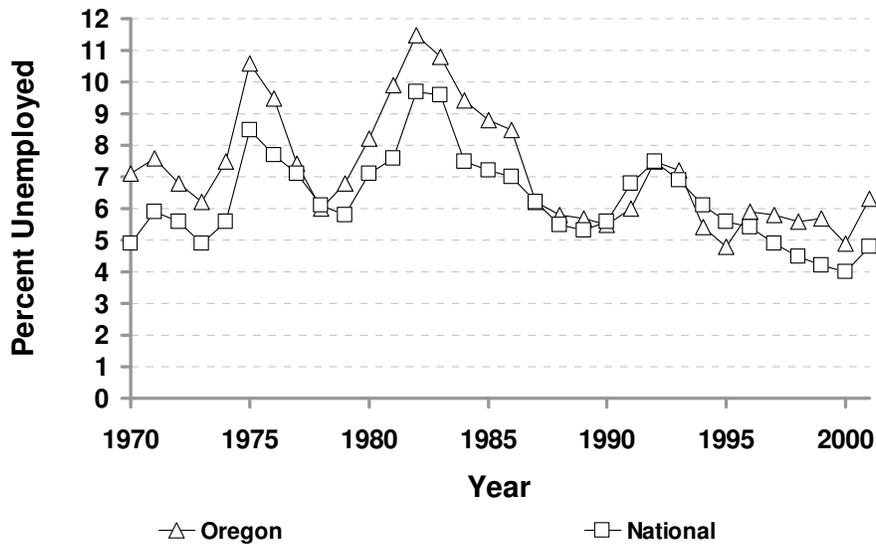
To the distress of the mayor, downtown businesses that had been flourishing now teetered on the verge of bankruptcy. Tax revenues sank drastically. The master plan turned out to be a major blunder, the consequences of which will burden this community for a long time to come.⁶⁶

Understanding economic interactions is fundamental to understanding how congestion is connected to travel, land use and economic development. A good part of daily life is involved in earning a living and shopping for necessities and luxuries. These activities involve economic transactions which require travel. Moreover, the economy is a web of economic transactions between manufacturers, wholesalers, distributors, retailers and consumers that result in the movement of goods and services around the country and the world.

Most of these economic transactions occur within urban areas and it is no coincidence that congestion is primarily an urban problem. People view congestion – and most travel time in general – as a cost to be avoided, but will bear it in order to have other things, such as a better job or access to urban amenities. Where people work and live and where businesses locate depends on how much it costs and what value they receive for the cost. Interpreting travel and congestion trends from an economic perspective is important to fully understand these dynamic interactions.

One result of taking an economic perspective is that it underscores the importance of looking at trends over a long enough period to account for economic changes. While some economic changes like stock market declines can occur fairly rapidly, others can take much longer. Examples of longer term changes include business cycles, such as those illustrated by the unemployment rates in Figure B-1, and even longer term structural changes in the economy, such as the decline in Oregon's wood products sector and growth of the technology sector since 1980.

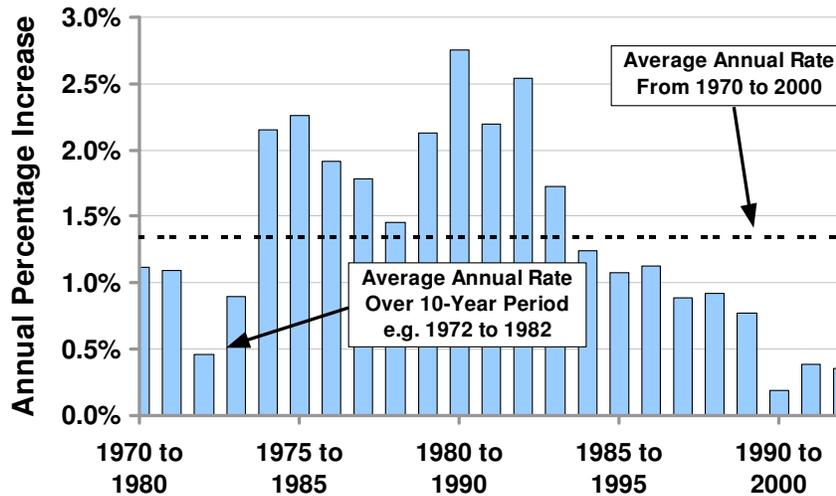
⁶⁶ Dietrich Dorner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations*, (Reading, MA: Addison-Wesley, 1996) 1-2.



Sources: Oregon Unemployment – State Employment Department, National Unemployment – Council of Economic Advisors, *Economic Report of the President*, January 2001, Table B-42

Figure B-1. Oregon and National Civilian Unemployment Rates: 1970-2000

It is risky for transportation analysts and policy-makers to ignore long-term economic trends. This can result in misleading interpretations of events. Figure B-2 illustrates this by comparing annual per capita VMT growth rates for 10-year intervals with the 30-year annual growth rate from 1970 to 2000.

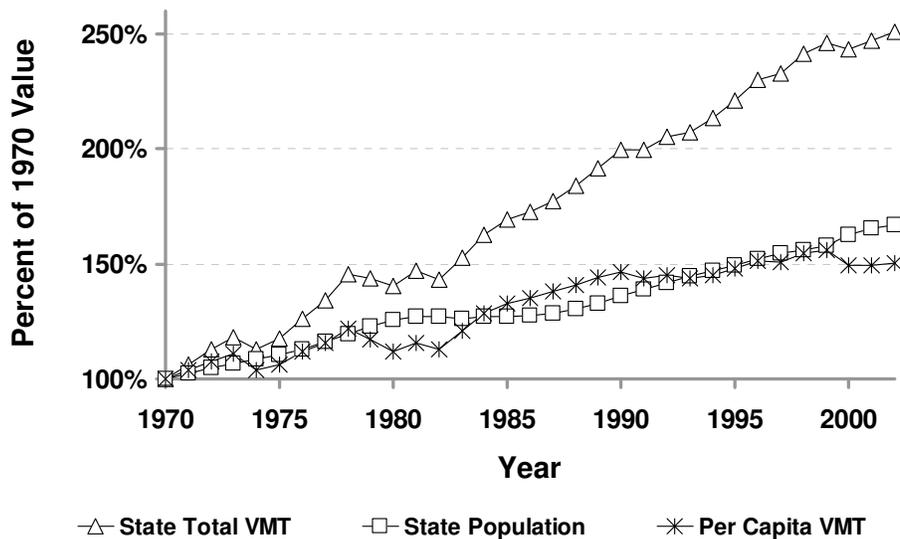


Sources: VMT–ODOT Finance Section; Analysis–ODOT Transportation Planning Analysis Unit

Figure B-2. Comparison of Growth in Per Capita VMT for 10-year Periods with 30-year Average: 1970-2000

Although the average annual rate for the entire period was 1.4 percent, the annual rates for the 10-year intervals varied from a low of 0.3 percent from 1990 to 2000 to a high of 2.8 percent from 1980 to 1990. The 1980-90 period is significant because major state and national transportation policies were adopted in the early 1990s based on travel trends from the 1980s. Most reporting of the time did not recognize how the per capita VMT growth rate during the 1980s was unusually high, and did not fully appreciate its relationship to the recession that began in that decade.

This economic cycle was particularly important in Oregon because the recession was accompanied by a decline in the wood products sector, which had been the most important industrial sector to the state's economy. Per capita VMT grew rapidly because the state's population grew very slowly over most of the decade while VMT grew rapidly after 1982 as the state climbed out of recession (Figure B-3). It is easy to see in hindsight how analysts misread the situation because they did not look at a long enough trend and did not consider the effects of business cycles.



Sources: Vehicle Miles Traveled—ODOT Finance and Policy Sections; Population—Portland State University, Center for Population Research & Statistics.

Figure B-3. Changes in Population and VMT in Oregon: 1970-2000

Taking a longer view from 1970 to 2002 spans several business cycles and covers some significant changes in the structure of our society and economy. These include:

- The entrance of Baby Boomers into the work force
- A large increase of women in the labor force
- The decline of Oregon's wood products sector and growth of the technology sector
- The rapid growth of suburbs in the Portland metropolitan area

- An increasing gap between the growth of travel demand and the expansion of the highway system

This time period also includes notable changes in land use and transportation policy. It spans the history of Oregon's land use planning program, from the passage of the landmark land use law Senate Bill 100 in 1973, through development of the Statewide Land Use Planning Goals, acknowledgement of city and county comprehensive plans by the Land Conservation and Development Commission, and numerous amendments and periodic updates to those plans. It also encompasses significant changes in federal and state transportation policy, including completion of the interstate highway system, construction of two light-rail lines in the Portland metropolitan area, and restructuring of federal transportation policy with the adoption of ISTEA in 1991 and the Transportation Equity Act for the 21st Century (TEA-21) in 1997.

RELATIONSHIPS BETWEEN ECONOMIC GROWTH, TRAVEL, URBANIZATION, AND CONGESTION

The following discussion of the relationships between economic growth, travel, urbanization and congestion may seem out of place in a report on traffic congestion. However, it provides a useful conceptual framework for understanding travel and congestion trends and can be instrumental in resolving some apparent paradoxes such as:

- Why large metropolitan areas keep growing even though they become more congested.⁶⁷
- Why more non-work travel is occurring during rush hours⁶⁸ even though rush hour congestion is growing.
- Why large increases in peak hour congestion have not resulted in large increases in commute times.⁶⁹

This discussion is necessarily general in scope. Many things affect the development of economies and cities, the location of businesses and households, and the travel decisions of the many different people who make up our society. The decisions of a person or business and the growth of an area depends on who they are and the specific circumstances which face them.

⁶⁷ For example, the Los Angeles metropolitan area population grew by 27 percent from 1982 to 1999 while the annual hours of delay per person rose by 80 percent. Los Angeles has the highest estimated delay per person. David Schrank and Tim Lomax, *The 2001 Annual Urban Mobility Report* (Texas Transportation Institute, 2001) Tables A-1 and A-5.

⁶⁸ Harry W. Richardson and Peter Gordon, *Counting Non-work Trips*, 48(9) (Urban Land, 1989) 6-12.

⁶⁹ See section on Urban Mobility Report findings. Also, David M. Levinson and Ajay Kumar in their article *The Rational Locator: Why Travel Times Have Remained Stable* (Journal of the American Planning Association, Vol. 60, No. 3, Summer 1994, pp. 319-332) found, from household travel survey data for 1968 and 1988 for the Washington D.C. metropolitan area, that the average home-to-work travel time had not changed over that 20-year period (32.5 minutes). This was consistent with the results of a 1957 survey sponsored by Fortune Magazine (33.5 minutes). Not only are the 1968 and 1988 averages the same, but the cumulative distributions are almost identical. Alan E. Pisarski in *Commuting in America II* (Lansdowne, VA: Eno Transportation Foundation Inc., 1996) p. 91, found that the national average travel time increased from 1980 to 1990 by only 40 seconds, from 21.7 minutes to 22.3 minutes. Figure 3-64 on page 92 shows that average commute times for most large metropolitan areas changed by less than 10 percent.

Nevertheless, people share some common motivations and circumstances, such as the desire to improve their economic well-being, the economic advantages of specialization and trade, the cost of travel and the competition for space. These commonalities explain much about general patterns of growth, development, travel and congestion.

Economic Growth Results from Specialization and Trade

Perhaps no economic principle is more important to the fundamental understanding of why economies develop, why there is travel, why cities grow and why congestion is so difficult to solve than that of comparative advantage. The principle of comparative advantage is that when people, firms, regions or countries differ in their relative costs for producing various items, all will be better off when each specializes by producing the items at the lowest relative cost, and trades for the items that would cost them relatively more to produce.⁷⁰

It is important to note that specialization and trade are advantageous even when the parties involved have no absolute cost advantages. It is only necessary that their relative costs for producing the items differ. Consider, for example, two medieval craftsmen who both make shoes and clothing. One can make one pair of shoes or two shirts in a day. The other can make two pairs of shoes or three shirts in a day. At first glance, it might appear that there would be no advantage for the second craftsman to trade with the first because he could make more shoes and more shirts in a day. But it turns out that both craftsmen are better off if the first one specializes in shirt production and the second in shoe production.

The first craftsman is relatively better at shirt production. He can produce two shirts in the time it takes him to produce one pair of shoes, whereas the second craftsman can only produce one and a half shirts for each pair of shoes he produces. If the first craftsman produces six shirts and trades them to the second craftsman, he could get back four pairs of shoes if the second craftsman trades at his production ratio. This is one more pair of shoes than the first craftsman could produce himself. If the second craftsman produces two pairs of shoes and trades them to the first craftsman, he could get back four shirts if the first craftsman trades at his production ratio. This is one more shirt than the second craftsman could have produced himself. Although neither craftsman would be willing to trade at his own production ratio, it is clear that there could be some intermediate terms of trade where both would be better off⁷¹.

⁷⁰ The principle of comparative advantage is variously referred to as an economic theory or law. It is credited to David Ricardo with the proof contained in his book *On the Principles of Political Economy and Taxation* published in 1821. Most economics textbooks discuss comparative advantage in terms of international trade (e.g. Paul A. Samuelson's *Economics*, now in the 17th edition), but the principle applies equally at the scale of individuals, firms and regions (see John P. Tiemstra, *Economics: A Developmental Approach*, 2nd ed., Loudonville, OH: Mohican Publishing Co., 1999). The relationship with comparative advantage regional specialization and interregional transportation is explored in Edward J. Taaffe, Howard L. Gauthier, and Morton E. O'Kelly in *Geography of Transportation*, 2nd ed., Prentice-Hall, Upper Saddle River, NJ, 1996.

⁷¹ For example, the second craftsman could trade four pairs of shoes for seven shirts. He would get one more shirt than he could produce in the same amount of time (7 vs. 6) and his trading partner could get an extra shoe for his work (4 pair vs. 3.5 pair).

The potential benefits of comparative advantage lead to specialization and trade. Although most people do not think about this principle, they do know that they will be materially better off if they obtain the knowledge, training and tools that allow them to specialize in some trade or profession and get higher pay. Recent decades have seen large changes in this regard as the percentage of women holding paid jobs increased greatly and households increasingly purchased services which were formerly done in the home. This change was accompanied by a rise in household and per capita incomes (and travel).⁷² The result of the principle of comparative advantage is that individuals and businesses are usually better off materially if they specialize in what they do best and trade for the rest, rather than if they try to do everything themselves. This is the general basis of trade and economic development.

The potential for turning economic advantage into comparative advantage depends on technology, transaction costs and market size. Comparative advantage is increased by investing in technologies that reduce production costs and/or improve product quality. Technological advancement and specialization reinforce one another in improving comparative advantage. Technological advancement is the product of specialized knowledge which, in turn, produces new specialties. For example, computers were invented by people with specialized knowledge in mathematics and electronics. Once invented, computers spawned a myriad of employment specialties.

The potential benefits of comparative advantage depend on transaction costs as well. To realize any economic benefits, the transaction costs have to be low enough to make trading worthwhile. In the example of the medieval craftsmen, trading four pairs of shoes for seven shirts would be beneficial to the first craftsman only if it would take less than half a day to make the trade. For the second craftsman, the trade would be worthwhile only if it could be made in less than a third of a day.

Since trading requires travel, the time and money costs of travel are principal components of transaction costs. Reducing the cost of travel reduces transaction costs and increases the potential benefits of comparative advantage. For example, several researchers estimate that past investments in highways stimulated a substantial amount of economic growth and a sizable return on investment.⁷³ This has been a primary motivation for expanding transportation systems and inventing faster and cheaper modes of transportation. In general, transportation improvements expand markets, trade and economies.

Market expansions also increase the potential benefits of comparative advantage. The dilemma of specialization is that while it increases the comparative advantage it also decreases the number

⁷² See Catherine T. Lawson, *Household Travel/Activity Decisions: Who wants to Travel?*, Discussion Paper 98-4 (Center for Urban Studies, Portland State University, July 1998). A version of this paper was also published in the 78th Annual Meeting of the Transportation Research Board. This paper reviews the literature regarding the relationships between household and market economy.

⁷³ David Alan Aschauer, *Public Investment and Private Sector Growth: The Economic Benefits of Reducing America's "Third Deficit"* (Washington, D.C: Economic Policy Institute, 1990). Kazem Attaran and Philippe Auclair, *Highway Stock and Private-Sector Productivity*, Transportation Research Record 1274 (1990): 119-124. Arthur C. Jacoby, *Recent Advances in Understanding the Effects of Highway Investment on the U.S. Economy*, Transportation Quarterly, Vol. 53, No. 3 (Summer 1999): 27-34.

of instances where those skills are needed. Therefore, the degree of specialization that can occur depends on the size of the market. For example, most towns are large enough to support one or more dentists because most people see their dentist at least a couple times a year. People see an oral surgeon much less frequently, so it is difficult for an oral surgeon to make a living in a small town. As markets enlarge – either through population growth or transportation improvements that increase the market area – they can support increased specialization, and with increased specialization they can take advantage of the economic development that comes from comparative advantage.

People Cluster their Activities to Reduce Transaction Costs

Trade requires communication and travel and the cost of both greatly affects population distributions.⁷⁴ Communication is required in order to become aware of trading opportunities and to make transactions. Travel also serves this purpose and is essential for delivering most goods and services. In general, reducing communication and travel costs results in lower transaction costs and increased opportunities to realize the economic benefits offered by comparative advantage. The primary means of reducing these costs is by clustering people and their activities and through advancing communication and transportation technologies.

Clustering people and their activities generally makes communication and travel easier and cheaper, thus reducing transaction costs and increasing trading opportunities. The economic advantages of clustering are often called agglomeration economies.

Pulling people together into a business or other organization may further reduce transaction costs. When people are grouped together in one organization, their costs for communication, transportation and other aspects of transactions may be cheaper than they would be if they individually made transactions through the market. Moreover, some production processes and technologies that involve much division of labor and/or mechanization are only possible when all of their components are clustered in one location to minimize transportation and communication costs (e.g. auto assembly line, integrated circuit production). When mass producing a good results in lower average costs, economies of scale are said to occur. Firms gain from efficiencies realized from specialization.

For scale economies and agglomeration economies, the key principle is that clustering people and activities reduces transaction costs and therefore allows more production to occur through increased specialization.

Advances in communications and transportation technologies reduce the effect of distance on transaction costs, increase market areas and reduce the need for clustering. For example, before the advent of modern media and broadcast technologies – such as newspapers, radio, television, and telephones – travel was necessary for people to be aware of trading opportunities. The medieval craftsmen in our earlier example had to travel to a centrally located market to trade. The marketplace had to be compact because all communication was face-to-face. With the

⁷⁴ Financial and legal institutions, like money, are also important to trade, but not to this discussion.

development of print and then electronic communication, it became possible for people to communicate trading opportunities without meeting face-to-face. This, along with faster modes of transportation, reduced the need for commercial activities to be located in central market areas. Although many transactions are still completed face-to-face, communication advances such as the telephone and the Internet have allowed part of the transactions process to be completed without travel. For example, the L.L. Bean Company is located in a fairly remote part of the United States but has become a major retailer because of these technologies. Broadband communications are now allowing electronic media-based products (recordings, movies, e-books) to be delivered without transportation, making distance practically irrelevant to transactions costs for these products.

Advances in transportation technologies have increased travel speeds, expanded market areas and reduced the need for clustering as well. Average urban travel speeds nearly tripled during the 20th century as increasing numbers of people owned private motor vehicles and used them instead of public transportation. This increased the accessible area in the same amount of time nine-fold, and allowed urban densities to be a ninth of their former value without reducing trading opportunities.⁷⁵

Metropolitan Areas Balance Benefits of Trade and Specialization with Costs of Crowding and Congestion

Clustering has economic costs as well as benefits, which is why urban areas became less dense with the deployment of roads, cars and trucks. Putting more people in an area increases the demand for space. This includes space for siting homes, businesses and other structures, as well as space on transportation facilities for moving people and goods. More people competing for limited space means that each person can have less space. When the demand for space exceeds peoples' tolerance, it is called *crowding* in the case of land uses and *congestion* in the case of roads and other transportation facilities. Although crowding and urban congestion are similar consequences of clustering, there are significant differences in the nature of the demand for land and transportation space and how that space is allocated.

In the case of land, people and businesses compete in a market to gain exclusive use of a piece of property. Allocation among land uses is managed primarily through the marketplace by prices, although government policies like zoning determine overall land allocations. In Oregon, urban growth boundaries establish where urbanization may occur and zoning regulates how the supply of potentially urbanizable land is allocated among fairly broad categories of uses. Other regulations, such as protection of wetlands and endangered species, also affect the amount of land that may be developed. Markets allocate land within these limitations. As the demand for space increases relative to its supply, the price goes up and people consume less of it. When the price gets high enough, it may become worthwhile to incur the additional costs of multi-story building construction to get more usable space out of a piece of property.

⁷⁵ Boris Pushkarev and Jeffrey Zupan. *Public Transportation and Land Use Policy*. (Bloomington IL: Indiana University Press, 1977) 5.

In the case of roads, government policy has a greater effect on the overall supply of space. Not only does the government regulate the construction and expansion of roads, it also is the primary provider of roads.

The use and allocation of road space is also different from land space. Unlike land area, the consumption of space on roads is dynamic. Travelers consume an area of space as they move along a road. The amount of space available to travelers affects the comfort, convenience and cost of their travel. For example, when roadway traffic is light, each vehicle has more space around it. This allows faster driving but still maintains enough space around the vehicles to operate safely. As traffic becomes heavier, the road becomes more crowded and each driver has less space available. Because less distance separates them from other vehicles, they need to slow down in order to provide adequate time to react to the movements of other vehicles. At very high levels of crowding, drivers have very little space available to maintain a cushion. If they try to maintain a cushion between themselves and the vehicle ahead, another driver will soon fill it. The result is that traffic will move slowly and haltingly because the close spacing of vehicles leaves drivers little time to react to each other.

This competition for space on transportation facilities is not limited to roads, although roads require more space per traveler and their performance is more affected by crowding than other modes of transport. Competition for space and crowding also occurs on elevators, sidewalks, buses and subways in densely developed cities like New York, London and Tokyo and adversely affects traveler comfort, convenience and travel time. While a subway train travels just as fast when it is full or empty, the full train is less comfortable to ride and takes longer to load and unload at platforms. Moreover, when the demand is high, travelers may have to wait for the next train having space available.

The dynamic nature of the demand for transportation space varies by time of day, day of the week and season of the year. On most urban roads, the times of greatest demand for road space are the morning and evening rush hours. This varies depending on trip purposes and the function and setting of roads. Roads lined with commercial developments often experience low demand during the morning rush hour and high demand during the afternoon, the evening rush hour and weekends.

Another important difference between land and road space is that land space is allocated among users primarily by price but road space is rarely allocated by price. With land, those who value more space can get it by paying for it. With most roadways, that is not possible. People are allocated space based on whether they are willing to crowd onto the roadway. People already on the roadway must accommodate those who are entering and it will make conditions even worse if they do not.⁷⁶ When the demand becomes too great, the rate of traffic flow declines so fewer people may be accommodated. In the case of freeways, overcrowding may be moderated (aside

⁷⁶ This happens often at merges. Merging occurs more smoothly if drivers take turns yielding to one another rather than if people refuse to yield.

from adding lanes) through ramp metering or by providing high occupancy vehicle and bus lanes.⁷⁷

People pay the same in gas taxes and other road user fees whether they use road space during times of peak demand or not. The only options for obtaining more space are to switch to a less crowded route, time of day, or mode of travel (e.g. train). Overcrowding and lower performance occurs because pricing does not reflect the varying benefits that travelers receive on different roads and at different times of day. Value pricing (also called congestion pricing) attempts to ameliorate this overcrowding by using pricing to balance demand with performance. There are a number of toll roads and bridges with time-based pricing in the U.S but they are few and the practice is controversial.⁷⁸ A value pricing study was initiated for the Portland metropolitan area to determine whether peak-period pricing is an appropriate way to achieve transportation goals.⁷⁹ One result of the study is that Portland Metro adopted a policy in the 2000 Regional Transportation Plan that all studies to add major highway capacity must consider peak period pricing as an alternative.

Since transportation facilities also consume land, they must compete with other land uses for that space. As land prices are driven up through clustering, the cost of expanding transportation facilities also increases. Land is used more intensively (less vacant land and larger buildings) as demand for a limited amount of land space increases. Consequently, there is a greater likelihood that transportation facility expansions will require more expensive construction methods to avoid buildings or other structures, or will have to pay for their removal or alteration.

The greater demand for road space in large urban areas requires that construction activities use as little space as possible during periods of peak transportation demand. This makes it necessary to build expensive temporary facilities, and/or time the construction work to occur when traffic demand is low (at night). As urban areas grow, the sources of construction materials can become more distant, increasing the costs of transportation. Because road construction costs rise as metropolitan areas become larger, it becomes increasingly more difficult to expand the road system to keep up with rising demand. The result is that congestion levels rise as cities get larger.

⁷⁷ A comprehensive study of ramp meter effectiveness was recently completed in Minnesota (Cambridge Systematics, *Twin Cities Ramp Meter Evaluation*, Minnesota Department of Transportation, February 1, 2001). The study compared conditions on the freeways when ramp meters were turned off (at the direction of the Minnesota legislature) with conditions when the meters were operating. It found that without ramp meters, freeway traffic throughput decreased by 14 percent, delay (including delay at meters) increased substantially amounting to over 25,000 hours annually, crashes increased by 26 percent, delay due to crashes and other incidents increased substantially (equivalent to 2.6 million hours annually), and emissions and fuel consumption increased.

⁷⁸ For example, in June 2003, the Maryland governor instructed the Department of Transportation to end consideration of high-occupancy toll lanes on freeways in the state. High occupancy toll lanes are dedicated to cars with a certain number of passengers, or for an extra toll. See

<http://www.gov.state.md.us/gov/press/2001/jun/html/hotlanes.html>

⁷⁹ *Traffic Relief Options Study: Peak Period Pricing Incentives to Relieve Congestion* was published by Metro in November 2000. It can be seen at <http://www.metro-region.org/transpo/tros/tros.html>. The following website is a clearinghouse for value pricing information

www.hhh.umn.edu/centers/slp/conpric/conpric.htm.

Although metropolitan areas generally become more congested as they grow, their economies can tolerate more congestion because the size of their markets grows as well. Having larger markets means that they can receive greater benefits from comparative advantage. This is one of the primary reasons why large metropolitan areas continue to grow even though they are congested. As metropolitan areas get larger and more densely developed, public transportation becomes more economical to provide and service levels improve. This provides alternatives to traveling on congested roadways and increases the number of passengers the transportation system carries during peak periods.

Economies can grow despite rising congestion because people and businesses have several options for making travel and location substitutions. These include:

- Using less congested routes
- Traveling during less congested times
- Chaining trips to accomplish more with each trip (e.g. shopping on the way home from work)
- Traveling to a destination which requires less travel on congested routes
- Using a transportation mode which is less affected by congestion or substituting communications for travel
- Moving to another location that is less affected by congestion

In general, people will first choose options that lower overall transaction costs without compromising the benefits they receive from transactions.⁸⁰

Some apparently paradoxical congestion-related trends may be explained by these substitutions. An example of this has been the increase in the amount of non-work travel occurring during peak hours. As peak-hour congestion increases, non-work travel could be expected to shift to less congested times. Exactly the opposite occurs because workers increasingly chain non-work trips with their morning and evening commutes in order to save time. As the percentage of adults in the labor force increases, the average amount of time available for doing household errands decreases. Workers, particularly women, economize by combining non-work trips with work trips.⁸¹

⁸⁰ Richard G. Dowling and Steven B. Colman, *Effects of Increased Highway Capacity: Results of a Household Travel Behavior Survey* (Paper presented at the Transportation Research Board Annual Conference, January 1997). Dowling and Colman found that people had the following order of preferences in how to cope with increasing travel time: 1st – Change route; 2nd – Change schedule; 3rd – Combine trips; 4th – Change travel mode; 5th – Change destination.

⁸¹ David Levinson and Ajay Kumar, *Activity, Travel, and the Allocation of Time*, Journal of the American Planning Association, Vol. 61, No. 4 (Autumn 1995) 458 - 470. This analysis of travel survey data for 1968 and 1988 in the Washington D.C. metropolitan area shows a two-hour shift in the peak for non-work auto trips from 7:00 p.m. in 1968 to 5:00 p.m. in 1988. Others have also researched or written about this shift including:

- James G. Strathman and Kenneth J. Dueker, *Understanding Trip Chaining*, 1990 NPTS Special Reports on Trip and Vehicle Attributes, Report FHWA-PL-95-033, (U.S. Department of Transportation, Federal Highway Administration, 1995).
- Anthony Downs, *Stuck in Traffic: Coping with Peak-Hour Traffic Congestion* (Washington, D.C.: The Brookings Institution, 1992).

VEHICLE TRAVEL AND ECONOMIC TRENDS IN OREGON

The economic theory presented in the previous section suggests that economic activity and travel are strongly correlated. Andreas Schafer and David Victor found support for this in their study of travel in countries around the world. "As average income increases, the annual distance traveled per capita by car, bus, train or aircraft (termed motorized mobility, or traffic volume) rises by roughly the same proportion. The average North American earned \$9,600 and traveled 12,000 kilometers (7,460 miles) in 1960. By 1990 both per capita income and traffic volume had approximately doubled."⁸²

Over the past 30 years in Oregon, the relationship between statewide economic activity and total VMT on roadways has been strong. A logical place to examine this relationship is with changes in statewide per capita VMT from 1970 to 2002. Figure B-4 shows that annual per capita VMT over that period rose by 50 percent.

Per capita VMT does not account for changes in the average amount of production per person. This can be addressed by comparing vehicle travel with total jobs and personal income. Total jobs are used rather than total number of employed persons because some people hold more than one job. The number of commuting trips should be more closely related to the number of jobs than the number of employees. Total personal income is used because it is a more complete measure of the economy than the number of jobs. Total personal income for all Oregonians includes net earnings (wages and salaries minus Social Security deductions), transfer payments (income maintenance, unemployment benefits, retirement), dividends, interest and rental income. The results for the two measures turn out to be fairly close.

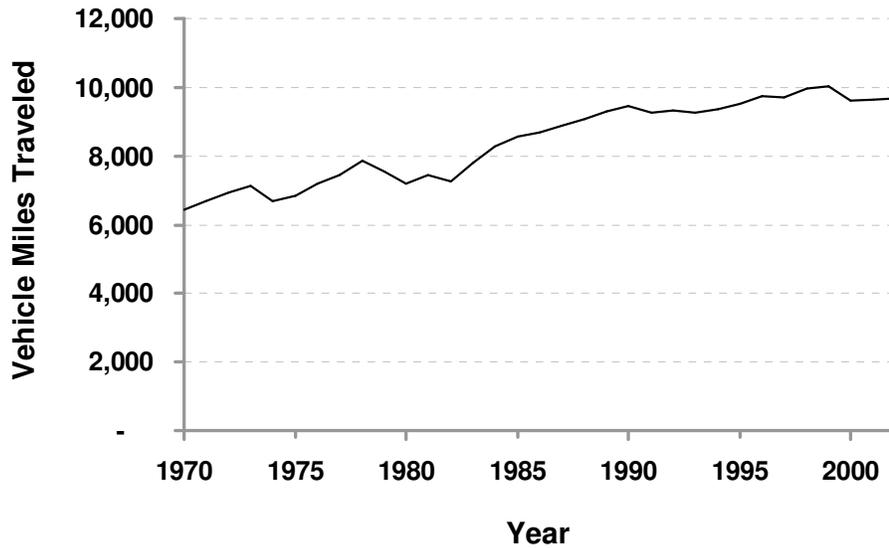
Whereas per capita VMT (Figure B-4) increased by about 50 percent from 1970 to 2000, VMT per job increased by only 5 percent (Figure B-5). VMT per job fluctuated between 14,000 and 15,000 annual miles in the 1970s and the beginning of the 1980's, climbed to around 16,000 annual miles in the 1980s and then very slowly declined.

The relationship shown in Figure B-5 is incomplete because it does not account for all economic activity. The average income per job could change over time or other income sources, such as retirement income, could affect the amount of vehicle travel. Wages and salaries make up about two-thirds of statewide personal income⁸³.

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- Catherine T. Lawson, *Household Travel/Activity Decisions: Who wants to Travel?* Discussion Paper 98-4, (Center for Urban Studies, Portland State University, July 1998).
 - Nancy McGuckin and Elaine Murakami, *Examining Trip-Chaining Behavior: A Comparison of Travel by Men and Women*, (Federal Highway Administration, 1995) NPTS <http://www-cta.ornl.gov/npts/1995/Doc/publications.shtml>

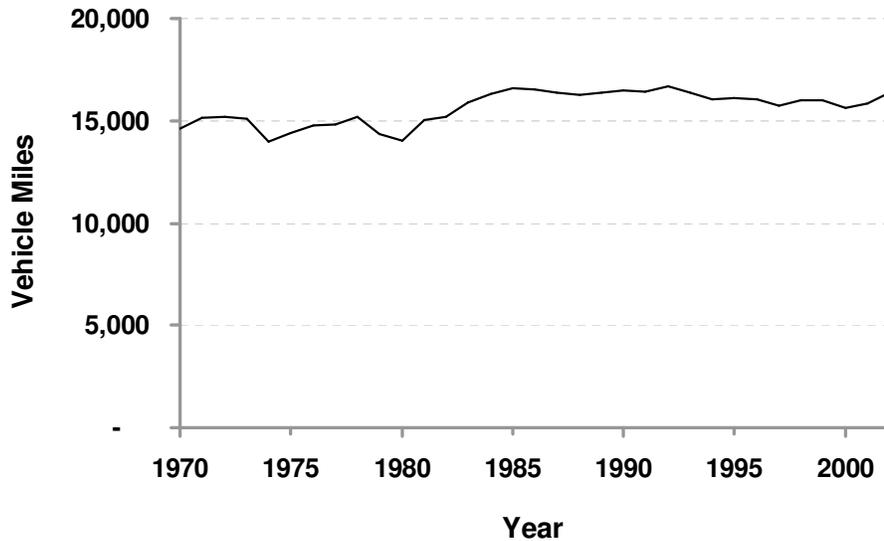
⁸² Andreas Schafer and David Victor. *The Past and Future of Global Mobility*, Scientific American, Vol. 277, No. 4 (October 1997) 59.

⁸³ In 2000, the total personal income in Oregon was \$94,999,226,000. Of this, 66 percent was wages, salaries and other labor income, not including deductions for Social Security taxes; 21 percent was dividends, interest and rental income; and 13 percent was transfer payments. Source: U.S. Bureau of Economic Analysis, *Regional Accounts Data, Annual State Personal Income*, Table SA05 Personal income by major source and earnings by industry – Oregon.



Source: VMT—ODOT Finance Section; Population—Portland State University, Center for Population Research & Census.

Figure B-4. Annual Per Capita VMT in Oregon: 1970-2002



Sources: VMT – ODOT Finance Section; Jobs – Bureau of Economic Analysis.

Figure B-5. Average VMT per Job in Oregon: 1970-2002

Figure B-6 shows the relationship between total statewide vehicle miles traveled and total statewide personal income adjusted for inflation.⁸⁴ This figure shows that the annual miles of vehicle travel per \$1,000 of income has stayed fairly constant at about 360 miles.



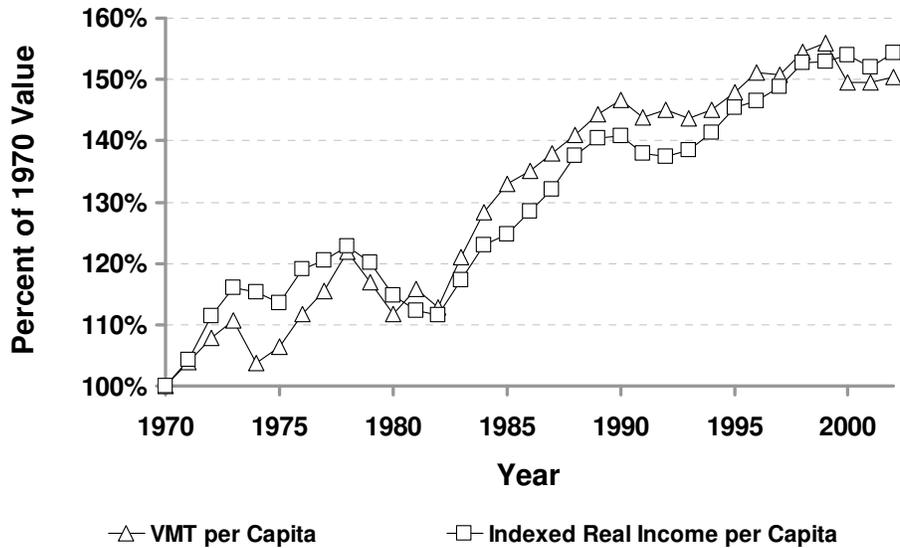
Source: VMT—ODOT Finance Section; Personal Income—US Bureau of Economic Analysis; CPI - Bureau of Labor Statistics (Portland area CPI).

Figure B-6. Average VMT per \$1000 of Personal Income in Oregon: 1970-2002

This constant trend suggests that the amount of travel required as an input to the state’s economy has not changed over the last 30 years. This trend is supported by information in Appendix A, which shows that the ratio of travel time to income in the Portland area remained almost constant between 1982 and 2001. The strength of the relationship between the growth of travel and the growth of the economy is shown in Figure B-7. The patterns of growth follow each other closely; VMT increases where income increases and vice versa.

The same pattern is shown for the relationship between state highway VMT and personal income. Since total statewide VMT and state highway VMT are estimated using different methods, the fact that both are strongly correlated with total personal income reinforces the strength of the relationship between VMT and the economy.

⁸⁴ Income was adjusted for inflation using the consumer price index for the Portland metropolitan area published by the Bureau of Labor Statistics. Prices are represented in year 2000 dollars.



Sources: VMT—ODOT Finance Section; Income—Bureau of Economic Analysis; CPI—Bureau of Labor Statistics (Portland area CPI); Analysis—ODOT Transportation Planning Analysis Unit

Figure B-7. Comparison of Per Capita Vehicle Travel and Real Personal Income in Oregon: 1970-2002

The relationship between statewide travel and statewide income illustrates the importance of the connection between travel and the economy. It is reinforced by the explanation in the previous section. Economic growth results from the economic benefits of comparative advantage that lead to specialization and trade. Trade requires transportation, so as growth occurs, so will travel.

WORK INCREASES VEHICLE TRAVEL

The previous section provides a theoretical underpinning of why the growth of travel is closely tied to the growth of the economy. The growth in vehicle miles traveled is strongly associated with growth in jobs and personal income. Since 1970, not only did the state’s population grow, but there were major demographic, social and economic changes that expanded the economy by shifting a large amount of personal time from unpaid household work and leisure into the market economy. Consequentially, the amount of specialization and trade increased and this simultaneously increased the size of the market economy and travel.

One of the most visible changes is in the number of people who are paid for their work. The labor force in Oregon more than doubled⁸⁵ from 1970 to 2001 while population increased by 65 percent.⁸⁶ The most significant contributing factors to the growth of the labor force are the

⁸⁵ The labor force includes those people who are working or who are actively pursuing work. In 1970, the labor force in Oregon was 864,500 and by 2000 rose to 1,794,000.

⁸⁶ Population in 1970 was 2,100,388 and in 2000 was 3,471,700.

transition of the baby boomer generation from dependent to worker, and the transition of a large share of women from home laborer to paid laborer.

Most of the baby boom generation entered the work force after 1970. From 1975 to 2001 (data is not available before 1975) the working age population (16+) increased from 72 percent to 76 percent of the population. Also during that period, the percentage of women participating in the labor force increased from 48 percent to 62 percent. Together these trends increased the proportion of the total population who were paid workers from 45 percent in 1975 to 53 percent in 1999.

Not only are more people working today, but many are also working more hours, a trend contrary to that of the rest of the industrialized world. According to The Harris Poll, the average number of hours spent working per week in the United States increased from 41 in 1973 to 50 in 1998 where it remained until 2002, when it dropped to 47 hours.⁸⁷ The recent drop is a result of the current economic recession. Labor force participants were working 163 more paid hours a year in 1987 than in 1969 (about an extra month). Women in the labor force were working 305 more paid hours a year.⁸⁸

According to the International Labour Organization, annual work in the United States increased from 1795 hours in 1960 to 1966 hours in 1998. Workers in the United States worked on average 171 more hours in 1998 than they worked in 1960, the equivalent of about a month's worth of work (21.4 days at 8 hours per day).⁸⁹ This is in contrast to the trends in Japan and European countries where the average annual hours dropped from 1960 to 1998 as follows: Japan from 2318 to 1889, Britain from 1958 to 1731, Germany from 2372 to 1560, France from 1919 to 1634.⁹⁰ This was accompanied by a relative decline in hourly wages in the United States compared to wages in Europe and Japan.⁹¹

Work hours in many European countries are lower in part because laws and collective bargaining agreements mandate paid vacations of from five to six weeks.⁹² That compares to the U.S. average of two weeks. These additional vacation weeks translate into fewer hours of annual work because workers and businesses do not increase hours in other ways.⁹³

The increase in working hours has economic roots. Average wage and salary income in Oregon has remained almost constant despite increased working hours (Figure B-8). Most workers saw declining wages despite longer work hours because an increasing share of income went to people

⁸⁷ *The Harris Poll*, #49, http://www.harrisinteractive.com/harris_poll/printerfriend/index.asp?PID=328 (September 25, 2002).

⁸⁸ Juliet Schor, *The Overworked American: The Unexpected Decline of Leisure* (New York, NY: Basic Books, 1992) 29.

⁸⁹ Reported in Kevin Phillips, *Wealth and Democracy* (New York: Broadway Books, 2002) 163, chart 3.28.

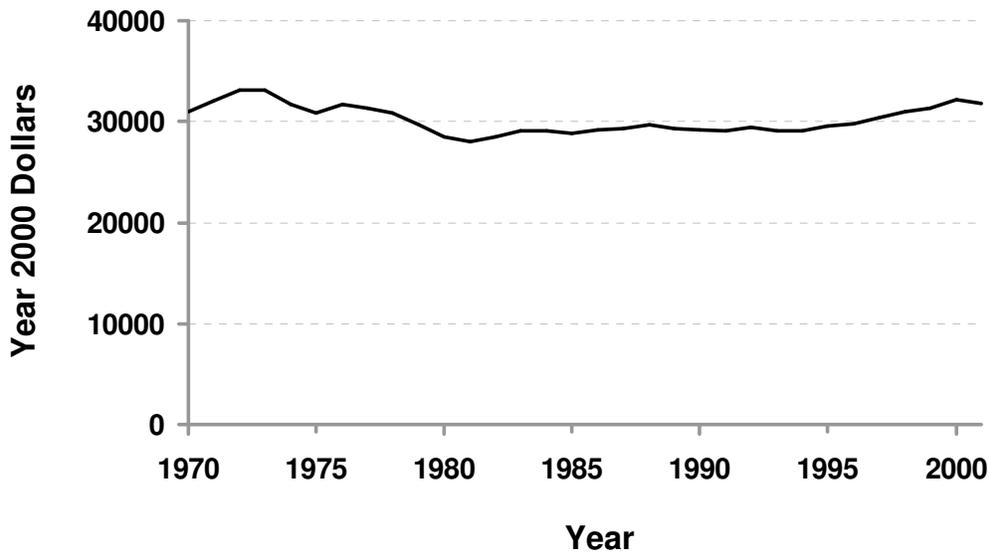
⁹⁰ Phillips.

⁹¹ Phillips, page 163, chart 3.29.

⁹² Schor, *The Overworked American*, 82.

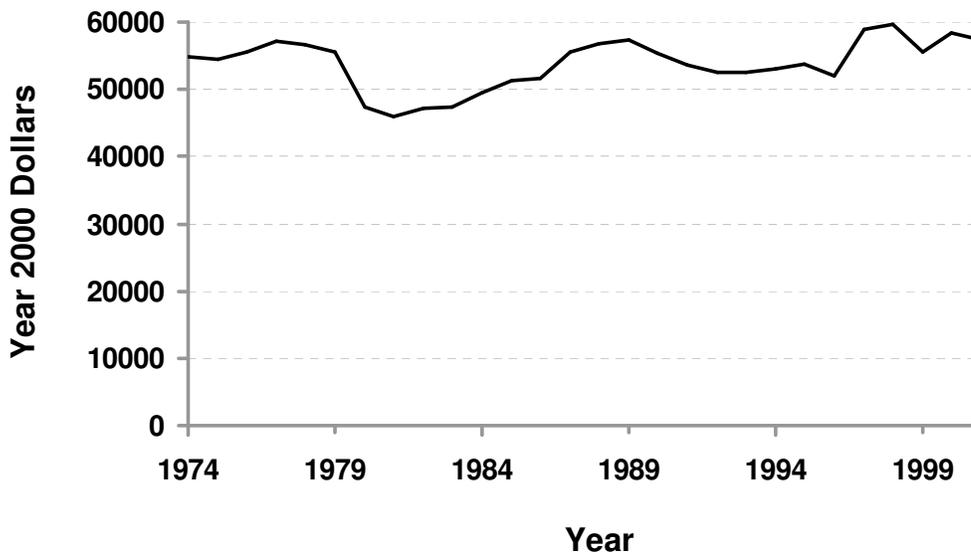
⁹³ Joseph G. Altonji and Jennifer Oldham, *Vacation Laws and Annual Work Hours*, Economic Perspectives, (Federal Reserve Bank of Chicago third quarter 2003) 19-29.

in the highest income brackets.⁹⁴ Most households experienced little or no economic gain despite working more hours (Figure B-9).



Sources: Income—Bureau of Economic Analysis; CPI—Bureau of Labor Statistics (Portland area CPI)

Figure B-8. Average Annual Wages in Oregon in Year 2000 Dollars



Sources: Income—U.S. Census Bureau, Median Income for 4-Person Families by State; CPI—Bureau of Labor Statistics (Portland area CPI)

Figure B-9. Median Income for 4-Person Families

⁹⁴ Kevin Phillips, *Wealth and Democracy* (New York: Broadway Books, 2002).

Of course, more workers working more days resulted in more commuting. But that was only one of the effects of increased work on travel. The bigger effects resulted from increasing specialization and trade as households put more hours into paid labor and fewer into household labor and leisure. This had a chain of effects on travel that are diagrammed in Figure B-10.

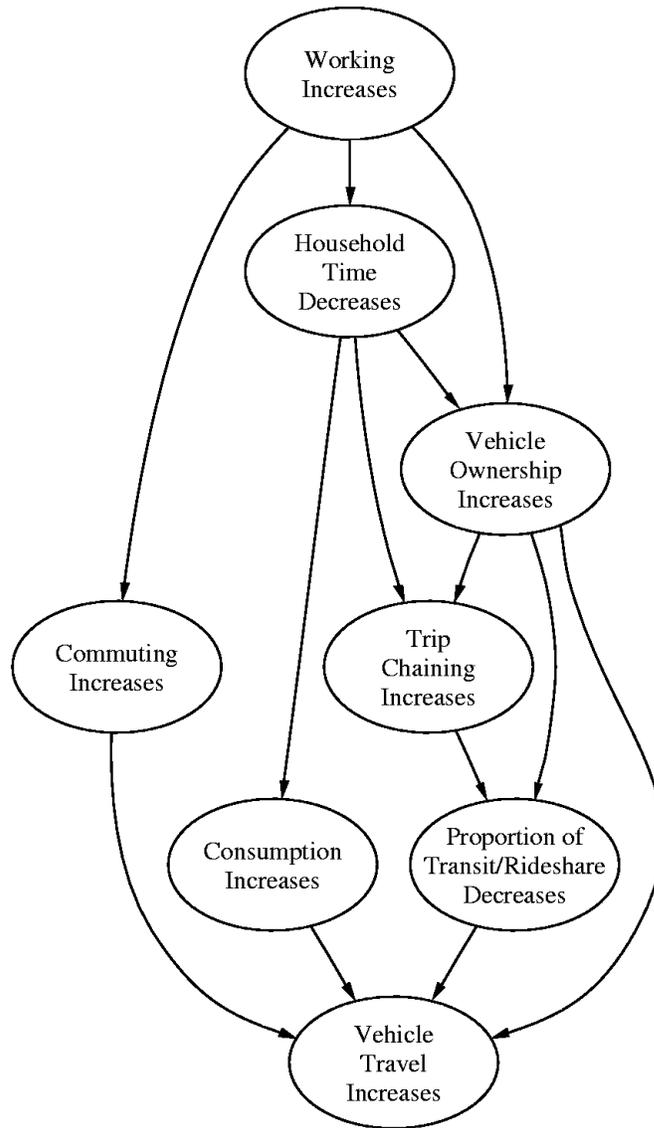


Figure B-10. Effects of Changes in Work and Consumption on Travel

Increased work hours resulted in decreased time available to do household activities such as caring for children, cooking and cleaning. From 1969 to 1987, the average time that women spent annually on household work declined by 249 hours while men's household work time

increased by 151 hours, resulting in an overall decline of about 70 hours per year per adult.⁹⁵ As the average time spent on household work declined, purchases towards household services increased. Workers hired others to assume some of the care for their children, purchased more prepared foods, and purchased more cleaning and household maintenance services among other things. For example, the number of paid childcare employees increased nationally from 190,000 to 468,000 from 1977 to 1992.⁹⁶ The proportion of household food expenditures spent on eating out increased from 26 percent in 1970 to 38 percent in 1997.⁹⁷ Nationally, per capita personal consumption expenditures doubled between 1970 and 2000.⁹⁸

Increases in consumption result in more travel. Shopping trips increased from about 29 percent of all household trips in 1969 to about 44 percent of all trips in 1995.⁹⁹ But shopping trips are only a part of the total number of trips that result from consumer purchases. For example, in the Salem metropolitan area, approximately 70 percent of all household trips involve travel for some item or service that is paid for such as shopping, eating out, seeing a movie or taking a child to daycare or school.¹⁰⁰

Not all of the increases in consumption are necessarily a result of increases in work and incomes. Since 1984, the average savings rate fell so a higher percentage of personal incomes is spent on consumption. From 1970 through 1984, the savings rate averaged 9.8 percent. Since then it has been on a predominantly downward trend and by 2001 fell to 2.3 percent.¹⁰¹ Consumer debt has also increased. On average, 18 percent of disposable personal income is spent on debt service, while average household debt (excluding home mortgage) roughly equals the average household

⁹⁵ Juliet Schor, *The Overworked American: The Unexpected Decline of Leisure* (New York, NY: Basic Books, 1992) 36.

⁹⁶ Lynne M. Casper and Martin O'Connell. *State Estimates of Organized Child Care Facilities*, Population Division, U.S. Bureau of the Census, Population Division Working Paper No. 21 (Washington, D.C., March 1998).

⁹⁷ Judith Jones Putnam and Jane E. Allshouse. *Food Consumption, Prices, and Expenditures, 1970-1997*, Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture, Statistical Bulletin No. 965, Table 99 – Food expenditures by families and individuals as a share of disposable personal income, 1970-97.

⁹⁸ Personal consumption expenditures in 1970 were \$2,317.5 billion in 1996 dollars and population was 205,052,000. In 2000, personal consumption expenditures were \$6,257.8 billion in 1996 dollars and population was 275,372,000. This equals an increase of 2.01. Source: *Economic Report of the President*, Council of Economic Advisors, February 2002, Tables B-2 and B-34.

⁹⁹ Johanna P Zmud and Carlos H. Arce, *Influence of Consumer Culture and Race on Travel Behavior*, Transportation Research Circular E-C026 – Personal Travel: The Long and Short of It (Transportation Research Board, 1999) 381. Data are drawn from the 1995 National Personal Transportation Survey (NPTS) and 1990 NPTS Databook, Vol. II.

¹⁰⁰ This is based on examination of the 1994 household travel survey data for the Salem-Keizer metropolitan area. It includes all person trips for items or services that are paid for. This includes retail purchases as well as goods and services that are paid for through annual or monthly charges, such as trips to an athletic club or to day care, and trips for services that are paid through taxes, most notably schools. It does not include trips that involved possible paid transactions such as trips to a church, community club, private residence or to a school for recreation.

¹⁰¹ Savings rate data from National savings rate, Bureau of Economic Analysis, National Accounts Data, saverate.xls, available at <http://www.bea.doc.gov/bea/dn1.htm>, updated July 6, 2001, personal savings as a percentage of disposable personal income.

income.¹⁰² Nationally, per capita personal consumption expenditures doubled between 1970 and 2000.¹⁰³

Consumer purchases induce additional travel resulting from the production of goods and services and their movement through the distribution chain. Consumer expenditures are responsible for about two-thirds of total national production.¹⁰⁴ Increases in consumer expenditures fueled the growth of new products and products that were formerly luxuries. Many consumer electronics products unknown in 1970, such as VCRs, CD players, video cameras and personal computers are now common household items being shipped across the country and around the world. Consumers also spend more on goods that were formerly seen as luxuries. For example, bottled water consumption in the United States increased from an average of 1.6 gallons per person per year in 1976 (354.3 million gallons) to 17 gallons per person per year in 1999 (4,646.1 million gallons).¹⁰⁵ The latter figure equates to about 18 million tons of water being transported in one million trucks on the nation's highways.¹⁰⁶

The increase in consumer expenditures and growth of the economy in general resulted in a greater rate of growth of truck traffic than traffic as a whole. From 1980 to 2002, medium and heavy truck VMT doubled compared to a 78 percent increase for cars and other light vehicles.¹⁰⁷

Increases in consumption also affect travel by changing the form of the retail landscape. Many types of commercial establishments provide a variety of convenience goods and services have grown up along suburban arterials. For example, the number of fast food restaurants grew at almost three and a half times the rate of population growth in the Portland metropolitan area and over four times the rate of population growth in the Eugene/Springfield metropolitan area.¹⁰⁸ This affects where people shop and where traffic is concentrated on the road system. Retail development is increasingly oriented to automobile access.

¹⁰² Schor, *The Overspent American: Upscaling, Downshifting, and the New Consume* (New York: Basic Books, 1998) 72.

¹⁰³ Personal consumption expenditures in 1970 were \$2,317.5 billion in 1996 dollars and population was 205,052,000. In 2000, personal consumption expenditures were \$6,257.8 billion in 1996 dollars and population was 275,372,000. This equals an increase of 2.01. Source: *Economic Report of the President*, Council of Economic Advisors (February 2002) Tables B-2 and B-34.

¹⁰⁴ 1997 total personal consumption expenditures were \$5,529,283 million and GDP was \$8,318,442 million. Source: Peter D. Kuhbach and Mark A. Planting, *Annual Input-Output Accounts of the U.S. Economy, 1997*, Survey of Current Business, January 2001) 9, Table A.

¹⁰⁵ International Bottled Water Association, http://www.bottledwater.org/public/volume_growth_and_consumption.htm.

¹⁰⁶ Eight pounds per gallon. About 37,000 lbs of water per truck estimated from ODOT truck commodity flow survey conducted in 1997.

¹⁰⁷ Based on estimates of annual statewide VMT from the ODOT Finance Section 1980 to 2001 and state highway VMT estimates from the ODOT Transportation Data Section for 1980 - 2002. In 1980 the total state annual VMT was about 19 billion and in 2002 it was about 34 billion. Medium and heavy truck VMT was about 1.2 billion in 1980 and about 2.4 billion in 2002.

¹⁰⁸ Between 1970 and 1995, the population of the counties comprising the Portland, Salem, Eugene, and Medford metropolitan areas grew by 48 percent, 68 percent, 41 percent and 74 percent while the phone book listings of fast food restaurants increased by 167 percent, 132 percent, 200 percent and 233 percent, respectively. Source: US Census Bureau and area phone books.

The residential landscape also reflects increasing levels of consumption. People are consuming larger quantities of housing space, thus reducing residential densities. In 1970, the national average new house size was about 1500 square feet. By 1997, this increased to about 2150 square feet (an increase of 43 percent). The average per capita consumption of space in new houses increased by an even greater amount (70 percent) because of falling household sizes.¹⁰⁹ This has not been just a "suburban sprawl" trend. Densities have fallen in older urban neighborhoods as singles, small families, and empty nesters purchase homes that formerly housed much larger families. For example, the population of a number of older neighborhoods in East Portland declined by 3 to 6 percent between 1990 and 2000.¹¹⁰

The increase in work and decrease in household time increases the need for families to economize on travel time. This leads to more use of private vehicles. The attractiveness of private vehicles is particularly strong for multiple worker families who are able to purchase extra vehicles and have greater needs to economize on travel time. Private vehicles can offer considerable time savings. For example, people who drive or ride in private vehicles spend on average half the time on their commutes as people who use public transit.¹¹¹ The number of vehicles per driving-age person in Oregon increased by about 18 percent from 1975 to 2001.¹¹² When households own more vehicles, they tend to use them more.

Workers also economize on their time by linking non-work activities such as shopping with commutes to and from work.¹¹³ Women workers in particular chain together work and non-work trips.¹¹⁴ In Oregon, around 20 to 30 percent of trips to work are chained and about half of all household trips are chained.¹¹⁵ While it is easy to chain trips when commuting by personal car, it is harder when commuting on public transportation or carpooling with others. Consequently, efforts to economize on travel time by linking non-work travel with daily commutes results in greater vehicle use as people substitute private vehicles for public transit or carpooling. For example, commuter carpooling in Oregon dropped dramatically from 17.6 percent of all

¹⁰⁹ Reported sources: National Association of Home Builders, *Environmental Building News*, Small Houses Supplement, Volume 8, No. 1 (January 1999); U.S. Bureau of the Census, Census Data, *House and Family Size 1940-1997*, see <http://www.buildinggreen.com/features/sh/small.html>. The average number of persons per household in 1970 was 3.14 and in 1997 was 2.64, so the average square feet per person was 478 and 814, respectively.

¹¹⁰ *The Oregonian*, Portland, OR (Friday, March 16, 2001) A1 & A16.

¹¹¹ Patricia S. Hu and Jennifer R. Young. *Summary of Travel Trends*, 1995 Nationwide Personal Transportation Survey (U.S. Department of Transportation, Federal Highway Administration, December 1999) 43, Figure 11.

¹¹² There were about 1,628,000 motor vehicles registered in Oregon in 1975 and 3,039,000 in 2001 (Source: *Highway Statistics*). The population 16 years and older in Oregon grew from about 1,666,000 in 1975 to about 2,633,000 in 2001 (Source: Oregon Employment Department).

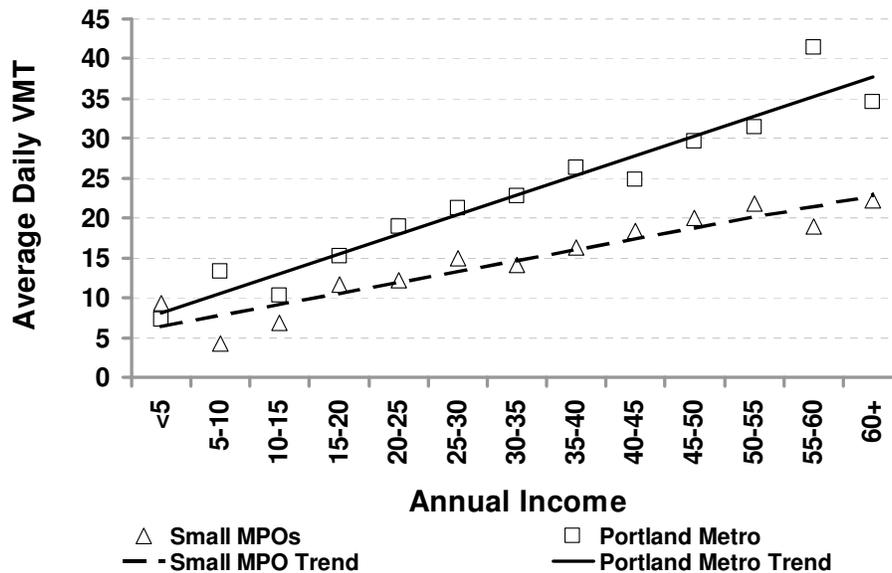
¹¹³ Levinson and Kumar, *Activity, Travel, and the Allocation of Time*, Journal of the American Planning Association, Vol. 61, No. 4 (Autumn 1995) 458 – 470.

¹¹⁴ Nancy McGuckin and Elaine Murakami. *Examining Trip-Chaining Behavior: A Comparison of Travel by Men and Women*, (Federal Highway Administration, 1995) NPTS at <http://www.cta.ornl.gov/npts/1995/Doc/publications.shtml>

¹¹⁵ ODOT Transportation Planning Analysis Unit. Analysis of household survey data for Salem, Eugene-Springfield and Medford metropolitan areas and for Clatsop, Coos, Deschutes, Josephine, Klamath, Lincoln, Malheur, and Umatilla counties.

commuters in 1980 to 12.8 percent of all commuters in 1990.¹¹⁶ By 2000, the percentage of workers who rideshare to work in Oregon declined to 12.6 percent.¹¹⁷ Nationally, the biggest declines in carpooling have come from the reduction in the number of carpools of three persons or more.¹¹⁸ Commuter carpools are increasingly likely to be composed of workers from a single household.¹¹⁹ The increase in trip chaining has the side effect of increasing congestion and extending the duration of travel peaks, particularly the afternoon peak.¹²⁰

Of course, not all persons or households were affected in equal measure by these changes. Work and consumption patterns vary with lifestyles. For example, jobs affect how much income a person makes, who they associate with and where they live. Household income in particular has a substantial impact on household travel. Figure B-11 shows that average daily VMT per household increases with increasing household income. Households in the Portland metropolitan area travel more than households in the smaller metropolitan areas (Salem, Eugene-Springfield, Medford). Moreover, household travel in the Portland metropolitan area increases at a faster rate with rising incomes. These travel differences are a result of Portland's much larger market, which supports more specialization and provides many more trading opportunities.



Sources: ODOT Transportation Planning Analysis Unit, analysis of Oregon Household Travel Survey data from 1994-1995

Figure B-11. Average Income and VMT for Households in Oregon's Metropolitan Areas

¹¹⁶ U.S. Bureau of the Census, *1980 Census*, Table 233. State of work during the reference week by selected characteristics, *1990 Census*.

¹¹⁷ U.S. Bureau of the Census, *2000 Census Supplementary Survey Summary Tables*, QT-03, Profile of Selected Economic Characteristics: 2000, Oregon

¹¹⁸ Pisarski *Communing in America II*, (Lansdowne, VA: Eno Transportation Foundation Inc., 1996) 61.

¹¹⁹ Pisarski, p. 62.

¹²⁰ Levinson and Kumar, *Activity, Travel, and the Allocation of Time*, *Journal of the American Planning Association*, Vol. 61, No. 4 (Autumn 1995) 468.

Consumption and travel are greatly affected by lifestyle choices. Expenditures and travel vary by income, age, number of household workers, number of children and other socioeconomic characteristics.¹²¹ They also are affected by less tangible factors such as attitudes. For example, the percentage of income that a person spends is closely related to, among other things, their choices of who they aspire to live like and how much television they watch.¹²²

Where people choose to live is also affected by their attitudes. Travel behavior studies found attitudes to be strongly related to travel behavior and more influential than neighborhood characteristics.¹²³ In other words, people select where they live based on how they want to live and travel as well as budgetary considerations. The variations in travel patterns that we observe around urban areas reflect these lifestyle choices. Market researchers recognized the relationship between location, lifestyle and consumption several decades ago and have been developing detailed geographic inventories of lifestyle clusters for analyzing markets for products and services. One example is the PRIZM system that identifies 62 different lifestyle clusters and maps these to neighborhoods throughout the United States.¹²⁴ For example, the "kids & cul-de-sacs" cluster is composed of upper-middle income families living in upscale suburban subdivisions. They spend a lot of time driving their kids to after-school and weekend activities in minivans and sport-utility vehicles.¹²⁵ In contrast, the "Single City Blues" cluster includes lower-middle-income singles living in older urban neighborhoods like Southeast Portland. They tend to be less acquisitive, buy used cars, and walk and bicycle more frequently than average.¹²⁶

While the statewide travel trends described reflect overall changes in lifestyles of Oregonians, travel trends in individual communities and neighborhoods reflect changes in the lifestyle composition of those areas as well. Such changes can occur as a result of changes in the social and economic characteristics (e.g., age, number of children, income) of the households in an area as well as differences in the lifestyle of people moving into and out of the area over time. This is an important consideration when evaluating transportation and land use policies that are intended to affect travel behaviors.

¹²¹ Ryuichi Kitamura, *Life Style and Travel Demand, A Look Ahead: Year 2020*, Proceedings of the Conference on Long-Range Trends and Requirements for the Nation's Highway and Public Transit Systems, Special Report 220 (Washington, D.C.: Transportation Research Board, 1988).

¹²² Schor. *The Overspent American: Upscaling, Downshifting, and the New Consumer*, New York, NY: Basic Books, 1998) 72.

¹²³ Ryuichi Kitamura, Patricia Mokhtarian and Laura Laidet, *A Micro-Analysis of Land Use and Travel in Five Neighborhoods in the San Francisco Bay Area*, Institute of Transportation Studies, University of California, Davis, UCD-ITS-RR-94-28 (November 1994).

¹²⁴ Michael J. Weiss, *The Clustered World: How We Live, What We Buy, and What it All Means About Who We Are* (New York, NY: Little, Brown and Company, 2000) 25.

¹²⁵ Weiss, pp. 198-199

¹²⁶ Weiss, pp. 280-281

TRAFFIC GROWTH IS PRIMARILY A RESULT OF ECONOMIC GROWTH IN OREGON

The evidence points to growth of total VMT in Oregon as being the consequence of economic growth. The statewide trends in real personal income and VMT (both total VMT and state highway VMT) is almost identical for three decades. Over this time period there was an average of 360 vehicle miles of travel per \$1,000 of real personal income. This amount varied by about 8 percent (+/- 29 miles per \$1,000).¹²⁷ Because average wages (per job but not per hour) were fairly constant, the ratio of VMT and jobs were also fairly constant at about 15,500 vehicle miles per job.

The constancy of this relationship is remarkable considering the variety of changes that occurred in Oregon over the past 30 years. These include changes in the labor force, the economic structure of the state, the distribution of population and jobs, and land use and transportation policies.

This relationship between vehicle travel and the size of the economy makes sense in light of the economic relationships discussed earlier. In general, economic growth occurred as a consequence of increased specialization and trade. Changes in the economy and labor force resulted in more people spending more time doing specialized paid labor and less time doing generalized household labor (and leisure). This also resulted in growth of trade and travel. The constancy of the relationship between total vehicle travel and total personal income implies that the average economic returns of vehicle travel in Oregon remained relatively constant over the past 30 years.

These findings raise questions about popular notions regarding the cause of growing VMT. Some assert that highway construction and suburban sprawl are the principal causes of increasing vehicle travel.¹²⁸ The theory is that demand for travel behaves like demand for most other goods and services - if the cost goes down, people will travel more.¹²⁹ Travel increases because people make more vehicle trips, make longer vehicle trips, substitute vehicle travel for riding public transportation or walking, or because households and businesses are encouraged to spread out by greater accessibility. This is called induced travel. The theory also predicts that suppression of travel will occur if the cost of travel goes up, for example, from increased congestion or increased road tolls.

This is an important issue to address because transportation policies developed according to the belief that highways and sprawl cause increased VMT could be very different than policies based on the belief that economic changes are primarily responsible for increased travel. At their strongest, induced travel arguments suggest that adding capacity is a futile activity because it

¹²⁷This is two standard deviations from the mean - 30 out of 31 years fall within this range.

¹²⁸ Surface Transportation Policy Project, *Why Are The Roads So Congested? A Companion Analysis of the Texas Transportation Institute's Data On Metropolitan Congestion* (November 1999).

¹²⁹ See *Working Together to Address Induced Demand* (Washington, D.C.: ENO Transportation Foundation, 2002). Much of the remainder of this discussion draws on this document.

will only cause sprawl and induce travel growth that will negate the benefits of highway expansion. The logic of this viewpoint is shown in Figure B-12.

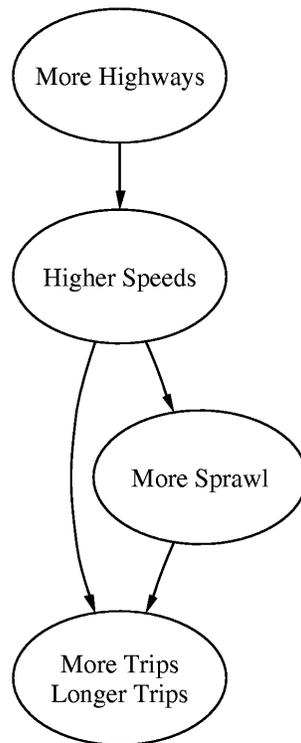


Figure B-12. Highway and Sprawl View on the Cause of VMT Growth

Expanding the highway system relieves congestion and permits people to travel faster. This in turn allows people to travel more in the same amount of time so they make more trips and longer trips. Higher speeds also allow development to spread out (sprawl) and this in turn promotes more and longer trips. Moreover, the sprawling development is automobile-oriented and therefore people are less likely to travel by a mode other than by motor vehicle. According to this viewpoint, congestion and other disincentives to vehicle travel are beneficial strategies for reducing wasteful travel and improving public welfare.

These strategies may have a different result, however, if vehicle travel grows primarily in response to how households cope with increased work demands and household time pressures. In this case, travel disincentives might increase the financial and time pressures on households who are already stressed.

Most researchers agree that induced travel is a real effect to some degree, but there is no consensus on the magnitude of the effect. Research results vary widely because of varying definitions of induced travel, methods of calculating induced travel, assumptions regarding causal relationships, and limitations in the quality of the data used. Consequently, the research

results cannot be directly applied to general transportation policy development or to specific transportation projects. Oregon's unique land use planning laws also make it difficult to apply general research results to the Oregon situation.

Definitions of induced travel depend on the view of the temporal and geographic extent of the effects. Typically, time is characterized as either short-run (soon after project completion) or long-run (several years after completion). Geographic extent is characterized as impacts experienced in the vicinity of a highway project or broadly over the whole region. Table B-1 shows the types of induced travel effects according to these characterizations.

| | Short-Range | Long-Range |
|----------------------------|--|--|
| Local/ Facility | Route diversions Temporal shifts | Induced development |
| Regional | New trips Longer trips Mode shifts | Induced development Behavior shifts |

Table B-1. Types of Induced Travel

In the short run, a highway that is widened may experience an increase in travel because more travelers use the road in preference to slower roads when congestion is relieved. More travelers may travel during peak hours once peak hour congestion is relieved. This induced travel on the widened highway shifts travel from other roads or times and therefore does not change the overall amount of travel in the region. If the highway expansion ends up encouraging longer trips, or trips that otherwise would not have occurred, or changes in travel mode, then the regional balance of vehicle travel is increased.

In the long run, more development may occur in the vicinity of an expanded highway than might otherwise have occurred. This additional development might result in more travel on the highway. There will be no regional effect if the development would occur elsewhere in the region and if the development does not encourage more or longer trips. There will be a regional effect if the development encourages long-term behavioral shifts, such as increased automobile ownership.

A fundamental problem for estimating the magnitude of induced travel is that only observational evidence is available. Studies to test the effects of highway expansions on travel are difficult because they can only observe what happens after highway expansions occur and try to estimate what would have occurred if highway expansions had not taken place. This is complicated because a number of factors can cause traffic to grow, including changes in the population, job growth and overall economic growth. Researchers need to estimate a baseline of what growth would have been in the absence of highway expansion and then estimate induced growth as the difference between what actually occurred and the baseline.

The first step is to establish the baseline. Early researchers considered population growth to be the baseline because they assumed that VMT should not grow faster than population. This baseline ignored that the number of workers, the amount of work, incomes and the economy might grow faster than population. It now appears that a new consensus is developing that a more appropriate baseline is the growth of the economy.¹³⁰ If this new baseline definition is used to determine whether induced travel occurred in Oregon, then the conclusion would have to be that there was little or no induced travel since per capita VMT and per capita income grew by about the same amount over the past three decades. Induced travel at most could account for the differences between the income and travel curves shown in Figure B-7.

After researchers define the baseline, it must be estimated. Most often, this is done using statistical analysis of different areas with differing amounts of highway expansions to try and account for the variety of different factors that affect travel. Although advanced statistical methods are used, they are all subject to limitations in data and assumptions.

Ideally, to estimate induced travel, data is needed on roadway traffic, capacity and travel speeds for a number of different urban areas for a number of years. Additional data over a number of years is needed on population, personal income, building activity, zoning, public service availability and other information that relates to land development and travel decisions. Unfortunately, the available data usually falls far short of the ideal. The main source of road data comes from the HPMS whose limitations were described previously. There is even less data related to land development and it is usually limited to data like population, population density and building square footage collected by the Census Bureau. Several important factors, including zoning and public service availability, are unaccounted for. Lack of consideration of zoning as a factor is a particular problem for trying to apply induced travel research results in Oregon because comprehensive planning and zoning is a major determinant of development patterns in the state.

The HPMS data that many induced travel studies rely on has a substantial amount of variation due to various errors (see Figure 7). These errors are not a problem for characterizing trends if the data is reported in an aggregate form or if the variations are smoothed out. They do pose problems for statistical studies of induced travel because those studies use the relative variations in highway lane-miles and VMT to establish the statistical relationship between these measurements.

The HPMS errors would not be a problem if the errors in VMT and lane-mile measurements were independent of one another but they are not. In the HPMS, VMT and lane-miles are measured for road segments. Concurrent changes in lane-miles and VMT can occur because of how the measurements are handled, for example:

¹³⁰ “The increased travel that occurs when a transportation facility is built or expanded constitutes induced demand. While population increases and economic growth often lead to more travel, induced demand refers to the increase in travel beyond that expected from projected increases in population and income.” ENO Transportation Foundation, *Working Together to Address Induced Demand*, p. 1.

- Expanding the definition of an urban area boundary adds all the lane-miles and VMT of the roads included by the boundary expansion.
- Road segment characteristics are not inventoried annually. When they are updated, some have increases in both lane-miles and VMT.
- Road segments may be reclassified from one type to another. This simultaneously increases the lane-miles and traffic in one category and decreases it in another.

The use of data with these errors in statistical analysis increases the estimated strength of the association between lane-mile additions and increased VMT but not because highway expansion causes increases in VMT. This is illustrated in Figure B-13. The figure shows the change since 1982 in lane-miles and VMT on freeways and other principal arterials in the Portland area. The blue lines show the lane-mile and VMT data for freeways. The green lines show the lane-mile and VMT data for other principal arterials. The black lines show the combined data for freeways and other principal arterials.

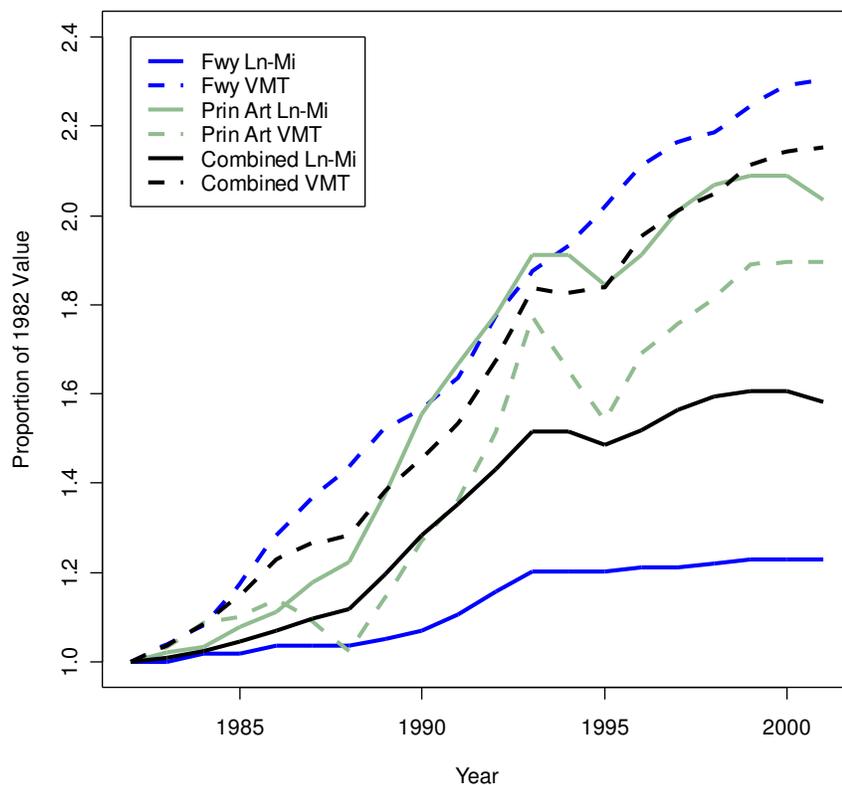


Figure B-13. Portland Urbanized Area Freeway and Other Principal Arterial Lane-Miles and VMT

Looking at just the black lines for combined freeway and other principal arterial data could lead to the conclusion that there must be some relationship between lane-miles and VMT. It appears as though changes in the shape of the lane-mile curve are accompanied by changes in the shape

of the VMT curve and a statistical analysis of these curves would show a strong relationship. However, looking at the component freeway and principal arterial curves suggests otherwise. Most of the changes in the combined data curves are due to changes in the principal arterials (green). These curves have some improbable characteristics - VMT fluctuates dramatically from year to year and lane-miles decrease substantially in several places. These features almost certainly result from data errors. Statistical analysis of this data would show a strong relationship between VMT and lane-mile growth because the errors occur in tandem. Unfortunately, if a researcher is not sufficiently aware of the errors in HPMS data they might conclude from this data that growth in lane-miles caused growth in VMT.

Another source of error in induced travel studies comes from how statistical results are interpreted. Statistical studies and the measures they generate implicitly assume that treatments being studied are randomly assigned. This helps assure that there is no bias in the outcome. Therefore, in the case of induced travel studies, it must be implicitly assumed that highway expansion treatments are randomly assigned in order to conclude that findings are not simply a result of selection bias. Public officials, however, do not randomly choose highway expansion projects. Projects are generally selected where the greatest perceived need exists. These perceptions are influenced by growth trends, land use policies, and judgments about where growth should and/or will occur. The decisions certainly are not random or non-biased.

This lack of random treatment not only introduces bias into the analysis, it also makes it hard to determine cause and effect. Statistics that show a relationship between highway expansion and VMT growth (assuming no data problems) could have two equally likely interpretations:

1. Highway expansion often induces VMT growth.
2. Highway planners often correctly anticipate where VMT growth will occur and highways are widened in those places.

Unfortunately, most of the induced travel studies assumed that only the first interpretation is correct. More recent research attempted to include both interpretations into statistical models in order to sort out their relative effects. One finding of this approach is that the growth-inducing effect of highway expansion was estimated to be much less than was found in previous studies.¹³¹ While including both fundamental pathways produces a sounder statistical model, it does not solve the problem of establishing causality.¹³²

Biases in assumptions and the presence of errors in data cast doubt on research claims that highway expansion results in substantial induced travel. It would be unwise to base policies for Oregon on such claims.

No induced travel studies have been done in Oregon, but related studies and information cast doubt on the possibility that induced travel and sprawl were significant causes of the growth of travel in Oregon over the past 30 years. It could be expected, for example, that Oregon's strong

¹³¹ Robert Cervero, *Road Expansion, Urban Growth, and Induced Travel: A Path Analysis*. Journal of the American Planning Association, Vol. 69, No. 2 (Spring 2003) 145-163.

¹³² Norman Cliff, *Some Cautions Concerning the Application of Causal Modeling Methods*, Multivariate Behavioral Research (1983) 18, 115-126.

land use planning laws had an influence on curbing sprawl and associated increases in travel. This was borne out by an Oregon study of the effects of highway expansions on land use changes.¹³³ The study compared urbanization trends in 20 Oregon cities with state highway improvements in those cities. It also did in-depth case studies of highway projects and changes in land use patterns in six Oregon cities. The case studies examined land use changes using a variety of data and interviews with local focus groups of city and county planning staff, ODOT staff, developers and realtors. The study found that:

- Developments occurring after highway improvements were generally consistent with the comprehensive plans established before the highway improvements were made.
- None of the highway improvements appeared to be associated with annexations or urban growth boundary (UGB) expansions.
- Development of all types occurring after highway construction was dispersed throughout the communities and was not concentrated around the highway projects.

No cases were found of major new developments occurring outside UGBs along highways that were expanded. Furthermore, the data from the UMR on travel growth and congestion in the Portland area show that a conclusion that sprawl and induced travel caused rising VMT is inconsistent with the theory of induced travel. The theory says that induced travel occurs when transportation system improvements reduce the cost of travel. Therefore, if induced travel occurred, it would be expected to see evidence that highway speeds increased. If sprawl were a cause, there should be evidence that the population of the Portland area became more dispersed.

Figure B-14 shows relevant trends for the Portland-Vancouver urbanized area using the UMR data. The black solid and dotted lines in the figure show the growth of freeway, other principal arterial lane-miles and VMT, respectively. The blue line shows changes in urbanized area population and the red line shows changes in urbanized area size.¹³⁴ The purple line shows the ratio of urbanized area size to population. It is an indicator of sprawl. If sprawl is increasing, then the average area per person should increase. Finally, the green line is an indicator of travel

¹³³ ECONorthwest and Portland State University, *A Guidebook for Evaluating the Indirect Land Use and Growth Impacts of Highway Improvements*, SPR Project 327, Oregon Department of Transportation (April 2001).

¹³⁴ The data on population and size come from the FHWA HPMS database and Oregon county population estimates from the Portland State University Center of Population Research and Census. The UMR size estimates are inconsistent with the HPMS database. This might be a result of UMR methods to smooth out size changes in the HPMS data. States update the population estimates every year, but only update the urban boundary size estimates every 10 years. The HPMS size estimates are 416 square miles from 1982 through 1992 and 469 square miles afterward. The UMR method for adjusting size results in a smaller boundary than was reported in 1982 (350 square miles) and a larger boundary than was reported in 2001 (500 square miles). It is not reasonable for the 1982 size to be smaller than what was reported because the size of the boundary was reevaluated at about that time. It is also not reasonable that the boundary was any larger in 2001 because the Oregon figures correspond to the size of the Metro urban growth boundary at that time and that accounts for about three-quarters of the urbanized area. The method used instead was to spread the change in size evenly between 1983 and 1993. Corrections were also made to the HPMS population estimates. The reported estimates for the Oregon portion of the urbanized area show a loss of over 100,000 people in 1987. Population is then shown growing on the order of a few tens of thousands a year until 1997 when it jumps upward by over 80,000. This did not occur. The populations for the Oregon counties that contain the urbanized area show steady gains in 1987 and all subsequent years. The urbanized area population was therefore adjusted upward to be consistent with the county growth trend.

speeds in the urbanized area. It was calculated using the Travel Rate Index (TRI) from the UMR. The TRI, like the TTI, indicates how much more time is required to travel during peak times vs. off-peak times. TRI does not include delay due to traffic accidents and other incidents. The effect of using the TRI rather than the TTI is that the curve is less steeply sloped downward. The inverse of the TRI is the ratio of the speed during peak periods to uncongested speeds.

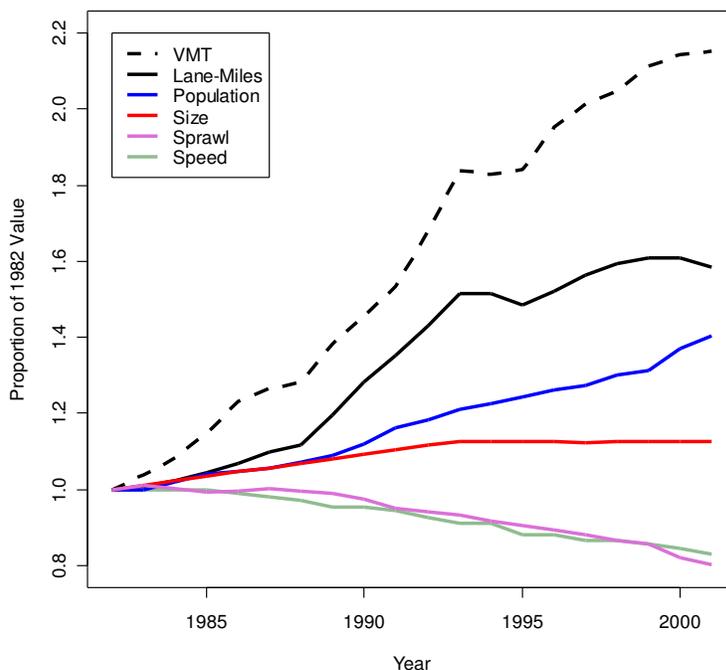


Figure B-14. Changes in Portland Urbanized Area Size, Major Road System Lane-Miles and VMT, Sprawl and Travel Speeds

The trends shown in Figure B-14 contradict the highway expansion and sprawl theory. Speeds continually decline even though highways were expanded. That is expected since travel demand grew faster than the highway system but it is inconsistent with induced travel theory. It can be argued that speeds increase where highways are expanded although system-wide average speeds decrease. If this were the case, then speeds must have declined even more than the overall average elsewhere on the system and this would suppress travel. Suppression of travel in places where speeds decrease should more than offset induced travel where highways were expanded. In addition, the sprawl trend line does not show a long-term increase over time. Instead, the trend is downward. Since sprawl decreased, it could not have contributed to the increase in VMT.

Highway expansion and sprawl may not be responsible for rising VMT because Oregon took a proactive approach to controlling urban sprawl beginning in 1973 with the passage of Senate Bill 100. Oregon's state planning laws contain urban growth within urban growth boundaries and keep rural development separate from agricultural and forest lands. In the Portland metropolitan area, a regional government (Metro) is responsible for setting the urban growth boundary and coordinating land use and transportation policies. State laws require all local governments to

develop comprehensive plans according to state rules and to coordinate their land use and transportation planning. These laws directly and indirectly reduce the potential for sprawling development to follow highway expansions.¹³⁵

The evidence does not support the argument that highway expansions and sprawl caused VMT to grow in Oregon in recent times. Economic changes are the most likely cause of the growth. Oregon's land use planning program may have helped the state avoid induced travel by curbing urban sprawl. The evidence to date shows that since the land use program has been in effect, highway expansions have little if any effect on planning and zoning decisions. This suggests that highway expansions may be a reasonable part of the solution to address congestion problems and the "build it and they will come" assertion is unfounded.

DECLINING RATES OF HIGHWAY INVESTMENT ARE PRIMARILY RESPONSIBLE FOR RISING CONGESTION

The straightforward explanation of the cause of rising congestion over the past 30 years appears to be the most likely explanation. Congestion is rising because expansion of road capacity has not kept pace with the growth of travel. Since the rate of growth of VMT is nearly identical to the rate of growth of the state economy, it can be speculated that if a relatively constant proportion of the state economy were invested in highway expansion, increasing congestion could have been avoided. This assumes that the relative costs of expansion remain constant and that expansion is done in a way that supports comprehensive plans and avoids induced travel. The capital investment in highways since the 1960s, however, declined substantially (Figure B-15). During the 1960s, an average of 2.5 percent of total state personal income was spent on highway capital outlay.¹³⁶ By the 1990s the average dropped to 0.8 percent.

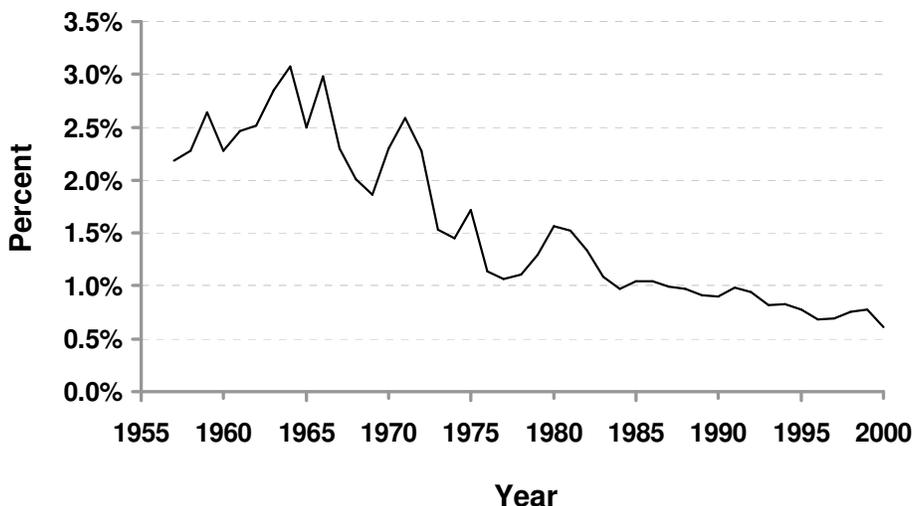
The UMR data illustrates the significance of the declining investment rate. The UMR calculates the lane-mile additions needed to avoid congestion growth assuming that if lane-miles are added at the same rate as VMT growth, congestion will not increase. A lane-mile deficit is calculated for all of the study area. This is the difference between the lane-miles added and what would be needed to keep up with VMT growth.

A similar approach can be used to assess the implications of the declining rate of capital highway investments. According to UMR data, daily VMT on the major road systems of Eugene, Portland and Salem grew by 43 percent from 1990 to 2000. Over that same time period, lane-miles grew by 20 percent or 37.5 lane-miles per year. If lane miles grew at the same rate as VMT, an annual rate of 80.6 lane-miles per year, or just over two times the rate, would have been added. The

¹³⁵ For example OAR 660-012-0060(4) states that "The presence of a transportation facility or improvement shall not be a basis for an exception to allow residential, commercial, institutional or industrial development on rural lands under this division or OAR 660-04-0022 and 660-004-0028."

¹³⁶ "Capital outlays are those costs associated with highway improvements, including: land acquisition and other right-of-way costs; preliminary and construction engineering; construction and reconstruction; resurfacing, rehabilitation, and restoration costs of roadway and structure; system preservation activities; and installation of traffic service facilities such as guard rails, fencing, signs, and signals." FHWA, *Highway Statistics 1999*, p. IV-5.

investment rate in the 1990s was a third of the rate during the 1960s. If spending on capacity had been the same as VMT growth rates, there may be no capacity deficit today.



Sources: Personal Income—US Bureau of Economic Analysis; Capital Expenditures—*Highway Statistics Summary to 1995*, Table HF-202C, *Highway Statistics* reports for years 1996-1999, Table HF2.

Figure B-15. Percentage of Total State Personal Income Spent on Highway Capital Outlay in Oregon: 1957-2000

The UMR shows that widening highways helps to reduce congestion. The results show that changes in roadway supply have an effect on traveler delay. Areas that have smaller lane-mile deficits tend to have less growth in traveler delay.¹³⁷

This simple example illustrates that the mobility that Oregonians have enjoyed in recent decades is the result of the high capital investment rates of the past. Congestion increased because the excess capacity created by previous investments has been used up and not replaced.

HIGHWAY EXPANSION IS ONLY PART OF THE RESPONSE TO CONGESTION

Although highway expansion can help alleviate congestion, it is unlikely to succeed as the only approach to congestion relief for several reasons. It is unlikely that investment levels in highway modernization will approach past levels. This is not only because the public is unlikely to approve large tax increases, but also because a large share of future expenditures are needed to replace aging bridges. The public has also chosen to limit highway expansions because of the amount of land they consume and their impacts on neighborhoods and the environment.

¹³⁷ David Schrank and Tim Lomax, *The 2003 Annual Urban Mobility Report*, (Texas Transportation Institute, September 2003) 31-33.

Highways become more costly to build as urban areas grow because property values increase, more buildings must be purchased and demolished, and more expensive construction techniques must be used to reduce neighborhood or environmental impacts. The UMR shows that very few urbanized areas have come close to matching the growth of traffic with added highway lanes. Only five of the study areas were able to keep the difference between traffic growth and lane-mile growth to less than 10 percent.¹³⁸ Successful approaches to alleviating congestion are likely to involve a combination of highway expansion with other complementary actions.

A variety of operational treatments can improve highway performance and reduce congestion and its effects. The UMR evaluated the effects of five of these: ramp metering, traffic signal coordination, incident management programs, high occupancy vehicle (HOV) lanes and public transportation service. The study found that ramp metering helps to maintain freeway speeds under heavy traffic loads and reduced delay by about four percent in the 26 areas with metering that were studied. Traffic signal coordination is estimated to produce about a 1.5 percent reduction in arterial delay in the study areas. Incident management programs are estimated to produce about five percent reduction in freeway delay in the 56 areas that have incident management programs. HOV lanes are estimated to lower delay by about one percent in the eight areas that have them. The UMR estimates that public transportation services in large urban areas that were studied reduces delay by over 16 percent.¹³⁹ The UMR estimates the total annual delay savings for these strategies in the Portland-Vancouver urban area to be over 15,000 hours in 2001. That is about 40 percent of the estimated delay in the urban area.¹⁴⁰

The estimated effect in the Portland-Vancouver area of public transportation services alone is a reduction in delay equal to about a third of the area's annual delay. The Portland metropolitan area has been building light-rail lines in capacity-constrained highway corridors, including the I-84 and US-26 corridors. Rail lines on separate rights-of-way are able to move large volumes of passengers at high speeds in a narrow corridor. Thus, they not only reduce demand on highways, but they also permit passengers to travel at speeds that are not encumbered by congestion and experience more reliable travel times.

Investments in public transportation in Portland appear to be paying off in the growth of transit ridership. In the last decade, travel on public transportation in the Portland area grew faster than travel on the road system. Table B-2 compares changes in daily passenger miles traveled on the Tri-Met system with changes in daily vehicle miles traveled on highways and other roads.

¹³⁸ David Schrank and Tim Lomax, *The 2003 Annual Urban Mobility Report*, (Texas Transportation Institute, September 2003)

¹³⁹ David Schrank and Tim Lomax, *The 2003 Annual Urban Mobility Report: Volume 2, Five Congestion Reduction Strategies and Their Effects on Mobility*, (Texas Transportation Institute, September 2003).

¹⁴⁰ Schrank and Lomax, *The 2003 Annual Urban Mobility Report*, p. 67, Exhibit A-5. Annual hours of delay are estimated to be 37,975. Delay reductions due to public transportation are estimated to be 12,820 hours annually. Delay reductions due to other operations programs are estimated to be 2,935 hours annually.

| Mode | 1990 (thousands) | 2000 (thousands) | Change (percent) |
|---|---------------------|---------------------|---------------------|
| Public Transport (units are passenger miles traveled) | 547 | 952 | 74 |
| Bus | 437 | 624 | 43 |
| Light Rail | 110 | 328 | 198 |
| Roads (units are vehicle miles traveled) | 19,398 | 26,254 | 35 |
| Freeway | 7,490 | 9,974 | 33 |
| Other Principal Arterial | 3,177 | 5,328 | 67 |
| Other Road | 8,197 | 10,952 | 34 |

Source: Daily passenger miles traveled (PMT) computed from annual data provided by Tri-Met at <http://www.trimet.org/inside/ridership.htm>. Highway and road VMT from ODOT HPMS databases.

Table B-2. Private and Public Transportation Daily Travel Growth in the Portland Area

The level of effect of operational treatments depends on the extent to which they are deployed. The UMR estimates that full deployment of ramp metering can reduce congestion delay by over 11 percent. Full deployment of traffic signal coordination can reduce delay by almost 3 percent. Full deployment of incident management can reduce delay by about 9 percent. The combined potential reduction from these operational strategies is about 23 percent. In 2001, the estimated delay reduction from the extent of deployment of these strategies in the Portland-Vancouver area was about 8 percent.

Land use planning is another strategy for managing the effects of congestion. Zoning and other land use policies that can improve travel speeds include:

- Manage the distribution of development so that development patterns more closely match the capabilities of the transportation system that serves them.
- Facilitate the construction of collector-distributor roads to serve development and facilitate circulation between nearby land uses and reduce traffic on arterials.
- Manage the location of access points to arterials and interchange areas to reduce the effects of driveway traffic on congestion.
- Use land use planning actions to preserve corridors for future major road construction and improve the likelihood that roads needed in the future can be built.
- Encourage higher density development in areas where high capacity public transportation is available.

Land use policies can reduce the impact of congestion on the public by reducing the length of travel in congestion. Compact urban areas and planning that places destinations near each other can reduce trip lengths which can offset the effects of rising congestion on travel time and delay. This appears to be what is happening in the Portland-Vancouver area. Although roadway

congestion has grown much faster than average for an area of its size, congested travel distances have grown more moderately. The result is that per capita delay is about average and per capita travel times are below average.

Value pricing offers another approach to managing congestion. By pricing special lanes (that may be shared with buses and carpools), value pricing offers people in a hurry the option of spending money to save travel time. For example, a parent who is rushing to the daycare provider to avoid paying a dollar a minute late fee could welcome such an option. The price is set at a level that optimizes road performance. The value pricing approach tries to alleviate concerns about fairness by compensating those who travel in the unpriced highway lanes with revenues generated from the priced lanes. Value pricing can improve the efficiency of providing transportation service to the public.¹⁴¹

Another pricing approach is to replace some of the fixed costs of driving with costs that vary with the number of miles driven. For example, automobile insurance can be paid on a per mile basis rather than on an annual basis. Although the costs do not vary with congestion, unlike value pricing, they reduce congestion by reducing vehicle travel. It is estimated that a national system of mileage-based automobile insurance will reduce driving by about 9 percent.¹⁴² An Oregon law adopted in 2003 encourages insurance companies to offer pay-as-you-drive insurance as an option.

Alternative approaches to congestion relief are to increase highway throughput by changing the characteristics of highways in more fundamental ways. One approach is to build separate lanes or facilities for cars and trucks. The "car-only" facilities can be built with narrower lanes and lower clearances to increase the number of vehicles that can occupy the space. This is particularly beneficial in tunnels or on structures to reduce construction costs. For example, the Cofiroute tunnels in Paris are being built with six double-deck lanes for passenger vehicles with 10-foot wide lanes and 8.5-foot high clearances.¹⁴³ Separate truck and passenger vehicle highway lanes can also make automated highways safer and more effective.

In the long run, it may be possible to greatly increase highway capacities and speeds by automating highways and vehicles.¹⁴⁴ Although the benefits will be substantial, the technical and institutional challenges are substantial as well. This is a growing area of investigation and may yield some surprising results in the next several decades.

¹⁴¹ Kenneth A. Small, *The Value of Value Pricing*, Access, Number 18 (Spring 2001) 23-27.

¹⁴² Edlin, Aaron S., *Per-Mile Premiums for Auto Insurance*, Institute of Business and Economic Research, Economics Department Working Papers, Paper E02'318, University of California, Berkeley (2002).

¹⁴³ Peter Samuel. *How to 'Build Our Way Out of Congestion': Innovative Approaches to Expanding Urban Highway Capacity*, RPPI Policy Study 20 (Reason Foundation, 1999).

¹⁴⁴ Steven E. Shladover, *What If Cars Could Drive Themselves*. Access, Number 16 (Spring 2000) 2-7.