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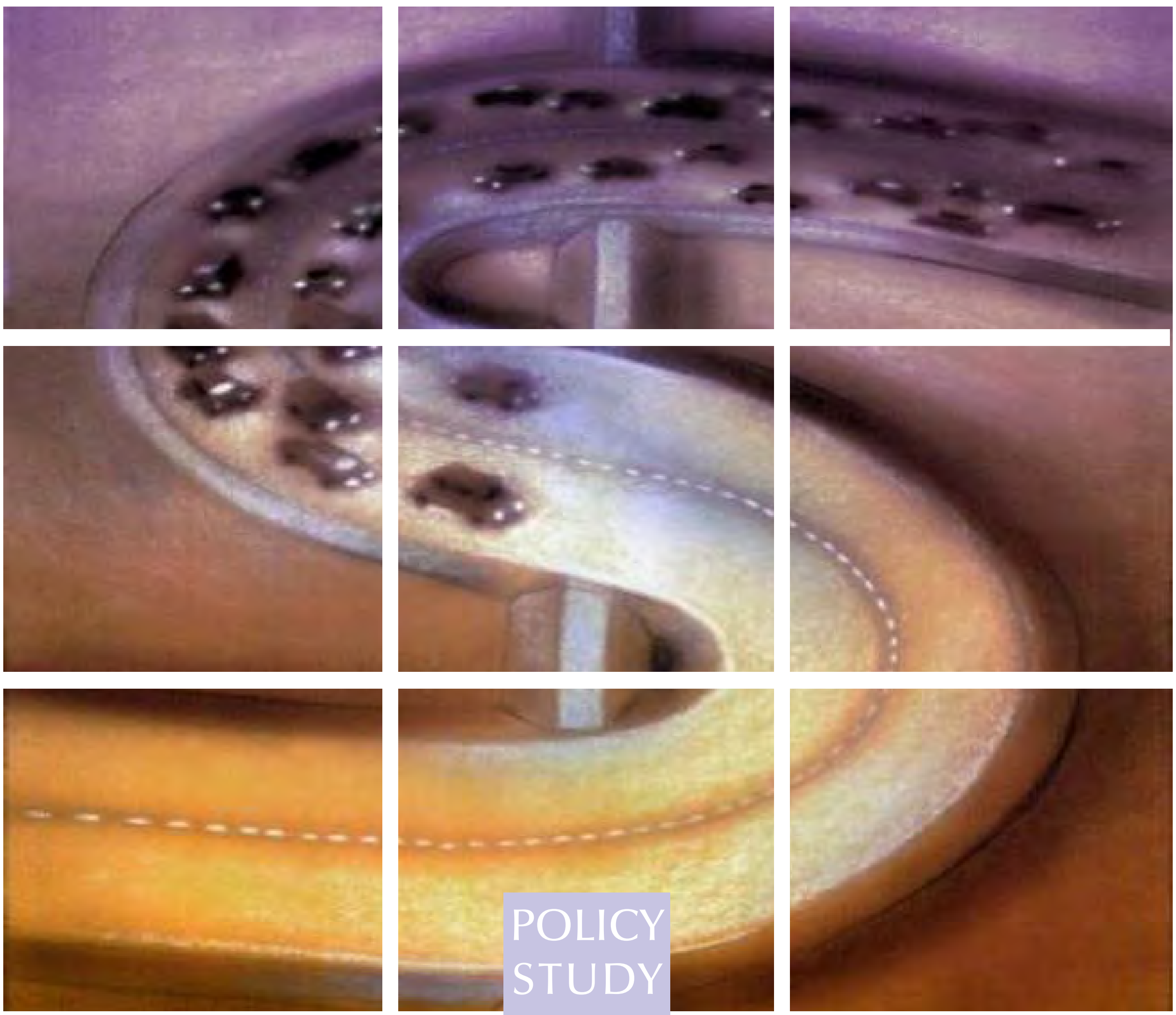
Gridlock and Growth: The Effect of Traffic Congestion on Regional Economic Performance

By David T. Hartgen, Ph.D., P.E. and M. Gregory Fields
Project Director: Adrian T. Moore, Ph.D.



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Gridlock and Growth: The Effect of Traffic Congestion on Regional Economic Performance

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The economic performance of cities has fascinated economists and regional scientists for centuries. The role of transportation in creating and maintaining easy and quick access to metropolitan areas and regional economic performance has been studied extensively, particularly in the past 30 years. The most recent efforts have attempted to tie regional performance to accessibility, congestion and transportation system performance. However, varying definitions of "access" and "performance" have confounded the research. A related problem is the exclusive attention to access to the central business district while ignoring other locations.

This report investigates how accessibility impacts the economic performance of large U.S. urban regions. The eight regions selected for this study are Charlotte, Salt Lake City, Seattle, Denver, San Francisco, Detroit, Dallas and Atlanta. First we defined accessibility as the number or percentage of jobs or residents within a given drive time from a point, measuring drive time via the available highway networks of the regions. We identified five major destinations, or "key points" for each region: the central business district (CBD), major mall, large suburb, university and airport, and correlated the accessibility to these points with regional productivity, defined as gross regional product per worker. We then quantified how much current and future traffic congestion (extrapolated for the year 2030) and total congestion relief would affect the economic productivity of each region. Specifically, the study addresses four key questions:

- How accessible are various points in urban regions?
- How will the accessibility of these points change in the future?
- What effect will removing congestion have on accessibility?
- How would improving accessibility affect the economic performance of the region?

We found that the CBD is generally the most accessible place in each region, with typically 30 to 60 percent of jobs and 25 to 50 percent of residents within 25 minutes of downtown under current congested conditions. Other key points have typically one-third to one-half the percentage of CBD jobs or residents within 25 minutes. Our research determined that in the future, rising traffic congestion and rapid suburban growth together mean that key points in most regions will become relatively less accessible than they are now. The reduction in access is typically 1 to 10 percent. But removal of congestion would increase the access to key points by 2 to 30 percent, allowing most regions to reverse the expected decline in access and making these key points relatively more accessible as the region grows.

The study also finds that a 10 percent decrease in CBD accessibility would decrease regional productivity by about 1 percent, about the same as observed in Europe and Korea in previous studies. But it also suggests that regional economies might be more dependent on access to suburbs, malls and universities than on access to downtowns. Not only are models of productivity somewhat stronger for these sites, but access to them has a stronger effect on regional productivity. In the cities studied, reducing congestion would boost Gross Regional product by 6 to 30 percent if targeted at suburbs, malls, and universities. The economic gains would be 4 to 10 percent if targeted at CBDs, and just 2 to 8 percent if targeted at airports. Free-flowing traffic conditions around these key areas would increase regional productivity, which in turn would increase tax revenues. Smart infrastructure investments that produce free-flowing road conditions will more than pay for themselves in future years by boosting the region's economy. The study concludes that the focus of transportation plans on CBD access may be misplaced, as regions grow and other locations become relatively more congested. It suggests a re-thinking of plans to improve access through congestion reduction particularly in non-CBD locations.

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Part 1

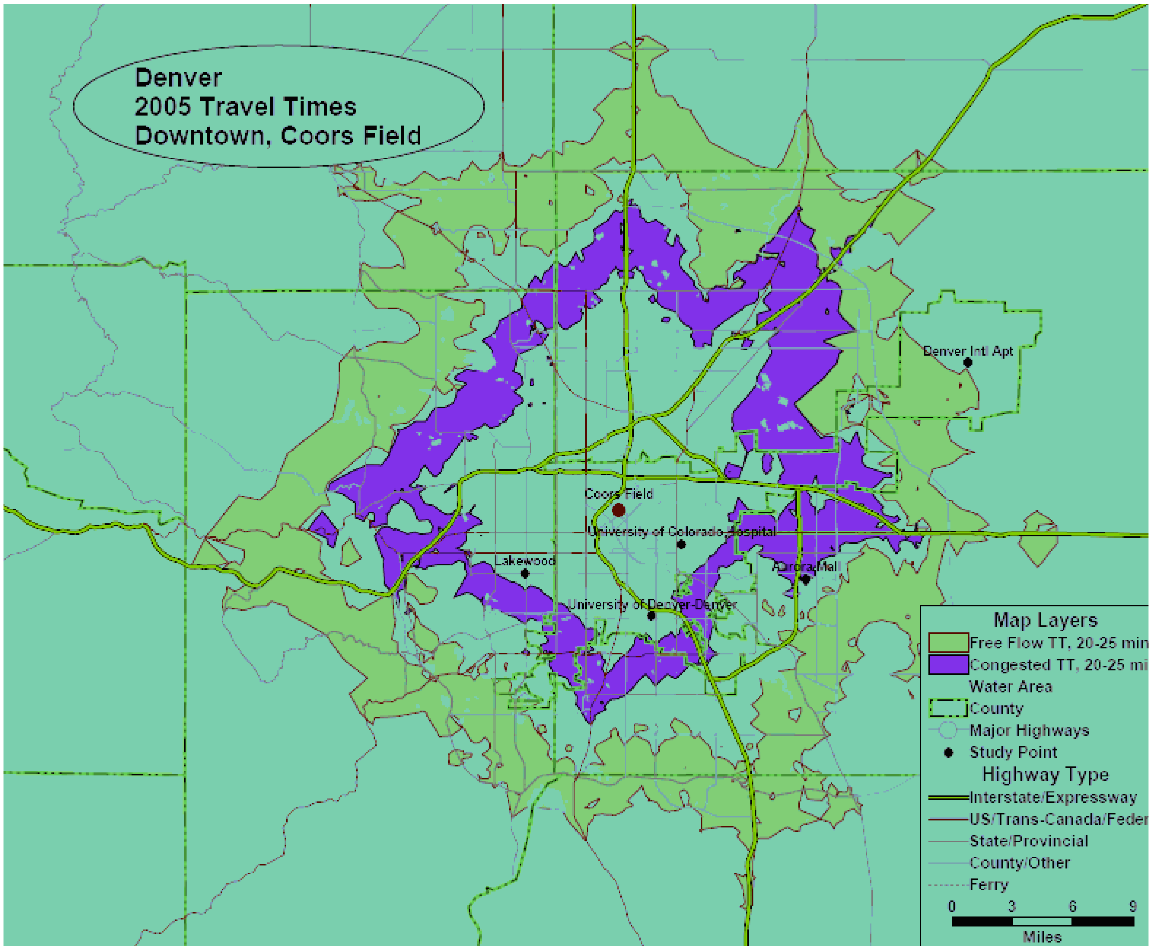
Introduction

The economic performance of cities has fascinated economists and regional scientists for centuries. The role of transportation in creating and maintaining easy and quick access to metropolitan areas and its effect on regional economic performance has been studied extensively, particularly in the past 30 years. The most recent efforts have attempted to tie regional performance to accessibility, congestion and transportation system performance.

However, varying definitions of "access" and "performance" have confounded the research. A related problem is the exclusive attention to access to the central business district (CBD) while ignoring other locations. Also, the causal link between congestion and economic competitiveness is nebulous. A recent comprehensive review of about 500 studies concluded that "[T]*here remains little agreement either on what the term 'competitiveness' means or on how policy intervention should try to enhance it…Empirical research* directly *assessing the role of transport in city competitiveness is relatively scarce…There are severe difficulties in attributing causality [between transport and competitiveness.]"*.[1] The link between traffic congestion and productivity is also not extensively studied. Although some work has been done in Europe and the U.S., few have made direct connections between congestion, accessibility and urban productivity.[2] In short, the linkages remain elusive, hinting of some (but perhaps not much) influence by mature transportation systems on regional performance.

A relatively recent empirical approach uses "drive time" contours that show the geographic area within a given travel time from a point, or the number of entities (jobs, households, income, population groups, etc.) reachable within that time. Drive time measures appear to be a more accurate measure of access than concentric circles, since they reflect both the directionality and the speed of transportation networks. For instance, Figure 1 shows the area enclosed by 25-minute drive time from the Denver downtown, with and without congestion.[3] The uncongested network permits higher 'free flow' speeds and hence a larger contour, particularly along major routes. This results in a significant increase in the number of jobs or residents within 25 minutes of downtown—or other parts of the metro area. These increases could (in theory) improve regional performance by reducing travel time and increasing the jobs available to residents, the workers and customers available to employers. Drive time contours express changes in access as transportation systems improve. They determine and illustrate how cities are growing over time, how access is improving or worsening, and how future improvements might change access.

Figure 1: Example of 25-Minute Drive Times for Denver Downtown



Drive time contours have also recently been used to describe and compare the productivity of regions. Studies comparing overseas locations in terms of drive time spheres of accessibility have revealed some correlation with productivity, but no cross-region study has focused on U.S. locations, which are more auto-dependent and larger geographically.

To understand the relationship between accessibility, regional economic performance and congestion, this study investigates how regional economic performance is related to access to downtowns and other major activity centers in the United States. We also look at how congestion affects access and how its reduction would help a region become more accessible and more productive. Specifically, the study addresses four key questions:

1. How accessible are various points in urban regions?
2. How will the accessibility of these points change in the future?
3. What effect will removing congestion have on accessibility?
4. How would improving accessibility affect the economic performance of the region?

Seeking a representative sample for this study we reviewed available data and selected the following cities: Charlotte, Salt Lake City, Denver, San Francisco, Seattle, Detroit, Atlanta, and Dallas-Ft. Worth. More cities could not be included, given time and other constraints. We gathered current and future demographic data by zone from each region's respective planning agencies, and identified points corresponding to central business districts, universities, airports, major malls and major suburban locations and translated this data into a consistent format for ease of analysis.[4] We determined drive time contours for base year and 2030, under both congested and free-flow conditions for each point, and estimated regional productivity, enabling us to examine not only the correlation between traffic congestion relief and regional productivity, but also the relative economic effects of congestion relief for various major destinations in each metropolitan area.[5]

Part 2

Accessibility to Regional Points

A. Statistics for Regions and Major Points

This study examines eight urban regions:

- Charlotte
- Salt Lake City
- Denver
- Seattle
- San Francisco
- Dallas-Fort Worth
- Detroit
- Atlanta

Table 1 summarizes key statistics for the urbanized areas comprising the eight regions.[6] In population they range from 855,000 for Charlotte to 4.172 million for Atlanta. Daily traffic (daily vehicle-miles-of-travel)[7] varies from 21 million for Salt Lake City to 128 million for Atlanta. "Density" is expressed in population per square mile. Daily freeway traffic volumes per lane range from 13,957 in Salt Lake City to 19,879 for San Francisco. The 'gross regional product (GRP)' is computed from the region's income-weighted share of gross state product (for the 'base year' of the demographic data). Regional productivity ranges from $81,700 for Salt Lake City to $125,400 for San Francisco.[8]

Table 1: Regional Economies and Traffic Statistics

Urbanized Area	Daily Travel, 2005 k VMT	Pop, 2005 k	Area, 2005 Sq m	Density, 2005	Freeway Daily Traffic/ Lane, 2005	Base Year of Demog. Data	Base Year Gross Regional Product $ Billions	Base Year Regional Jobs K	Base Year GRP/ Worker K
Charlotte	29,513	855	583	1,467	15,026	2000	$73.1	785.4	$ 93.1
Salt Lake City	21,294	970	342	2,836	13,957	2001	$49.9	611.3	$ 81.7
Denver	52,437	2,092	814	2,570	15,905	2005	$121.7	1044.2	$ 116.5
Seattle	69,967	3,002	1,185	2,533	16,891	2000	$165.2	1457.0	$ 113.4
San Francisco	73,251	3,110	721	4,314	19,879	2000	$251.6	2006.3	$ 125.4
Dallas	119,648	3,746	1,712	2,188	18,204	1999	$242.0	2465.1	$ 98.2
Detroit	104,126	3,931	1,439	2,732	17,220	2005	$200.6	1870.5	$ 107.3
Atlanta	128,353	4,172	3,027	1,378	19,329	2005	$234.8	2095.3	$ 112.0

Table 2 summarizes the current congestion and planned transportation expenditures for the eight regions (the 2003 population data is slightly different from the above 2005 statistics). All are expected to grow substantially over the next 25 years, and congestion (the portion of the TTI index to the right of the decimal) is expected to increase sharply.[9]

The "TTI" or "travel time index" is a measure of traffic congestion. Free-flow conditions are represented by "1.0" and congestion by the number after the decimal, thus the impact of Charlotte's current congestion is "1.31", i.e., congestion increases travel time by 31 percent. Charlotte's congestion index is predicted to increase from 1.31 to 1.62, doubling delay; Salt Lake City, Denver, Seattle and Dallas predict similar results.

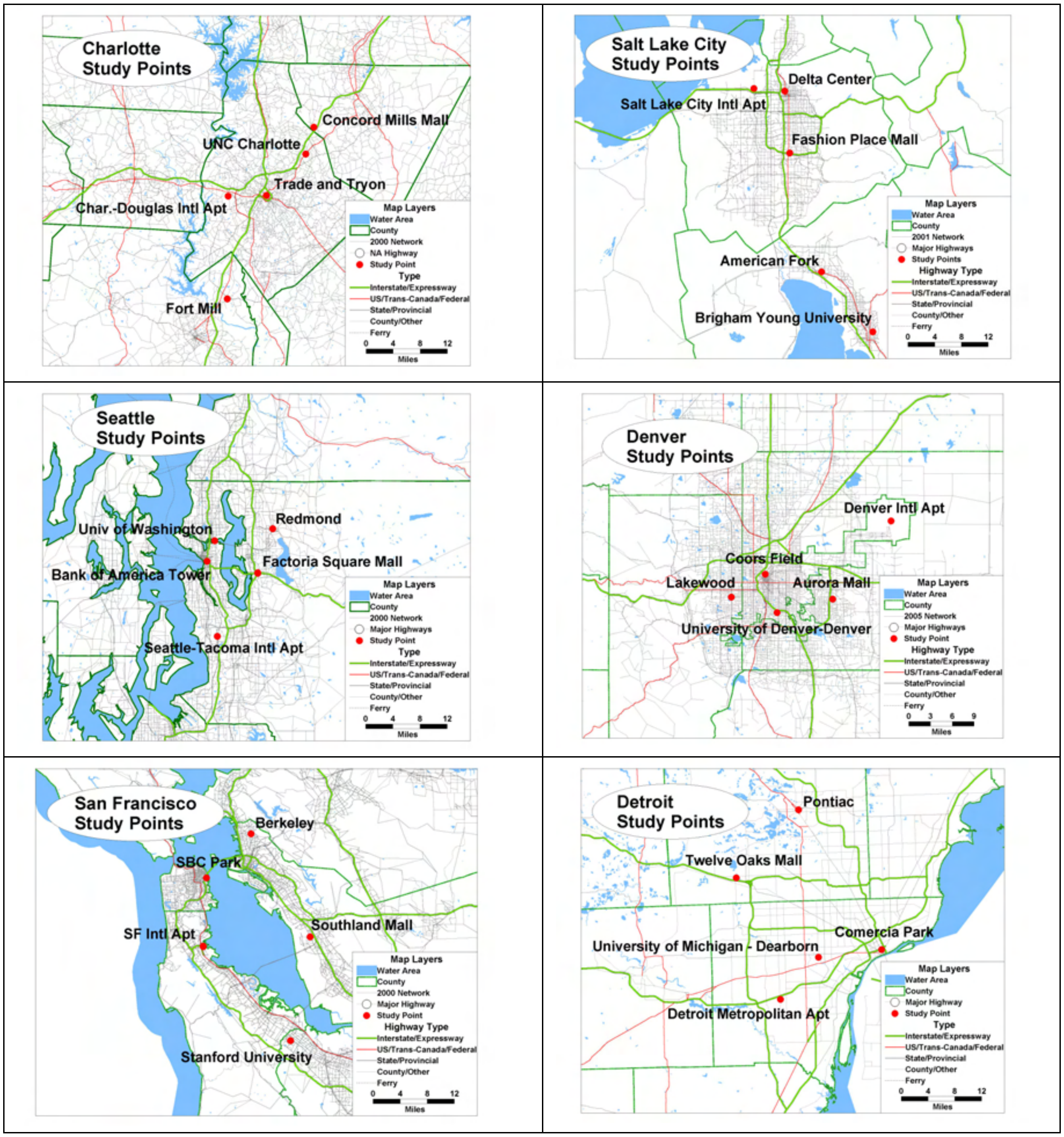
Table 2: Summary of Regional Traffic and Congestion Statistics

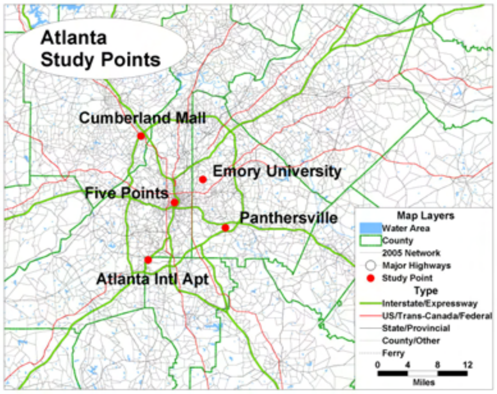
	2003 Urb Area		2030 Urb Area		2030 Long-Range Plan Costs ($B)			Cost to Remove LOS F Congestion by 2030 ($B)
Region	Pop, K	TTI	Pop, K	TTI	Highway Costs	Transit Costs	Total Costs	
Charlotte	725	1.31	1,185	1.62	$4.7	$6.3	$11.0	$2.9
Salt Lake City	877	1.28	1,251	1.59	$3.2	$17.3	$23.0	$1.2
Denver	2,050	1.40	3,210	1.80	$53.9	$23.4	$87.8	$10.0
Atlanta	2,924	1.46	5,009	1.85	$29.6	$21.5	$53.0	$13.1
Seattle	2,946	1.38	3,963	1.79	$49.4	$46.3	$101.6	$4.8
Detroit	3,939	1.38	4,277	1.50	$31.5	$9.3	$41.0	$24.1
San Francisco	4,120	1.54	4,968	1.86	$47.0	$76.0	$118.0	$29.2
Dallas	4,312	1.35	7,014	1.73	$30.6	$13.5	$45.1	$26.4

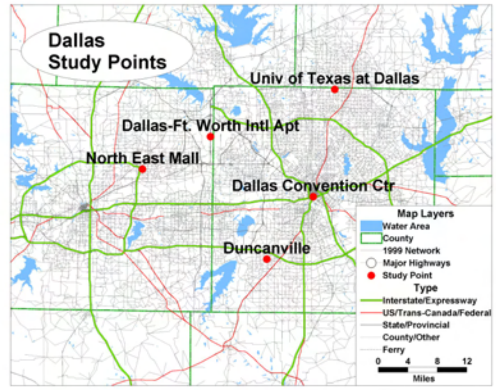
Each region's long-range plan contains a 'fiscally constrained' estimate of costs, by mode. The regions' plans propose substantial highway and transit expenditures, costing from $11.04 billion for Charlotte to $118.0 billion for San Francisco. However, even with these expenditures, congestion will continue to increase. Forecasts of congestion reflect analysis of historical congestion trends in each region and predicted traffic and population growth.[10] The cost of removing severe congestion (based on unit cost estimates multiplied by predicted system congestion mileage as determined earlier by the authors) ranges from a low of $1.2 billion for Salt Lake City to a high of $29.2 billion for San Francisco.[11]

Figure 2 shows the major road network and study points for each region. These data come initially from each region's transportation modeling agency in the form of networks and demographics. Road networks are typically the higher-level road system (excluding local streets) and contain link travel times at posted (free flow) speeds and at congested (traffic-delayed) speeds, link length, functional class and other items. For this report the driving times over these networks are refined to reasonably approximate 'on the ground' travel times to facilitate drive time contours and estimate accessibility.[12]

Figure 2: Study Points for Eight Regions







There are many definitions of accessibility. In this study, *absolute accessibility* is defined as "the number of residents or jobs reachable within 25 minutes driving time from a given point." *Relative accessibility* is defined as "the percentage of regional residents or jobs within 25 minutes of a given point." Defined as such, absolute accessibility can (and will, due to increased population density) increase, and at the same time relative accessibility can decrease, as rim population increases faster than inner-city population density. The 25-minute drive time is used because it closely approximates the median peak-hour travel time for auto-mode commuters in major cities. This straightforward definition relates directly to road speed, extent and traffic congestion during peak hours. It is also computationally straightforward and comparable across regions and from year to year, and is well understood by planners and interested citizens. However, it does not capture the much larger area that, say, 90 percent of commuters come from. The use of a larger catchment area or a longer commute time would probably strengthen our modeling results.[13]

The figure also shows five selected destination points in each of these eight regions. The specific points are:

- Central business district (CBD, "downtown")
- Major university
- Major mall
- Suburban community
- Airport

While these points are certainly not the only major points in regions, they are indicative of the range of locations which allow the region to function economically. They would also undoubtedly be chosen as starting points in local travel time studies.

B. How Accessible Are Points Within Regions?

Table 3 shows that accessibility (the number and percent of jobs or population within 25 minutes of a point) varies substantially across the eight regions. Generally, the CBD (downtown) is the most accessible point, with the percentage of the region's residents within 25 minutes ranging from 26 percent for Charlotte to 55 percent for Salt Lake City. Other points are generally one-third to one-half as accessible as the CBD. Jobs are more concentrated, with 32 to 64 percent of regional jobs within 25 minutes of the CBD; in a few cases, other points have even more jobs within 25 minutes.

Figure 3 shows this data comparatively, for population. While San Francisco has the highest total regional population, Salt Lake City actually has the highest percent of regional population (54.6 percent) within 25 minutes of the CBD, and thus the highest regional accessibility. Similarly, Figure 4 shows jobs accessibility comparatively. For jobs, San Francisco has the largest number of jobs in its total region, but Salt Lake City also has the highest percent of jobs (63.8 percent) within 25 minutes of the CBD.

Table 3: Population and Jobs within 25 Minutes of Key Points

		Population Within 25 Minutes		Jobs Within 25 Minutes	
Region	Location	Number (k)	Pct of Region	Number (k)	Pct of Region
Charlotte	Total	1681	100	901	100
	CBD	442	26.3	446	49.4
	Mall	403	23.9	361	40.0
	Airport	362	21.5	420	46.5
	University	295	17.5	281	31.2
	Suburb	163	9.7	150	16.6
Salt Lake City	Total	1467	100	707	100
	Mall	817	55.4	448	63.6
	CBD	801	54.6	454	63.8
	Airport	775	53.0	445	63.0
	Suburb	489	33.3	203	28.7
	University	351	24.1	139	19.8
Seattle	Total	3270	100	1747	100
	Mall	998	30.5	971	55.5
	CBD	967	29.5	946	54.1
	University	839	25.6	808	46.2
	Airport	751	22.9	752	43.0
	Suburb	631	19.3	697	39.9
Denver	Total	2635	100	1319	100
	CBD	1250	47.2	733	55.6
	University	1140	43.2	758	57.4
	Suburb	930	35.3	597	45.2
	Mall	596	22.6	273	20.7
	Airport	211	8.0	103	7.8
Atlanta	Total	4329	100	2226	100
	CBD	1460	33.7	1100	49.0
	Suburb	1300	30.0	817	36.7
	Mall	1190	27.5	960	43.2
	University	1100	25.4	904	40.6
	Airport	982	22.8	641	28.8
San Francisco	Total	6771	100	3720	100
	CBD	1870	27.6	1190	31.9
	Mall	1490	22.0	789	21.2
	Suburb	1410	20.8	1020	27.3
	Airport	1320	19.5	966	25.9
	University	1060	15.5	922	24.8

Table 3: Population and Jobs within 25 Minutes of Key Points

		Population Within 25 Minutes		Jobs Within 25 Minutes	
Region	Location	Number (k)	Pct of Region	Number (k)	Pct of Region
Detroit	Total	4939	100	2777	100
	CBD	2040	41.2	1120	40.1
	University	1460	29.4	815	29.3
	Airport	1040	21.0	532	19.1
	Mall	945	19.1	660	23.7
	Suburb	901	18.2	695	25.0
Dallas	Total	4848	100	3067	100
	CBD	2130	43.9	1770	57.9
	Airport	1350	27.7	1110	36.1
	Mall	1290	26.4	828	27.0
	Suburb	1190	24.4	847	27.6
	University	1140	23.4	740	24.1

Figure 3: Total Population and Population within 25 Minutes of Key Points

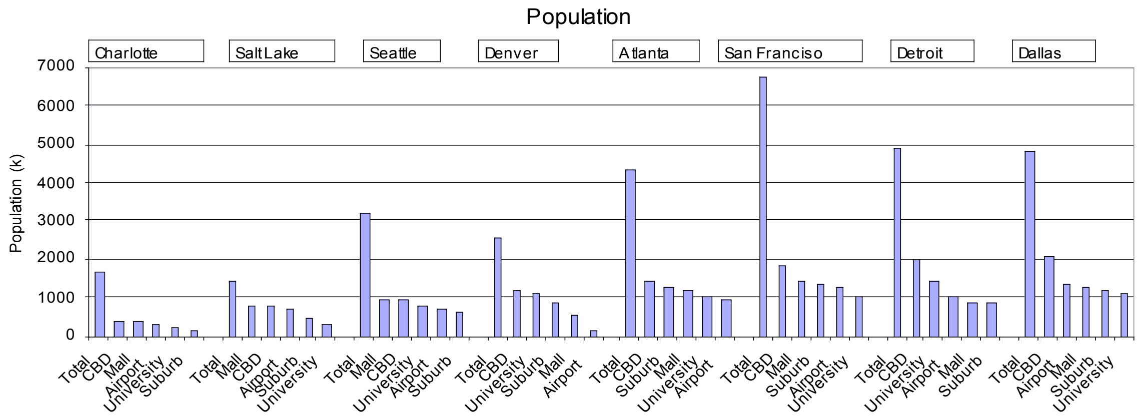
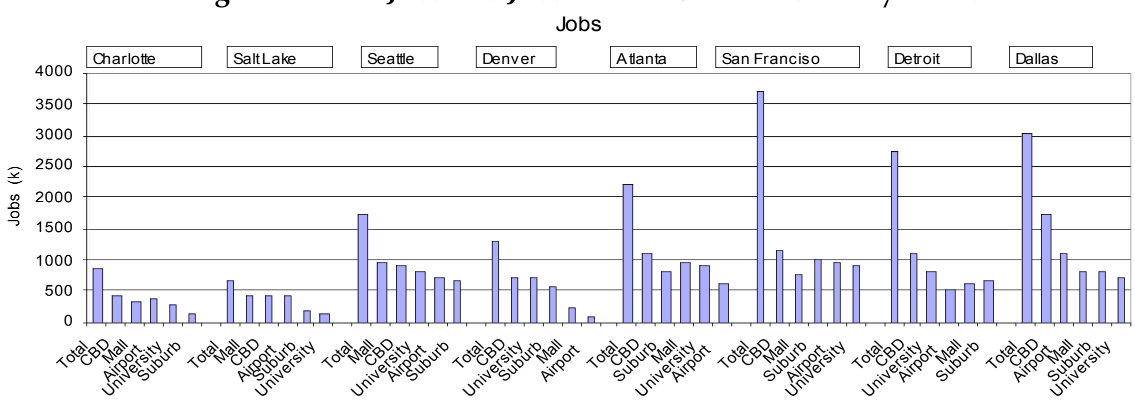


Figure 4: Total Jobs and Jobs within 25 Minutes of Key Points

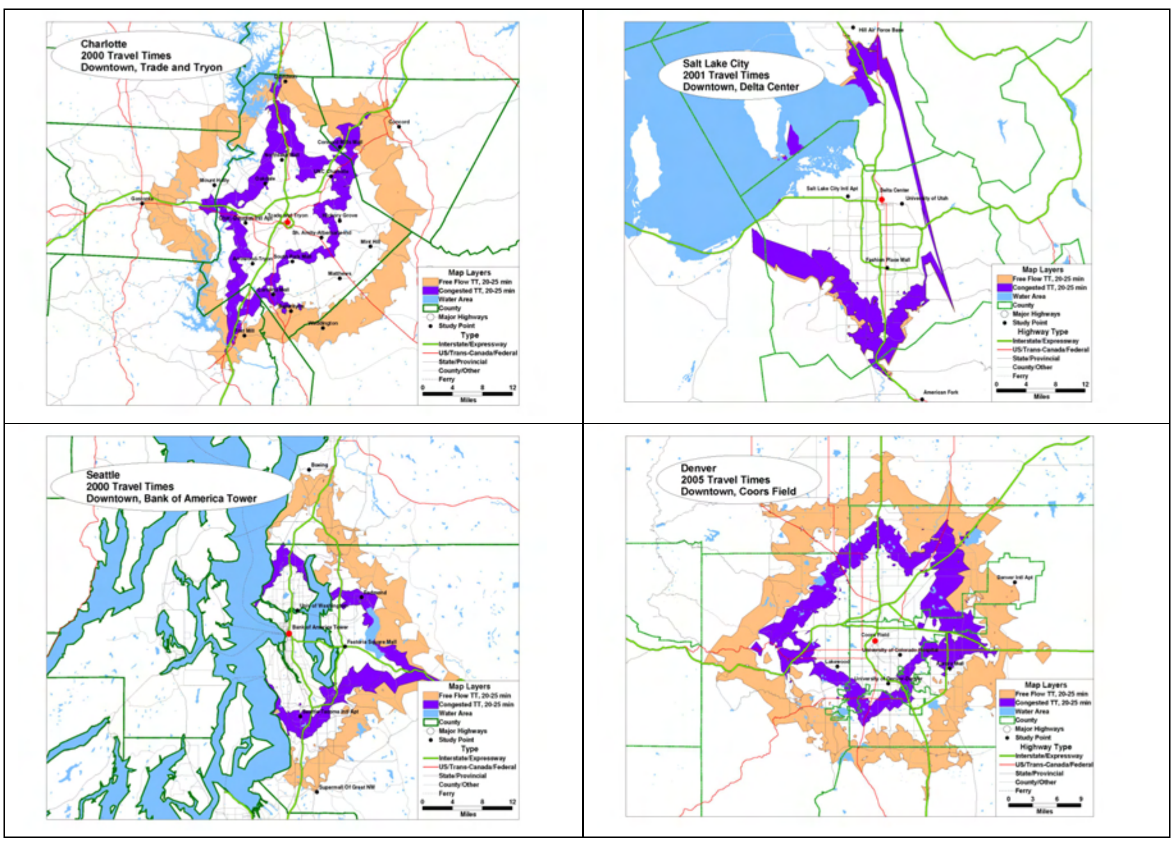


C. Future Changes in Accessibility

To determine future changes in accessibility, we computed the proportion of residents and jobs within 25 minutes of each point in each region, for present and future (year 2030) networks, and with and without congestion. We then determined the change (in percent) in accessibility by comparing the base case with other cases. Our assessments are based on "equilibrium" traffic models for each region which account for congestion, population and employment growth, new and committed roads and transit service, changes in trip origins and destinations, and shifts of routes to faster roads. We used these computations to estimate drive times for congested regions.[14]

Table 4 and Figure 5 summarize the findings for the CBDs. Of the eight, seven will experience future declines in the relative access of their CBDs, ranging from -1 percent (meaning 1 percent less accessible than the base year) for Seattle to -17 percent for Denver. This will occur because the suburbs of these regions will grow more rapidly than the inner areas. (All regions will grow in absolute accessibility due to an increase in population density). But removal of congestion would yield significant improvements, between 1 and 41 percent in CBD access, more than offsetting suburban growth in seven of the eight cities.

Figure 5: 25-Min Drive Time Contours for Downtown Areas.



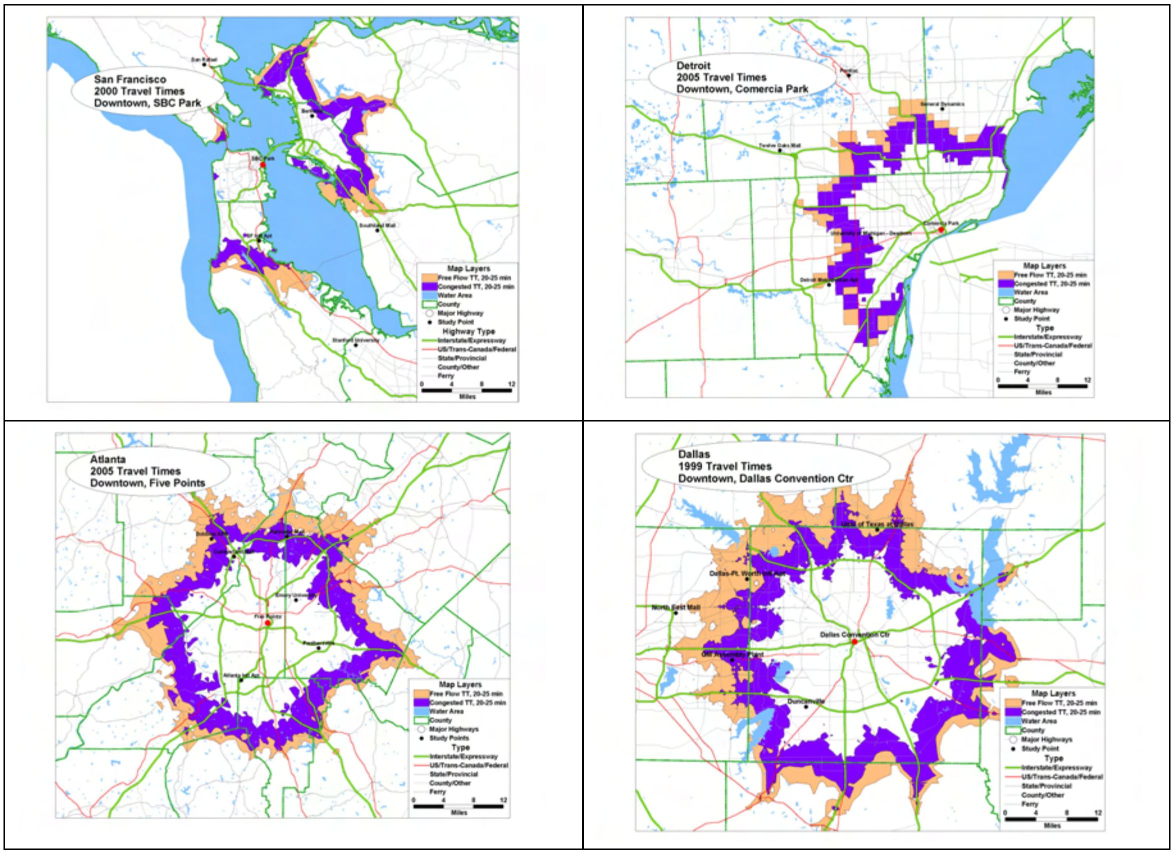


Table 4: Changes in Accessibility for CBDs				
CBD for:	Population Within 25 Min of CBD	Percent Change in Relative Accessibility, Base Yr vs. Future Yr.	Percentage Change in Relative Accessibility, Congested vs. Free Flow	Percentage Change in Relative Accessibility, Base Congested vs. Future Free Flow
Charlotte	441,000	1 to 3	20 to 28	22 to 31
Salt Lake City	801,000	-6 to -9	0.5 to 1	-6 to -8
Seattle	966,000	-1 to -3	14 to 21	13 to 18
Denver	1,181,000	-1 to -17	29 to 41	23 to 28
Atlanta	1,458,000	-5 to -15	9 to 15	0.5 to 4
San Francisco	1,868,000	0 to -3	4 to 5	2 to 4
Detroit	2,035,000	-3 to -6	1 to 6	-3 to 0.4
Dallas	2,129,000	-6 to -13	11 to 14	1 to 5

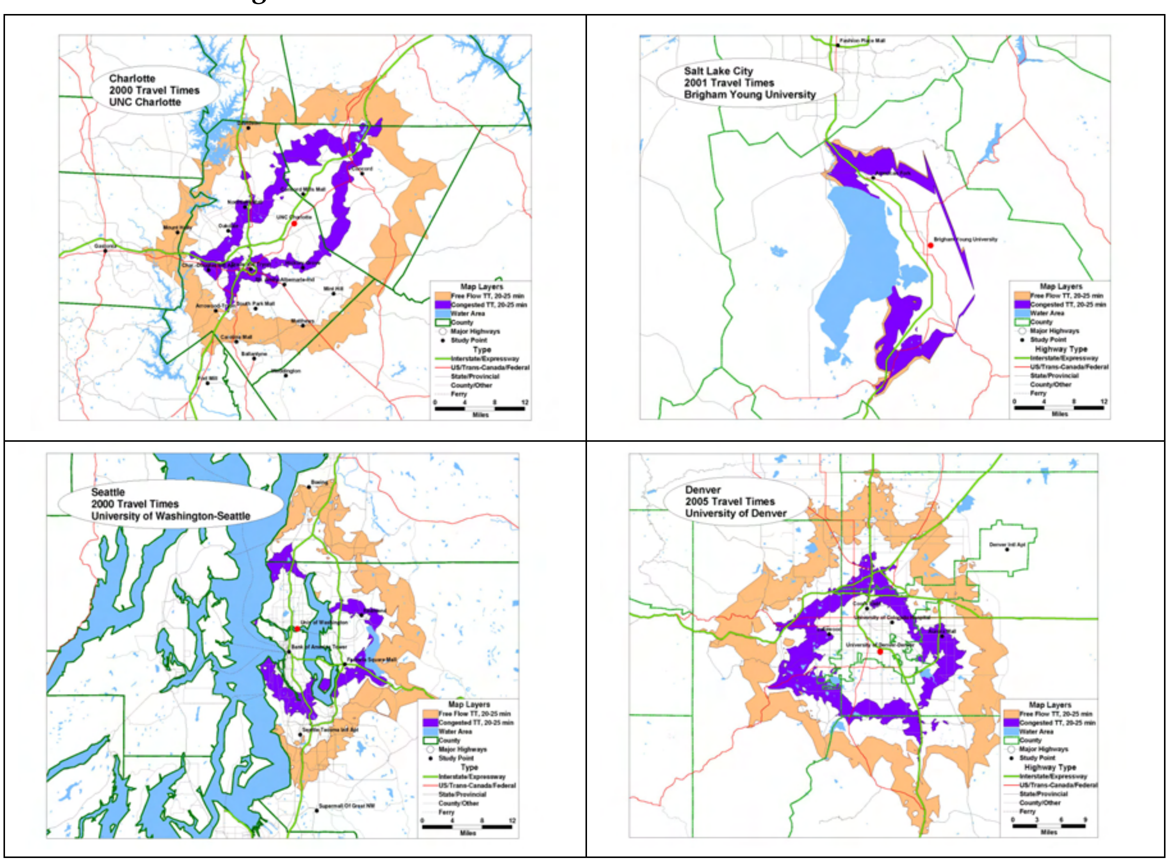
Of the eight regions, the seven largest show essentially the same findings: the CBD is likely to decline in relative accessibility as most future growth goes to the suburbs. But total congestion removal would more than offset this projected decline, in some cases by a significant amount. For the smallest city (Charlotte), CBD access will increase slightly, but congestion removal would also greatly improve it. For Salt Lake City, CBD access will decline but since congestion is relatively low the decline is mostly due to suburban growth and removing congestion will have little effect on CBD access.

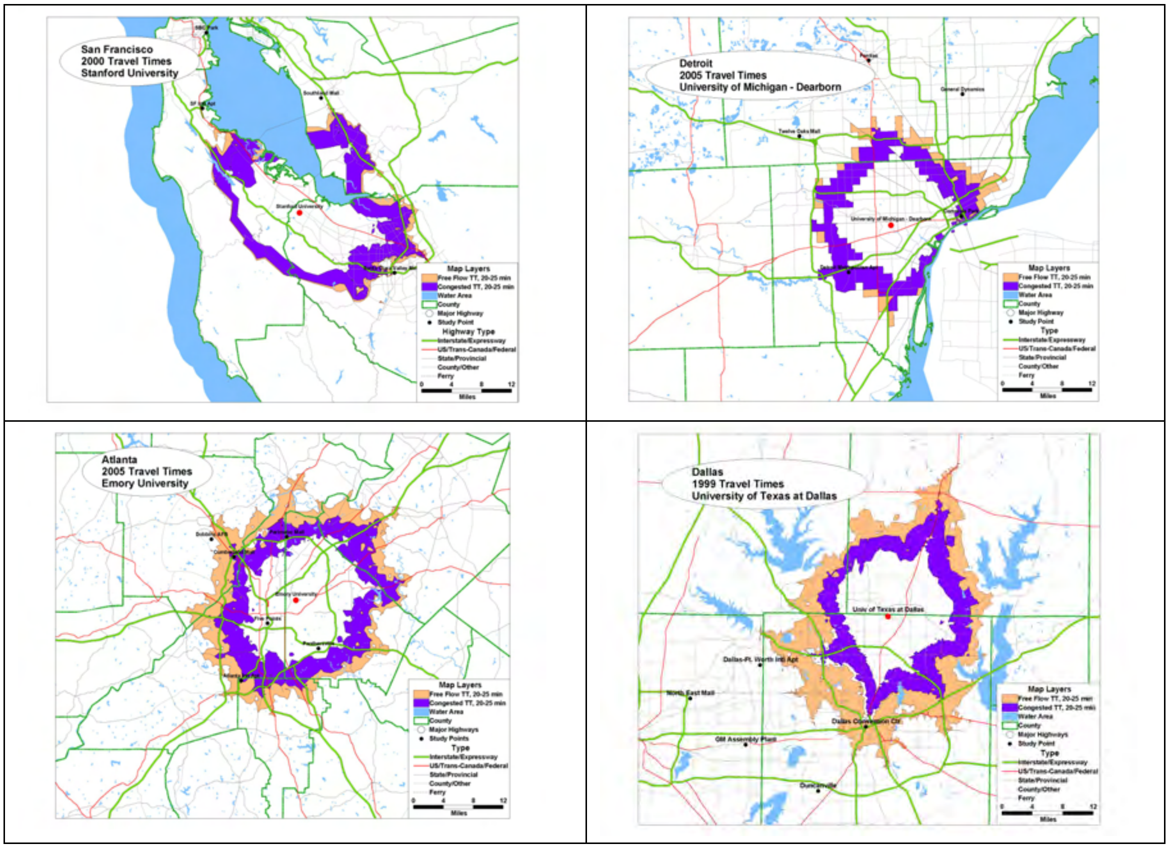
A similar but even more dramatic effect is observed for accessibility to universities. The population and jobs within 25 minutes are generally less for universities than for downtowns, but suburban growth is likely to impact them more. Table 5 and Figure 6 show that six of the eight regions' major universities will become relatively less accessible as the region grows and congestion increases. The reductions in relative accessibility range from -1 to -16 percent. (The two exceptions are Charlotte and Salt Lake City). However, the effect of removing congestion from the network is even more substantial on university access than on CBD access. The effect is largest for Charlotte and Denver, and smallest for Detroit. The increase in relative accessibility ranges from a low of -1 in Salt Lake City, to a high of 37 percent for Charlotte.

Table 5: Changes in Accessibility for Universities

Major University in:	Population Within 25 min of Major Univ.	Percentage Change in Relative Accessibility, Base Year vs Future Year	Percentage Change in Relative Accessibility, Congested vs. Free Flow	Percentage Change in Relative Accessibility, Base Congested vs. Future Free flow
Charlotte	294,000	2 to 8	29 to 35	36 to 37
Salt Lake City	350,000	0.5 to 3	0 to 1.2	2 to 3
Seattle	838,000	-1 to -3	21 to 24	20 to 21
Atlanta	916,000	-4 to -16	9 to 19	2 to 4
San Francisco	1,050,000	-1 to -4	2 to 5	2 to 3
Dallas	1,133,000	-0.3 to -4	14 to 26	10 to 24
Denver	1,138,000	-2 to -17	25 to 46	23 to 29
Detroit	1,454,000	-3 to -4	2 to 4	0 to -0.8

Figure 6: 25-Min Drive Time Contours for Universities.



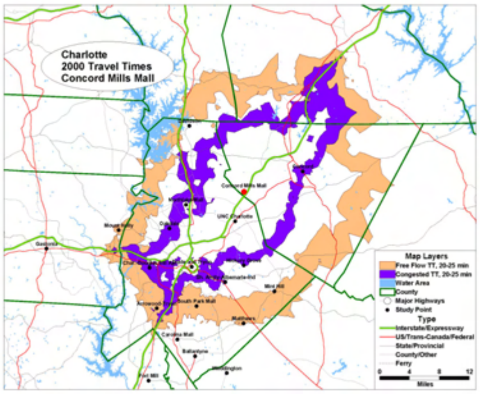


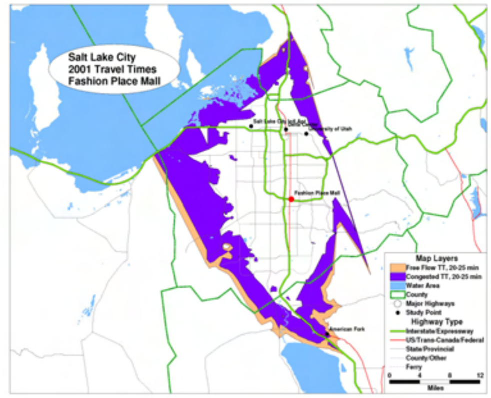
The impact of congestion removal on accessibility to major malls is not as dramatic. Table 6 and Figure 7 show that seven of the eight regions' major malls will decline in relative accessibility as the region grows (the exception is Charlotte). However, the removal of congestion from the regional network would more than offset that effect in all regions, and would have the effect of making the major malls considerably more accessible than at present. The largest effect would be for Denver's Aurora Mall (42 to 54 percent) and the smallest for Salt Lake City's Fashion Place Mall (-1 to -4 percent) where the removal of congestion would be insufficient to turn around declining access.

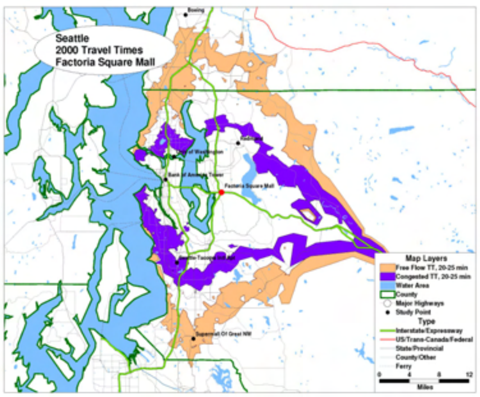
Table 6: Changes in Accessibility for Major Malls

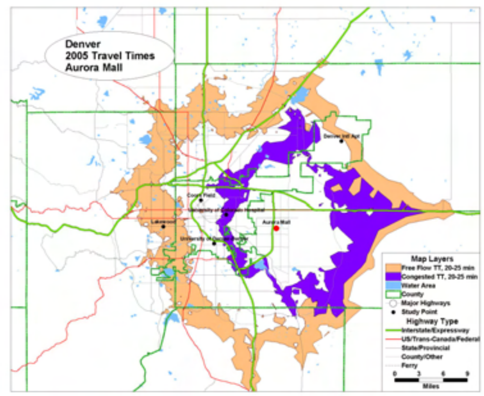
Major Mall in:	Population Within 25 min of Major Mall	Percentage Change in Relative Accessibility , Base Year vs. Future Year	Percentage Change in Relative Accessibility, Congested vs. Free Flow	Percentage Change in Relative Accessibility, Base Congested vs. Future Free Flow
Charlotte	402,000	5 to 7	20 to 22	25 to 27
Denver	595,000	- 3 to -7	47 to 57	42 to 54
Salt Lake City	817,000	- 3 to -7	2 to 4	- 1 to -4
Detroit	944,000	- 0.1 to -3	4 to 8	4 to 5
Seattle	998,000	- 1 to -2	14 to 22	13 to 20
Dallas	1,280,000	- 3 to -5	10 to 17	8 to 13
San Francisco	1,489,000	- 0.1 to -3	4 to 11	5 to 8
Atlanta	1,890,000	- 5 to -9	16 to 20	10 to 11

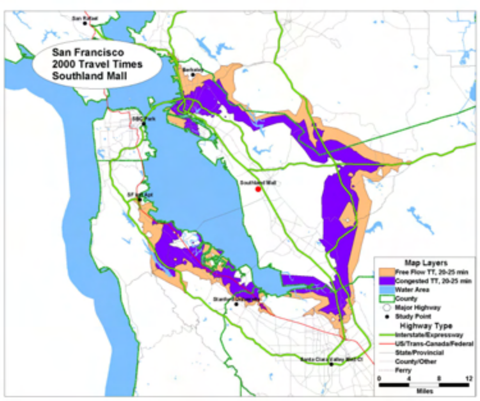
Figure 7: 25-Min Drive Time Contours for Major Malls

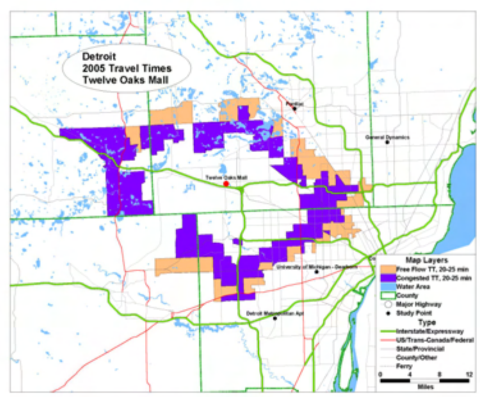

Charlotte
2000 Travel Times
Concord Mills Mall

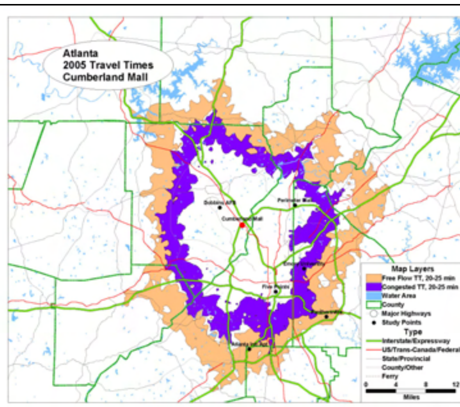

Salt Lake City
2001 Travel Times
Fashion Place Mall

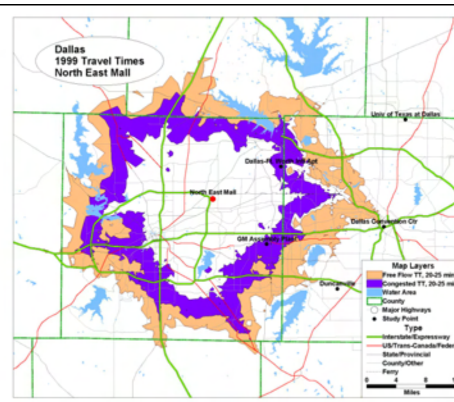

Seattle
2000 Travel Times
Factoria Square Mall


Denver
2005 Travel Times
Aurora Mall


San Francisco
2000 Travel Times
Southland Mall


Detroit
2005 Travel Times
Twelve Oaks Mall


Atlanta
2005 Travel Times
Cumberland Mall

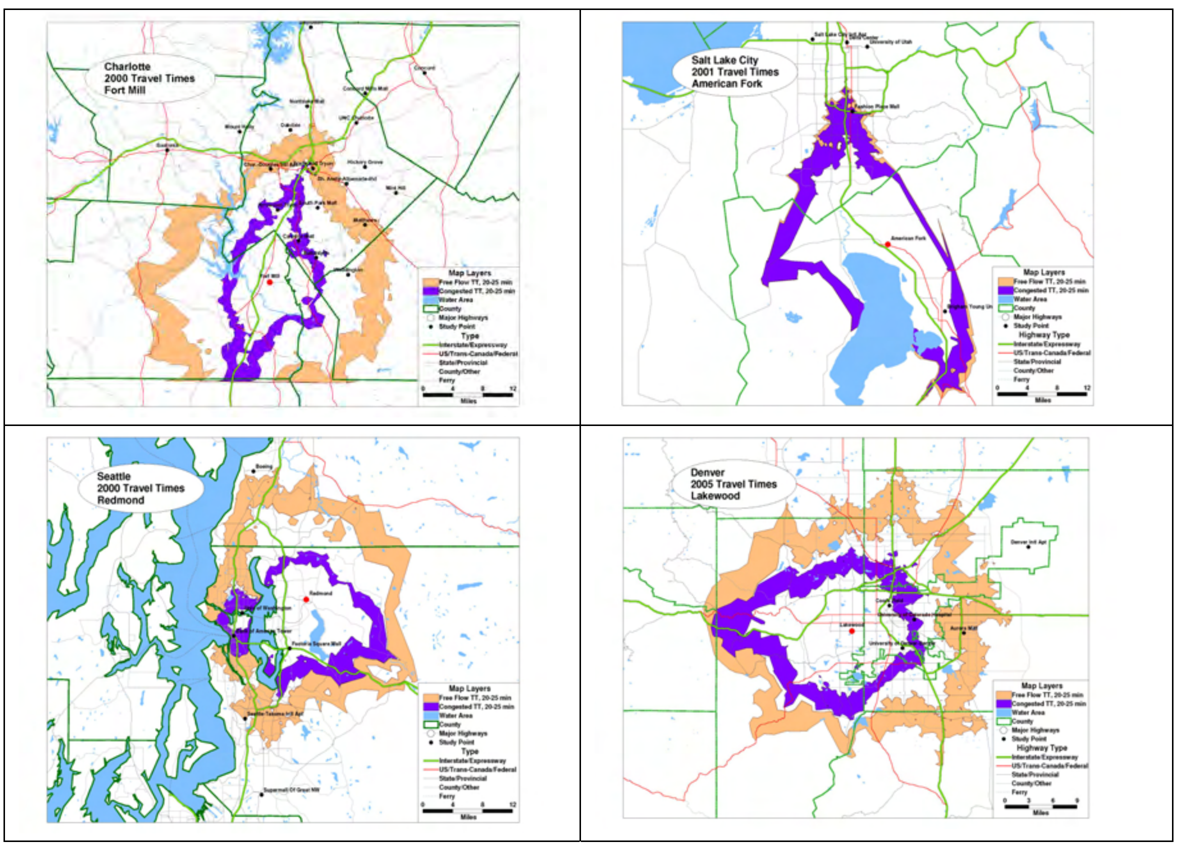

Dallas
1999 Travel Times
North East Mall

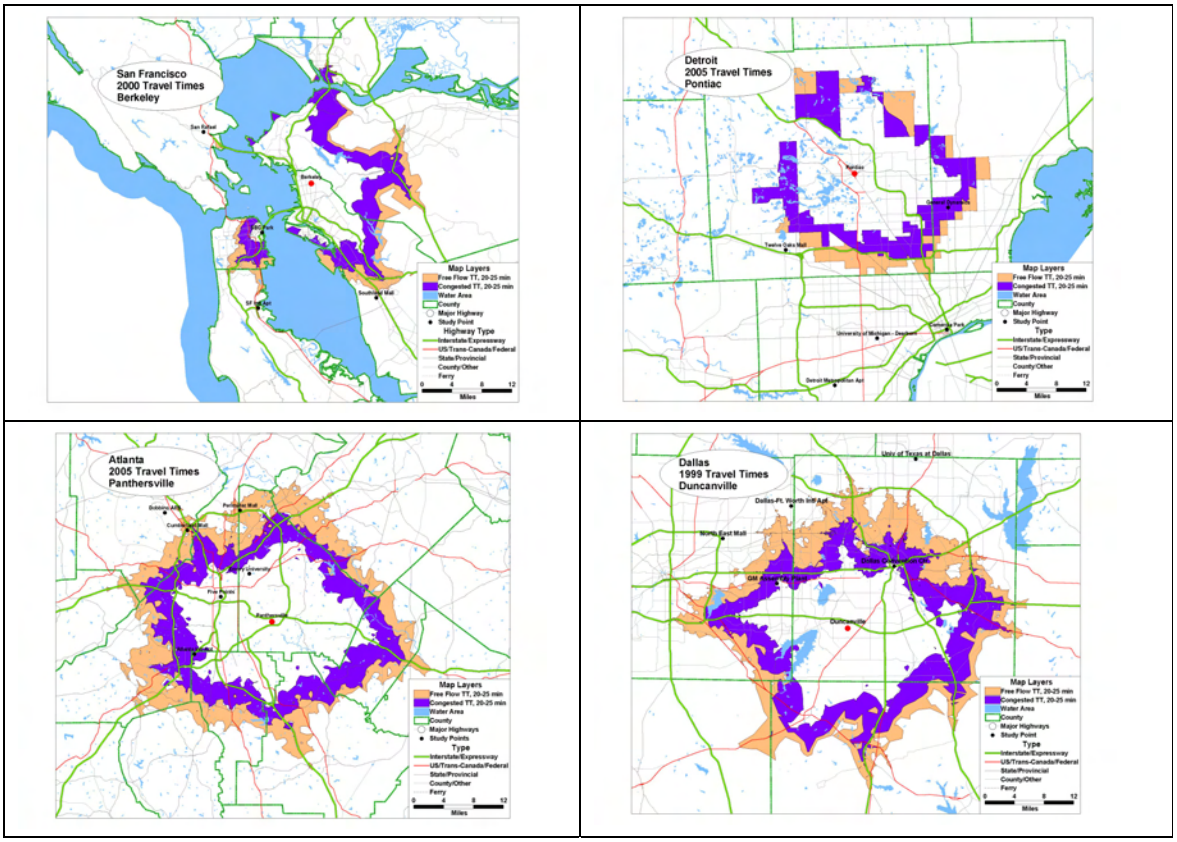
Looking at major suburbs (Table 7 and Figure 8) the results are more modest in scale but similar overall: removal of congestion from the regional networks would enable these present-day nearby suburbs to improve their access relative to the remainder of the region.

Table 7: Changes in Accessibility for Major Suburbs

Major Suburb for:	Population Within 25 min of Major Suburb	Percentage Change in Relative Accessibility, Base Year vs. Future Year	Percentage Change in Relative Accessibility, Congested vs. Free Flow	Percentage Change in Relative Accessibility, Base Congested vs. Future Free Flow
Charlotte	163,000	-1 to -2	24 to 35	26 to 33
Salt Lake City	489,000	2 to 4	3 to 6	6 to 7
Seattle	630,000	- 0.6 to -2	22 to 24	21 to 23
Denver	930,000	- 5 to -17	36 to 48	27 to 31
Atlanta	1,300,000	-3 to -11	10 to 20	7 to 9
San Francisco	1,408,000	0.4 to -3	4 to 7	2 to 5
Detroit	901,000	2 to -1	3 to 6	3 to 6
Dallas	1,182,000	-3 to -6	12 to 18	8 to 13

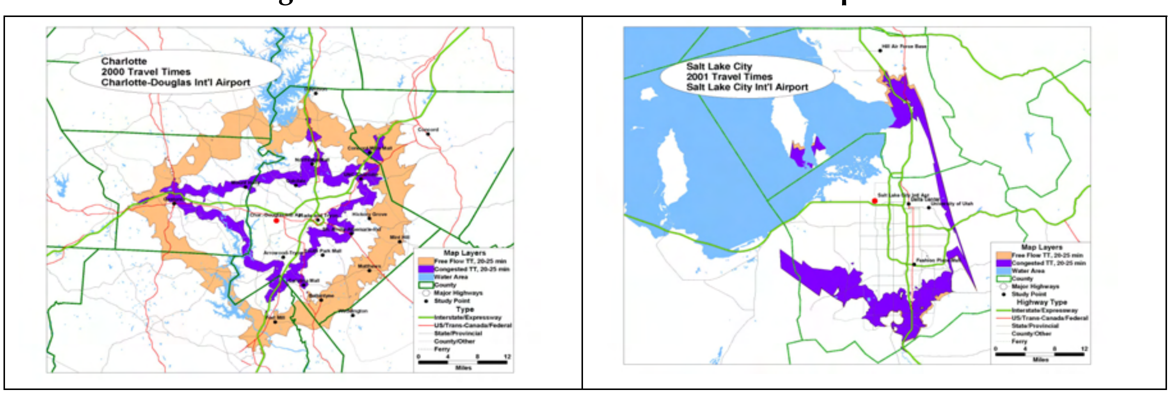
Figure 8: 25-Min Drive Time Contours for Major Suburbs





The overall results for airports are also similar (Table 8 and Figure 9). Removal of congestion would allow likely declines in airport accessibility to be reversed, increasing the access to the region's airport relative to other points. Only for Salt Lake City is the removal of congestion too small in impact to offset the likely regional decline of airport access caused by suburbanization.

Figure 9: 25-Min Drive Time Contours for Airports



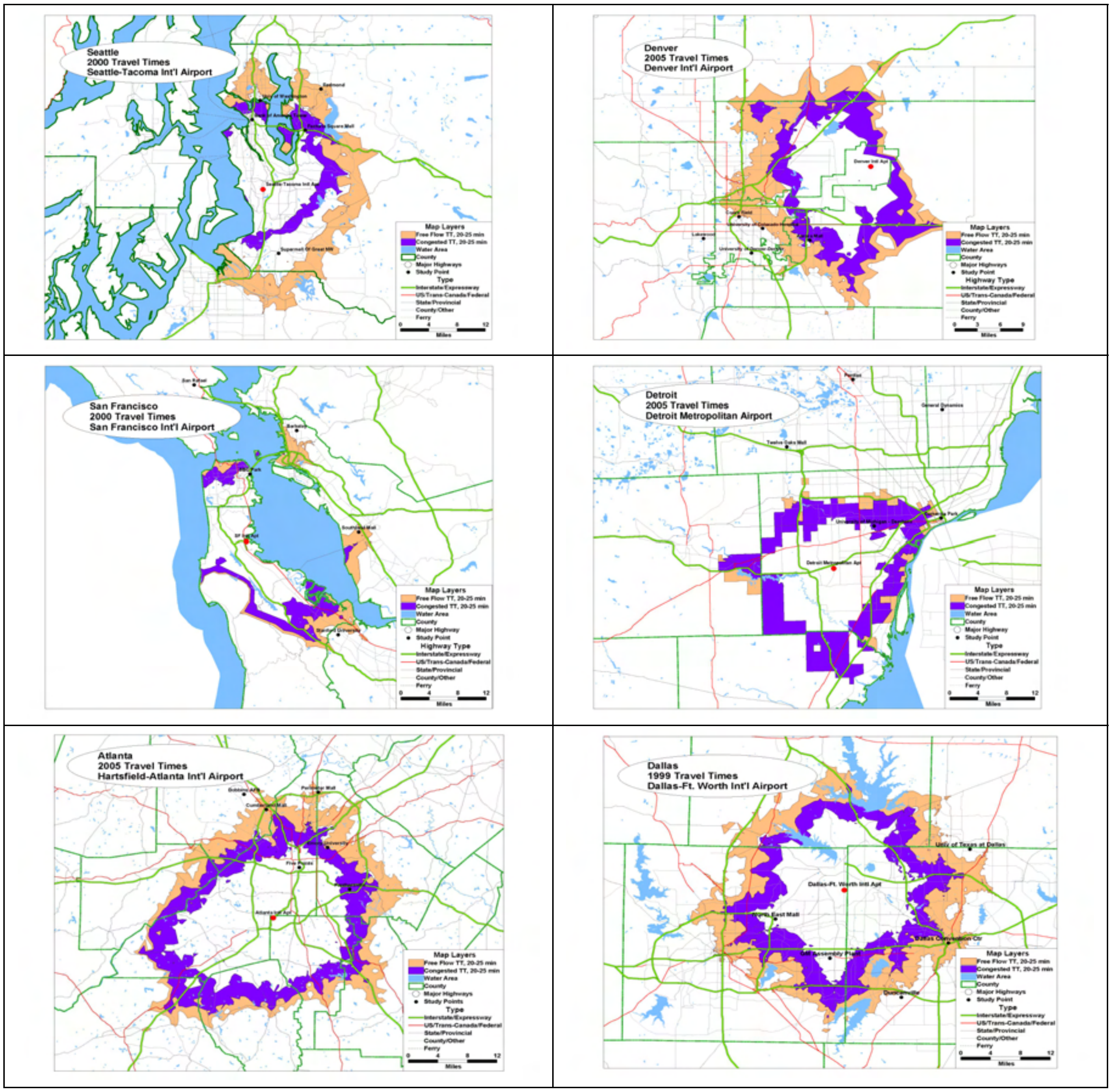


Table 8: Changes in Accessibility for Airports

Major Airport for:	Population Within 25 min of Airport	Percentage Change in Relative Accessibility, Base Year vs. Future Year	Percentage Change in Relative Accessibility, Congested vs. Free Flow	Percentage Change in Relative Accessibility, Base Congested vs. Future Free Flow
Charlotte	361,000	-0.1 to 9	16 to 31	21 to 34
Salt Lake City	774,000	- 4 to -7	0.1 to 2	- 5 to -4
Seattle	750,000	-1 to -3	18 to 21	17 to 20
Denver	210,000	-2 to 6	13 to 23	16 to 22
Atlanta	987,000	- 5 to -7	10 to 17	7 to 10
San Francisco	1,319,000	- 1 to -3	5 to 7	4 to 5
Detroit	1,038,000	- 0.6 to -2	3 to 4	1 to 4
Dallas	1,343,000	- 3 to -6	14 to 25	11 to 22

Part 3

How Does Accessibility Affect Regional Economic Performance?

The Gross National Product is commonly defined as the sum of the value of all goods and services produced annually by the nation. Analogously, one can also think of a Gross State Product or Gross Regional Product as the sum of the value of all goods and services produced annually by a state or urban region.

To determine changes in regional economic performance related to changes in accessibility, we first estimated the 'Gross Regional Product' of each area, proportional to state GSP and county income data for the base year. Dividing by the number of workers (jobs) in each region gives the regional productivity, or gross regional product per worker (job). These range from $81,700 for Salt Lake City to $125,400 for San Francisco.[15]

Accessibility between jobs and universities or major suburbs shows a stronger and more sensitive relationship with regional productivity than accessibility of population to CBDs. Since the impact of job access to universities, suburbs and major malls is an often-overlooked element of regional access, the findings suggest that analysts should turn to other major points within urban regions in evaluating how access will influence regional performance.

The information in Table A-3 (our statistical results on page 39) is generally consistent with that reported by Prud'homme and Lee, who found that a 10 percent improvement in 25-minute CBD population accessibility improved regional performance by about 1.3 percent for 22 cities in France. Our data found about 1 percent for the same model.

How will congestion removal affect the economic performance of a region? To determine this we calculated the change in regional productivity that would occur if each region were able to remove severe congestion. Results are shown in Table 9. The analysis indicates that removal of severe congestion in these eight cities would lead to significant improvements in regional economic performance. The largest gains come from improving access to suburbs, malls and universities. Of course not all congestion can be removed from a region; this assessment therefore provides an upper bound on the impact of likely congestion-removal strategies.

Table 9: Impact of Congestion Relief on Regional Economies

Region	Location	Base Year Product-ivity per Worker	Increase In Worker Productivity With Free-Flow Traffic	Percent Increase In Worker Productivity If Congestion Is Removed	Productivity Per Worker With Free-Flow Traffic Conditions	Estimated Gross Regional Product Under Free-Flow Conditions	Possible Annual Increase in GRP Due to Free-Flow Traffic	Potential New Tax Revenues From Free-Flow Conditions Over 20 Years at 7%	Estimated Cost to Remove LOS F Congestion by 2030
		($)	($)		($)	($B)	($B)	($B)	($B)
Charlotte	Suburb	93,136	28,638	30.7	121,774	95.6	22.5	31.5	$ 3-5 B
	University	93,136	18,499	19.9	111,635	87.7	14.5	20.3	
	Mall	93,136	5,468	5.9	98,605	77.4	4.3	6.0	
	CBD	93,136	4,178	4.5	97,314	76.4	3.3	4.6	
	Airport	93,136	1,887	2	95,023	74.6	1.5	2.1	
Salt Lake City	Suburb	81,678	1,155	1.4	82,832	50.6	0.7	1	$ 1-2 B
	Mall	81,678	210	0.3	81,888	50.1	0.1	0.2	
	University	81,678	57	0.1	81,735	50	0	0	
	CBD	81,678	15	0	81,693	49.9	0	0	
	Airport	81,678	6	0	81,683	49.9	0	0	
Seattle	Suburb	113,419	9,216	8.1	122,635	178.7	13.4	18.8	$ 5-10 B
	University	113,419	9,081	8	122,500	178.5	13.2	18.5	
	CBD	113,419	3,241	2.9	116,660	170	4.7	6.6	
	Mall	113,419	3,233	2.9	116,652	170	4.7	6.6	
	Airport	113,419	2,495	2.2	115,914	168.9	3.6	5.1	
Denver	Mall	116,533	36,823	31.6	153,356	160.1	38.5	53.8	$ 10-15 B
	Suburb	116,533	13,809	11.8	130,342	136.1	14.4	20.2	
	University	116,533	8,884	7.6	125,417	131	9.3	13.0	
	Airport	116,533	8,558	7.3	125,091	130.6	8.9	12.5	
	CBD	116,533	6,661	5.7	123,194	128.6	7	9.7	
San Francisco	Mall	125,402	5,326	4.2	130,728	262.3	10.7	15	$ 29-40 B
	Suburb	125,402	2,539	2	127,942	256.7	5.1	7.1	
	University	125,402	2,316	1.8	127,718	256.2	4.6	6.5	
	CBD	125,402	1,714	1.4	127,116	255	3.4	4.8	
	Airport	125,402	1,475	1.2	126,878	254.6	3	4.1	
Detroit	Suburb	107,258	3,925	3.7	111,183	208	7.3	10.3	$ 25-30 B
	University	107,258	2,621	2.4	109,879	205.5	4.9	6.9	
	Mall	107,258	2,051	1.9	109,309	204.5	3.8	5.4	
	CBD	107,258	1,726	1.6	108,983	203.8	3.2	4.5	
	Airport	107,258	934	0.9	108,191	202.4	1.7	2.4	
Dallas	University	98,162	18,651	19	116,813	288	46	64.4	$ 26-30 B
	Suburb	98,162	9,391	9.6	107,554	265.1	23.2	32.4	
	Mall	98,162	7,259	7.4	105,421	259.9	17.9	25.1	
	Airport	98,162	3,042	3.1	101,205	249.5	7.5	10.5	
	CBD	98,162	2,289	2.3	100,452	247.6	5.6	7.9	
Atlanta	Suburb	112,049	7,334	6.5	119,382	250.1	15.4	21.5	$ 13-15 B
	Mall	112,049	6,021	5.4	118,070	247.4	12.6	17.7	
	University	112,049	5,878	5.2	117,927	247.1	12.3	17.2	
	Airport	112,049	2,618	2.3	114,667	240.3	5.5	7.7	
	CBD	112,049	2,537	2.3	114,586	240.1	5.3	7.4	

Removing congestion can clearly have a significant impact on GRP. In Charlotte, for instance, removing congestion in suburbs would boost regional performance by about 30 percent. For other regions the economic effects are generally proportional to the increase in access:

- **Salt Lake City's** regional network is currently not as congested as other cities, so removal of congestion would have a marginal impact on its regional economy.
- **Seattle's** economy would be most improved in productivity by focusing congestion relief on access to suburbs and universities.
- **Denver's** economy would benefit most from accessibility improvements to malls and suburbs.
- **San Francisco's** economy would be most improved by access improvements to malls and suburbs**.**
- **Detroit's** economy would benefit most from accessibility improvements to suburbs and universities.
- **Dallas's** economy would benefit most from accessibility improvements to universities, suburbs and malls.
- **Atlanta's** economy would benefit most from focusing congestion relief on suburbs, malls and universities.

Of the five types of sites we looked at, the biggest improvement in regional performance tended to come from improving access to major suburbs and malls. Airport access seems to be the least important player in regional economic performance, even though it is often mentioned by companies looking to relocate. Perhaps they are already reasonably accessible, or perhaps residents and businesses make so few airport trips that airport access is not as critical as some would think.

Part 4

Conclusion, Recommendations and Regional Access Summaries

A. Conclusion

The most accessible place in most regions is the central business district, with 25 to 54 percent of population and 31 to 63 percent of jobs within 25 minutes peak hour drive time. Other points typically have fewer jobs or residents within 25 minutes than the central business district. However, growing congestion and suburban growth together mean that key points in most regions, including the CBD, will become *relatively* less accessible in the future. Most key points within regions will decline in relative access as the region grows. These points are already built up, and so they will be surrendering their prior access advantages to other points currently developing.

However, the impact of removing severe congestion and improving access to these points is substantial. Removal of congestion, would allow regions to reverse the declining access of key points and instead raise their relative access**.** If these points are to remain accessible to the rest of the region then congestion reduction will be a key strategy in that effort.

Most studies of productivity have focused on CBD access; this study suggests that other sites may be more important in the regional economies. Regional productivity seems to depend more on access to other locations than on access to downtown. Not only is regional productivity more sensitive to access to non-CBD points, but the cost of congestion relief for those points may be less too. An implication of this study is that current transportation plans may be placing too much focus on downtowns. In mid-sized cities where car use is overwhelmingly predominant the impact of suburban transportation improvements will be particularly effective in spurring regional economic performance. Clearly, the role of suburbs, malls and universities in regional economic performance needs to be more fully explored.

Another important finding of the study is that access to jobs is more important in regional economic performance than is access to population. Not only is the impact on regional productivity greater, but the impacts from congestion removal are greater when viewed through a job prism than a resident prism. Regions depend on fluid movement between jobs and other locations like malls and universities, as well as residential connections to these sites.

B. Recommendations

It is vital that planners and policymakers recognize that congestion reduces workers' access to jobs and causes employers to have access to fewer workers, which has a significant impact on the regional economy. City leaders and planners have long been aware that congestion wastes fuel and time, but our findings show that it is a drag on the productivity and growth of the regional economy as well.

Pay more attention to the accessibility of other locations, not just CBDs. Improving accessibility to other key points in the region may provide overlooked opportunities to improve regional performance at a fraction of the cost of improving CBD access.

Improve accessibility in other locations. Suburbs, malls and universities, in particular, showed more potential for access improvement and more impact on regional productivity.

Remove bottlenecks throughout regions. Relatively modest expenditures spent on removal of bottlenecks in a road system can have substantial impact on accessibility, particularly if congestion is relatively concentrated geographically. These locations should be the first to be explored for improvement.

Add capacity in the rims of cities. Our findings suggest that investment in suburban accessibility is likely to be productivity-gaining. Not only is access likely to improve more per dollar invested than in the CBD, but future growth is likely to be higher.

Conduct an accessibility assessment for each city. From a planning perspective accessibility studies are a convenient way of understanding the impact of congestion removal, and of comparing alternate treatments. They are under-used in transportation planning, however, because until recently they were difficult to undertake. New software has made the task easier.

Reconsider arguments against sprawl. This study suggests that an overlooked benefit of congestion reduction is the ability to improve accessibility. This finding dents the planning wisdom that higher density will yield greater productivity and is therefore preferable. Adding the benefits of greater access may be sufficient to tip arguments in favor of greater, not less, highway access.

C. Regional Access Summaries

Charlotte:

Downtown (441,000 people within 25 minutes)

- About 441,000 people (26.3 percent of region) are within 25 minutes of the CBD. This will grow to 919,000 (29.5 percent of 2030 region) by 2030. This means that the region will get more accessible, by about 3.2 percent, even with congestion.
- Similar results occur for employment, and for free-flow conditions with increases in the 1.4 to 5.3 percent range.
- Removal of congestion produces a 19.5-27.6 percent increase in access, about 8-10 times the increase occurring from regional growth.

- **Conclusion: Congestion removal would significantly accelerate the already improving access.**

University (294,000 people within 25 minutes)

- About 294,000 people (17.5 percent of 2000 region) are within 25 minutes of UNC Charlotte. This will grow to 777,000 people (25.0 percent of 2030 region) by 2030. This means that the area will become more accessible, by about 7.5 percent, even with congestion.
- The results are similar for employment, and free-flow conditions, with results ranging from 2.0 to 7.5 percent increases.
- Congestion removal would produce a 28.6 to 34.8 percent increase in accessibility.
- **Conclusion: Congestion removal would significantly accelerate the already improving access.**

Major Mall (402,000 people within 25 minutes)

- About 402,000 people (23.9 percent of 2000 region) are within 25 minutes of Concord Mills Mall. This will grow to 980,000 people (31.3 percent of 2030 region) by 2030. This means that the mall area will become more accessible, by about 7.4 percent, even with congestion. ,
- The results are similar for employment and free-flow conditions, with increases in the 4.7 to 5.5 percent range.
- Congestion removal would produce a 19.6 to 27.6 percent increase in accessibility, about three to five times the increase from regional growth.
- **Conclusion: Congestion removal would significantly accelerate the already improving access.**

Major Suburb (163,000 people within 25 minutes)

- About 163,000 people (9.7 percent of 2000 region) are within 25 minutes of Fort Mill. This will grow to 278,000 population (9 percent of 2030 region). This means that the area will become less accessible, by -0.7 percent.
- The results are similar for employment, with reductions in the -1.3 to -2.0 percent range. Free-flow employment enjoys an increase of 2.5 percent.
- Congestion removal would produce a 23.6 to 34.7 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in access.**

Airport (361,000 people within 25 minutes)

- About 361,000 people (21.5 percent of 2000 region) are within 25 minutes of Charlotte-Douglas International Airport. This will grow to 935,000 people (30.0 percent of 2030 region) by 2030. This means that the area will become more accessible, by 8.5 percent, even with congestion.
- The results for employment and free-flow conditions are mixed, with a -0.1 percent decline in free-flow employment access, but 2.2 and 5.3 percent increase in congested free-flow population and congested employment access, respectively.
- Congestion removal would produce a 15.9 to 31.3 percent increase in accessibility.

- **Conclusion: Congestion removal would further accelerate the already improving access, and reverse any losses in access for free-flow conditions.**

Salt Lake City:

Downtown (about 801,000 people within 25 minutes of CBD)

- About 801,000 people (54.6 percent of region) are within 25 min of the CBD. This will grow to about 1,081,000 (45.4 percent of region) by 2030. (-9.2 percent change). This means that the region will become less accessible, as most growth will be in the edges. The decline in access is -6.8 to -9.2 percent)
- Similar results occur for employment and for free-flow conditions, with reductions in the -6.4 to -8.9 percent range.
- This region is not very congested (TTI 1.28, future 1.59), relative to size. Removal of congestion produces only about a 0.5-1.1 percent improvement in access.
- **Conclusion: Congestion removal would only slightly improve declining access.**

University (350,000 people within 25 minutes)

- About 350,000 people (24.1 percent of 2001 region) are within 25 minutes of Brigham Young University. This will grow to 580,000 people (24.6 percent of 2030 region) by 2030. This means that the area will become more accessible, by about 0.5 percent.
- Similar results occur for employment and free-flow conditions, with increases ranging from 1.3 to 3.1 percent.
- Congestion removal would only produce a 0 to 1.2 percent increase in access.
- **Conclusion: Congestion removal would marginally increase already improving access.**

Major Malls (817,000 people within 25 minutes)

- About 817,000 people (55.4 percent of 2001 region) are within 25 minutes of Fashion Place Mall. This will grow to 114,7000 people (48.1 percent of 2030 region) by 2030. This means that the mall area will become less accessible, by about -7.3 percent.
- Similar results occur for employment and free-flow conditions, with reductions ranging from -2.6 to -5.9 percent.
- Congestion removal would only produce a 1.5 to 3.5 percent increase in access.
- **Conclusion: Congestion removal would slightly improve declining access.**

Major Suburbs (489,000 people within 25 minutes)

- About 489,000 people (33.3 percent of 2001 region) are within 25 minutes of American Fork, which will grow to 839,000 (35.3 percent of 2030 region). This means that the area will become more accessible, by about 2 percent, even with congestion.
- Similar results occur for employment and free-flow conditions, with increases ranging from 3.0 to 4.0 percent.
- Congestion removal would further increase accessibility by 2.6 to 6.0 percent.
- **Conclusion: Congestion removal would approximately double the access improvements already projected.**

Major Airports (774,000 people within 25 minutes)

- About 774,000 people (53 percent of 2001 region) are within 25 minutes of Salt Lake City International Airport. This will grow to 1,097,000 people (46.2 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -6.8 percent.
- Similar results occur for employment and free-flow conditions, with results ranging from -3.9 to
  -5.8 percent.
- Congestion removal would slightly improve accessibility by 0.10 to 1.7 percent.
- **Conclusion: Congestion removal would slightly improve, but not reverse, the declining access.**

Seattle:

Downtown (966,000 people within 25 minute of the CBD)

- About 966,000 people (54.1 percent of region) are within 25 minutes of the CBD. This will grow to 1,653,000 people (51.9 percent of 2030 region) by 2030. So, the region will become less accessible, by about -2.4 percent.
- Similar results occur for employment and free-flow conditions, with reductions in the -1.3 to -2.7 percent range.
- Congestion removal would yield a 14.1-21.0 percent increase in accessibility; about six times the decline in access caused by growth.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility.**

University (838,000 people within 25 minutes)

- About 838,000 people (25.6 percent of 2000 region) are within 25 minutes of the University of Washington – Seattle. This will grow to 1,065,900 people (23.5 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -2.1 percent.
- Similar results occur for employment and free-flow conditions, with reductions of -1.1 to -2.8.
- Congestion removal would yield a 20.8 to 23.5 percent increase in accessibility.
- **Conclusion: Congestion removal would significantly reverse the projected decline in accessibility caused by growth.**

Major Mall (998,000 people within 25 minutes)

- About 998,000 people (30.5 percent of 2000 region) are within 25 minutes of Factoria Square Mall. This will grow to 1,294,000 people (28.6 percent of 2030 region) by 2030. This means that the mall will become less accessible, by about -1.9 percent.
- Similar results occur for employment and free-flow conditions, with reductions of -1.00 to -2.3 percent.
- Congestion removal would yield a 13.7 to 22.1 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Suburb (630,000 people within 25 minutes)

- About 630,000 people (19.3 percent of 2000 region) are within 25 minutes of Redmond. This will grow to 839,000 people (18.6 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -0.7 percent.
- Similar results occur for employment and free-flow conditions, with reductions of -0.6 to -1.7 percent.
- Congestion removal would yield a 21.6 to 23.5 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Airport (750,000 people within 25 minutes)

- About 750,000 people (22.9 percent of 2000 region) are within 25 minutes of Seattle-Tacoma International Airport. This will grow to 1,399,000 people (21.5 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -1.4 percent.
- Similar results occur for employment and free-flow conditions, with reductions of -1.6 to -3.1 percent.
- Congestion removal would yield an 18.2 to 21.4 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Denver:

Downtown (1,181,000 people within 25 minutes of the CBD)

- About 1,181,000 people (47.2 percent of region) are within 25 min of the CBD. Growth will increase this to 1,244,000 people (29.9 percent of 2030 region) by 2030. Most of the growth will be in the suburbs, so downtown's accessibility will decline sharply (-17.3 percentage points) according to growth location.
- Similar results (but a wide spread ranging from -0.8 percentage points to -17.3 percentage points) occur for employment and free-flow conditions.
- Congestion removal would yield a 28.8-40.7 percent point increase in access, about three times the decline caused by growth.
- **Conclusion: Congestion removal would reverse the decline in access caused by suburban growth.**

University (1,138,000 within 25 min)

- About 1,138,000 people (43.2 percent of 2005 region) are within 25 minutes of the University of Denver. This will decrease to 1,027,000 people (26 percent of 2030 region) by 2030. This means that the area will become less accessible by about -17.2 percent.
- Similar results occur for employment and free-flow conditions, with reductions varying widely between -2.2 and -17 percent.
- Congestion removal would yield a large 24.7 to 46.2 percent point increase in access.
- **Conclusion: Congestion removal would significantly reverse the projected decline in accessibility caused by growth.**

Major Mall (595,000 people within 25 minutes)

- About 595,000 people (22.6 percent of 2005 region) are within 25 minutes of Aurora Mall. This will grow to 620,000 people (15.7 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -6.9 percent.
- Similar results occur for employment and free-flow conditions, with reductions of -2.5 to -4.9 percent.
- Congestion removal would yield a large 47.3 to 57.0 percent increase in access.
- **Conclusion: Congestion removal would significantly reverse the projected decline in accessibility caused by growth.**

Major Suburb (930,000 people within 25 minutes)

- About 930,000 people (35.3 percent of 2005 region) are within 25 minutes of Lakewood. This will decline to 804,000 people (20.4 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -14.9 percent.
- Similar results occur for employment and free-flow conditions, with reductions of -4.6 to -17.3 percent.
- Congestion removal would yield a large 35.7 to 48.4 percent increase in access.
- **Conclusion: Congestion removal would significantly reverse the projected decline in accessibility caused by growth.**

Airport (210,000 people within 25 minutes)

- About 210,000 people (8 percent of 2005 region) are within 25 minutes of Denver International Airport. This will grow to 250,000 people (6.3 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -1.7 percent.
- Similar results occur for employment, but free-flow shows increases of 3.9 to 5.9 percent.
- Congestion removal would yield a 12.9 to 23.2 percent increase in access.
- **Conclusion: congestion removal would reverse the projected decline in accessibility caused by growth, and would more than double the congested access.**

Atlanta:

Downtown (1,419,000 people within 25 minutes of the CBD)

- About 1,458,000 people (33.7 percent of the 2005 region) are within 25 minutes of the Five Points. This will decrease slightly to 1,419,000; also will be lower by percentage (23.2 percent of 2030 region) since most growth will be in the suburbs. This means that the Atlanta CBD will become relatively less accessible, by about -10.5 percent.
- Similar results occur for employment access. The CBD will decline in relative access, from 49.0 percent of jobs to 34.0 percent of jobs within 25 minutes, between 2005 and 2030.
- Under free flow conditions, we find similar results. The range is from -5.5 percent to -14.6 percent. But congestion removal would increase the Atlanta CBD access by 9.2-15.1 percent, more than offsetting the decline in access caused by suburban growth.

- **Conclusion: Congestion removal would reverse the decline in access caused by suburban growth and allow the region's CBD to improve its accessibility, by about 3.7 – 0.5 percent.**

University (916,000 people within 25 minutes)

- About 916,000 people (25.4 percent of 2000 region) are within 25 minutes of Emory University. This will grow to about 1,097,000 people (15 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -10.4 percent.
- Similar results occur for employment and free-flow conditions, with reductions ranging from -4.3 to -16.4 percent.
- Congestion removal would yield an 8.5 to 18.7 percent increase in access.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Mall (1,189,000 people within 25 minutes)

- About 1,189,000 people (27.5 percent of 2000 region) are within 25 minutes of Cumberland Mall. This will grow to about 1292000 people (21.2 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -6.3 percent.
- Similar results occur for employment and free-flow conditions, with reductions ranging from -5.0 to -9.2 percent.
- Congestion removal would yield a 15.5 to 20.2 percent increase in access, about two to three times the decrease in access due to growth.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Suburb (1,300,000 people within 25 minutes)

- About 1,300,000 people (30.1 percent of 2000 region) are within 25 minutes of Panthersville. This will grow to about 1,350,000 people (22.1 percent of 2030 region) by 2030. This means that the area will become less accessible, by -7.9 percent.
- Similar results for employment and free-flow conditions, with reductions ranging from -2.9 to -11.2 percent.
- Congestion removal would yield a 10.10 to 20.2 increase in access
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Airport (987,000 people within 25 minutes)

- About 987,000 people (22.8 percent of 2000 region) are within 25 minutes of Atlanta-Hartsfield International Airport. This will grow to about 1,416,000 people (17.9 percent of 2030 region) by 2030. This means that the area will become less accessible, by about -4.9 percent.
- Similar results occur for employment and free-flow conditions, with reductions ranging from -2.8 to -6.9 percent.
- Congestion removal would yield a 10.00 to 16.5 percent increase in access
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

San Francisco:

Downtown (1,868,000 people within 25 minutes of the CBD)

- San Francisco has 1,868,000 people (27.6 percent of region) within 25 minutes of CBD. This will increase to 2,179,000 people (24.9 percent of region) by 2030. This means that the region is getting slightly less accessible, by -2.7 percentage points.
- Similar modest results occur for employment and free-flow conditions. Results range from -1.8 to -2.6 percent.
- Congestion removal would yield a 3.7 to 4.6 percentage point increase in accessibility.
- **Conclusion: Congestion removal would hold the CBD at its current level of access, essentially reversing the small decline caused by suburban growth.**

University (1,050,000 people within 25 minutes)

- About 1,050,000 people (15.5 percent of 2000 region) are within 25 minutes of Stanford University. This will grow to about 1244000 people (14.2 percent of 2030 region) by 2030. This means that the area will decline in access by -1.3 percent.
- Mostly similar results occur for employment and free-flow conditions, with employment decreasing by -1 percent free-flow conditions, and -3.5 percent congested. Free-flow conditions population reach shows and increase of 0.4 percent.
- Congestion removal would yield a 2.2 to 5.0 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Mall (1,489,000 people within 25 minutes)

- About 1,489,000 people (22 percent of 2000 region) are within 25 minutes of Southland Mall. This will grow to about 1,707,000 people (19.5 percent of 2030 region) by 2030. This means that the mall area will decline in access by -2.5 percent.
- Mostly similar results occur for employment and free-flow conditions, with employment decreasing by -0.1 percent free-flow conditions, and -3.2 percent congested. Free-flow conditions population reach shows and increase of 0.30 percent.
- Congestion removal would yield a 4.4 to 10.9 percent increase in accessibility, about twice the amount of decrease due to growth.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Suburb (1,408,000 people within 25 minutes)

- About 1,408,000 people (20.8 percent of 2000 region) are within 25 minutes of Berkeley. This will grow to about 1,614,000 people (18.4 percent of 2030 region) by 2030. This means that the area will decline in access by -2.4 percent.
- Similar results occur for employment and free-flow conditions, with reductions ranging from -1.0 to -2.7 percent.
- Congestion removal would yield a 3.7 to 6.9 percent increase in accessibility, about twice the amount of decrease due to growth.

- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Airport (1,319,000 people within 25 minutes)

- About 1,319,000 people (19.5 percent of 2000 region) are within 25 minutes of San Francisco International Airport. This will grow to about 1,494,000 people (17.1 percent of 2030 region) by 2030. This means that the area will decline in access by -2.4 percent.
- Similar results occur for employment and free-flow conditions, with reductions ranging from -1.3 to -2.5 percent.
- Congestion removal would yield a 4.8 to 7.3 percent increase in accessibility
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Detroit

Downtown (2,034,000 Pop within 25 minutes of CBD)

- Detroit has 2,034,000 people (41.2 percent of 2000 region) within 25 minutes of the CBD. This will increase slowly to 2,207,000 people (37.0 percent of 2030 region) by 2030. So the CBD will become less accessible by -.4.2 percentage points.
- Similar results occur for employment and free flow. Results range from -3.4 to -6.4 percentage points.
- Congestion relief would yield a 1.3 to 5.8 percent point increase in access.
- **Conclusion: Congestion removal would reverse and essentially offset modestly declining CBD access.**

University (1,454,000 people within 25 minutes)

- About 1,454,000 people (29.4 percent of 2000 region) are within 25 minutes of University of Michigan – Dearborn. This will shrink to 1,448,000 people (26.8 percent of 2030 region) by 2030. This means that the area will decline in access by -2.6 percent.
- Similar results occur for employment and free-flow conditions, with reductions in access ranging from -2.5 to -4.0 percent.
- Congestion removal would yield a 1.8 to 4.0 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Mall (944,000 people within 25 minutes)

- About 944,000 people (19.1 percent of 2000 region) are within 25 minutes of Twelve Oaks Mall. This will grow to 910,000 people (16.8 percent of 2030 region) by 2030. This means that the mall area will decline in access by -2.3 percent.
- Similar results occur for employment and free-flow conditions, with reductions in access ranging from -0.10 to -2.9.
- Congestion removal would yield a 4.0 to 7.9 percent increase in accessibility, or just more than double the decline in access caused by growth.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Suburb (901,000 people within 25 minutes)

- About 901,000 people (18.2 percent of 2000 region) are within 25 minutes of Pontiac. This will grow to 1,018,000 people (18.8 percent of 2030 region) by 2030. This means that the area will increase in access by 0.6 percent, even with congestion.
- Similar results occur for congested employment, with increases in access of 2.2 percent. Free-flow conditions, however, will have reduced access of between -0.2 and -1.4 percent.
- Congestion removal would yield a 2.7 to 6.1 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the slight projected decline in free flow accessibility by growth, and would further accelerate already improving congested conditions.**

Airport (1,038,000 people within 25 minutes)

- About 1,038,000 people (27.7 percent of 2000 region) are within 25 minutes of Detroit Metropolitan Airport. This will grow to 1,053,000 people (19.5 percent of 2030 region) by 2030. This means that the area will decline in access by about -1.5 percent.
- Similar results occur for free-flow conditions, with reductions between -0.6 and -1.9 percent. Congested employment access shows an increase of 0.5 percent.
- Congestion removal would yield a 2.5 to 3.8 percent increase in accessibility, or just more than double the decline in access caused by growth.
- **Conclusion: Congestion removal would reverse the slightly declining accessibility.**

Dallas:

Downtown (2,129,000 people within 25 minutes of CBD)

- Dallas has 2,129,000 people (43.9 percent of region) within 25 minutes of the CBD. This will increase to 2,873,000 people (33.8 percent of 2030 region) by 2030. This means that the CBD will become less accessible, by -10.0 percentage points.
- Similar results occur for employment and free flow. Results range from -6.4 percentage points to
  -12.6 percentage points.
- Congestion removal would increase CBD access by 11.1-13.9 percentage points, just balancing the decline caused by suburban growth.
- **Conclusion: Congestion removal would essentially balance the decline in access caused by suburban growth.**

University (1,133,000 people within 25 minutes)

- About 1,133,000 people (23.4 percent of 2000 region) are within 25 minutes of the University of Texas - Dallas. Will grow to 1,681,000 (19.8 percent of 2030 region). This means that access will decline by – 3.6 percent.
- Similar results occur for free-flow and congested conditions, between -0.3 and -3.3 percent.
- Congestion removal would yield a 13.5 to 25.8 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Mall (1,280,000 people within 25 minutes)

- About 1,280,000 people (26.4 percent of 2000 region) are within 25 minutes of North East Mall. This will grow to 1,815,000 people (22.9 percent of 2030 region) by 2030. This means that access will decline by – 3.5 percent.
- Similar results occur for free-flow conditions, between -2.5 and -4.9 percent. Congested employment access is expected to increase by 1 percent.
- Congestion removal would yield a 9.6 to 17.2 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Major Suburb (1,182,000 people within 25 minutes)

- About 1,182,000 people (24.4 percent of 2000 region) are within 25 minutes of Duncanville. This will grow to 1,702,000 people (20.0 percent of 2030 region) by 2030. This means that access will decline by – 4.4 percent.
- Similar results occur for free-flow and congested conditions, between -3.0 and -5.8 percent.
- Congestion removal would yield a 12.1 to 17.6 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the projected decline in accessibility caused by growth.**

Airport (1,343,000 people within 25 minutes)

- About 1,343,000 people (27.7 percent of 2000 region) are within 25 minutes of Dallas-Ft. Worth International Airport. This will grow to 2,060,000 people (24.2 percent of 2030 region) by 2030. This means that access will decline by -3.5 percent.
- Similar results occur for free-flow conditions, with results ranging from -2.9 to -6.1 percent. Congested employment shows improvements in the amount of 0.1 percent.
- Congestion removal would yield a 14.3 to 25.2 percent increase in accessibility.
- **Conclusion: Congestion removal would reverse the slightly declining accessibility.**

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Appendix: Technical Discussions and Methodology

We reviewed the extensive literature available on accessibility measures. We also considered the urban productivity literature where it is relevant to spatial structure and network. Most recently, Prud'homme and Lee[16] developed equations relating the productivity (output per worker) of 22 French and three Korean regions to accessibility, defined as the number of jobs or residents within a maximum reasonable commuting time from the CBD. Their tantalizing work found modest elasticity (about 0.10) between accessibility and productivity, but did not investigate the causality direction or account for other explanations. Cervero[17] extended the work to sub-regional analysis, but no cross-region comparable study has been conducted focusing on U.S. regions, which are more auto-dependent and larger geographically.

High-level studies are often accompanied with caveats and this one is no exception. The number of regions reviewed here is small, necessitated by the effort required to conduct accessibility analysis. A larger sample or a different set of cities might yield different results. Particularly, smaller regions are not represented. In smaller cities, accessibility effects of congestion removal are likely to be less substantial, since they are generally less congested, but it might also be more easily accomplished. Further, the locations chosen for accessibility within regions may not be representative of non-CBD locations. The accessibility data itself may be suspect, based solely on local inventories, traffic assessments of unknown accuracy, and plans for growth—but this is the same information all other transportation analysis and planning is based on. Transit is not in the mix; that might weaken access in most regions and improve access in larger ones. And the data is cross-sectional; more insight might be gained by tracking changes in accessibility against changes in performance over time.

Many factors influence regional productivity—not just access. Among the commonly noted are educational quality, crime rates, tax rates, job mix, recreational and amenity availability, utility rates, income transfer payments and private capital investment. None of these factors are included here, and if included they might overshadow the impacts of access. Also, congestion relief is a complex, long-term and expensive undertaking, for example we have not accounted for so-called "induced travel"—whereby decreased congestion fosters an unforeseen increase in per capita travel—which might eat into the apparent gains from major capacity additions. These and other considerations indicate that our analysis is not perfect, but our primary findings are that access improvements via congestion relief can have significant regional economic impacts.

We derived our findings by following this methodology:

1. Select the cities to be studied and the study points within those cities.

We chose the eight regions based on favorable interaction with the various MPOs during a previous study. The regions provided the data we needed and worked with us to resolve any problem areas. (Since these regions are larger than most, they adequately cover the upper range of U.S. cities but not the lower range.) We selected categories of study points that represent situations common to all regions; we then selected the specific study points within each category based on relative size and dispersion within the network coverage area. The following table summarizes the points selected in each region.

Table A.1: Selected Study Points

Region	Category				
	Downtown	Airport	University	Major Mall	Major Suburb
Atlanta	Five points	Atlanta-Hartsfield	Emory Univ.	Cumberland	Panthersville
Charlotte	Trade and Tryon	Charlotte-Douglas Int'l	UNC-Charlotte	Concord Mills	Ft. Mill
Dallas	Dallas Convention Center	Dallas-Ft. Worth	Univ. of Texas-Dallas	North East	Duncanville
Denver	Coors Field	Denver Int'l	Univ. of Denver	Aurora	Lakewood
Detroit	Comercia Park	Detroit Metro	Univ. of Michigan-Dearborn	Twelve Oaks	Pontiac
Salt Lake City	EnergySolutions Arena	Salt Lake City Int'l	Brigham Young Univ.	Fashion Place	American Fork
San Francisco	AT&T Park	San Francisco Int'l	Stanford Univ.	Southland	Berkeley
Seattle	Band of America Tower	Seattle-Tacoma	Univ. of Washington-Seattle	Factoria Square	Redmond

2. Conduct a drive time contour analysis for each point in each city.

a. Collect demographic and network data from each of the study cities.

We contacted the eight MPOs to obtain both demographic and network data for a base year and a future year. We requested that the network data have variables that reflected free-flow (posted) speed or travel time and congested (peak hour) speed or travel time. In every case but Detroit, the MPO provided us the networks on which to base our analysis. Detroit provided us a "skim" matrix which shows the total travel times between zones rather than a network with the route paths. We converted networks and demographic data to TransCAD layers, so that we had a consistent format across regions. Collected data is reflected in the table below.

Table A.2: Technical Data for Regional Networks								
City	Years Base - Fut		Transportation Network		Coordinate System	Free Flow Speed/Time	Congested Speed/Time	TAZ Layer
Atlanta	2005	2030	2005	2030	NAD83 1002:GA, West Feet	SPEED	CGSTDSPD	Yes
Charlotte	2000	2030	2000	2030	NAD83 3200:NC Feet	SPfreeAB	SPpeakAB	Yes
Dallas	1999	2030	1999	2030	TransCAD	PKFRTIME_AB	PKTIME_AB	Yes
Denver	2005	2030	2005	2030	TransCAD	FF SPEED	CONG SPD	Yes
Detroit	2005	2030	2005 Skims	2030 Skims	NAD83 2113:MI, South Feet	Free Flow	DE05AM DK30AM	Yes
Salt Lake City	2001	2030	2001	2030	UTM - UTM 12 GRS 1980 Meters	SFF_TIME	AM_TIME	Yes
San Francisco	2000	2030	2000	2030	UTM - UTM 10 GRS 1980 Meters	FFT	CTIM_2_4	Yes
Seattle	2000	2030	2000	2030	NAD83 4601:WA, North Feet	AB FF TT	AB Cong TT-0	Yes

b. Develop drive time contours for selected points in each of the regions.

We used the TransCAD 'band' procedure to develop drive time contours around each study point, for both free-flow and congested conditions, for both the base and the future year networks (a total of 20 analyses for each region). We used the travel time variables directly (if they were provided) or calculated the travel times in each category (free-flow or congested) from the speed and length variables. (For Detroit, we used the skim matrix to develop these contours, which were not quite as precise as the ones we developed from the networks, but nevertheless were satisfactory.)

c. Calculate the number of people and the number of jobs in each band.

Using the 'overlay' function in TransCAD and the TAZ (traffic analysis zones) demographic layers provided by the MPOs, we calculated the population and the employment by location in each of the travel time contours. We then rolled these band totals up to cumulative totals from the origin, and determined trends in population and employment 'reach' in the various categories.

3. Determine the productivity by worker for each region.

For each region, we used national statistics to estimate regional productivity (gross regional product/worker) corresponding to the base year of the demographic data, ranging from 1999 to 2005.

a. Obtain the total employment and annual payroll for each of the eight regions and their respective states for their appropriate base years. (Per Table 1 in the main report, there were four base years: 1999, 2000, 2001, and 2005.) We extracted both employment and payroll data for all geographies from the County Business Patterns, U.S. Census Bureau, available at: http://censtats.census.gov/cbpnaic/cbpnaic.shtml.

b. Obtain the Gross State Product for each of the study states in their respective base years and the United States as a whole in each of the four base years. Here, we used data from the Bureau of Economic Analysis, U.S. Department of Commerce, available at: http://www.bea.gov/regional/gsp/.

c. Calculate the 'Gross Regional Product' (the region's share of the Gross State Product (GSP)). Based on the idea that the ratio of the total MSA payroll to the total state payroll is a good proxy for the ratio of the gross city product to the GSP, we used these ratios for each of the appropriate base years to calculate the gross regional products.

d. Calculate the productivity per worker. We then divided this gross regional product by the total MSA employment, from the County Business Patterns to calculate productivity by worker.

4. Estimate productivity models.

We used straightforward log-linear regression models to estimate models relating regional productivity (GRP per worker) to accessibility measures for each of the five different types of regional points.

$$Ln(GRP/w) = \ln a + bLn\ (X_{tt})$$

where the X_{tt} is the size of the population or the jobs within 'tt' minutes of the point.

Regional product*ivity,* literally the product divided by the number of workers or per capita, is related to these and other factors such as accessibility, tax rates, crime, education, and other features, and are typically expressed in log-linear form.[18] The coefficients of the log-linear model (b, c, etc.) are particularly useful because they represent the elasticity of productivity with respect to the factors of production. This means that a 100 percent change in X will, for instance, yield a 'b' percent change in productivity. This very useful result can be embedded in a forecasting tool which can be used to estimate the change in productivity caused by a given percent change in X/w[19]. Using this model the impact on regional productivity from changes in X such as a reduction of congestion can be estimated. Ideally, with enough data points (greater than 30, say), the effects of several factors can be determined. However, with only eight points, as is the case here, only one or at most two factors can be studied.

To determine the relationship between productivity and accessibility, we regressed productivity against accessibility (number of residents or jobs within X minutes of the point), and included a 'time' variable to pick up any residual differences performance in the base years of the data. Consolidating our findings for locations and accessibility criteria, the following table (Table A.3) summarizes the models for 25-minute drive time contours, in order of model strength:

Table A.3: Summary of Best 25-Minute Productivity Models

Criterion	Location	Time Band	Intercept (a)	t-value	Accessibility	t-value	time var	t-value	RSQ	n

					Elasticity (b)		(c)			
Jobs	University	25	9.2	17.1	0.18	4.3	0.003	0.2	0.81	8
Jobs	Suburb	25	9.6	13.8	0.15	2.8	0.009	0.5	0.64	8
Pop	University	25	9.15	8.8	0.18	2.3	-0.003	-0.1	0.55	8
Pop	Suburb	25	10.0	10.5	0.11	1.6	0.007	0.3	0.38	8
Jobs	CBD	25	10.0	7.8	0.11	1.2	0.022	0.9	0.28	8
Pop	Mall	25	9.5	5.6	0.14	1.2	0.021	0.8	0.27	8
Pop	CBD	25	10.2	7.9	0.10	1.0	0.015	0.6	0.24	8
Jobs	Mall	25	10.0	6.3	0.12	1.0	0.023	0.9	0.23	8
Jobs	Airport	25	10.9	8.2	0.04	0.5	0.027	0.8	0.11	8
Pop	Airport	25	11.09	8.5	0.03	0.3	0.021	0.7	0.09	8

These results are quite comparable to those reported by Prud'homme and Lee for France; there, for a similar travel time band, the elasticity productivity to 30-minute job access to the CBD was 0.15 with an RSQ of 0.46, compared with our estimate of 0.11 with an RSQ of 0.28. For 30-minute 'population' access, Prud'homme and Lee found an elasticity of 0.13 with an RSQ of 0.43, compared to our estimate of 0.10 and an RSQ of 0.24. So, our models are slightly weaker, and less sensitive, than those found for France. The differences may be due to different densities (French regions are typically more compact than U.S. and are less auto-oriented), and differences in industry mix. The models with wider time bands (55-60 minutes) were stronger overall and more sensitive to accessibility.

To ensure that these findings are not just surrogates for region size (population, employment) we tested several models, regressing productivity against total regional population and employment, using 55+ minutes as the accessibility band. Results show somewhat stronger RSQs and higher elasticity, suggesting that aggregate simple measures of size, such as total regional population and total regional employment are themselves a stronger indicator of productivity than are interim accessibility bands. However, the use of total regional employment and population would not lead to useful policy results regarding congestion relief or in directional differences in accessibility that our measures contain. So, although our method is more time-consuming that the simpler approach, it is also richer in policy implications.

5. Summarize findings.

For each group of points and each region, we summarized findings and prepared summary tables and maps.

a. Detailed Findings for Central Business Districts

Figure A.1 below shows the 25-minute drive time contours for CBDs in these eight regions, with and without congestion. The following charts and tables show the cumulative data for population and employment, by 5-minute intervals, for Atlanta CBD.

Figure A.1: 25-Min Drive Time Contours for Downtown Areas.

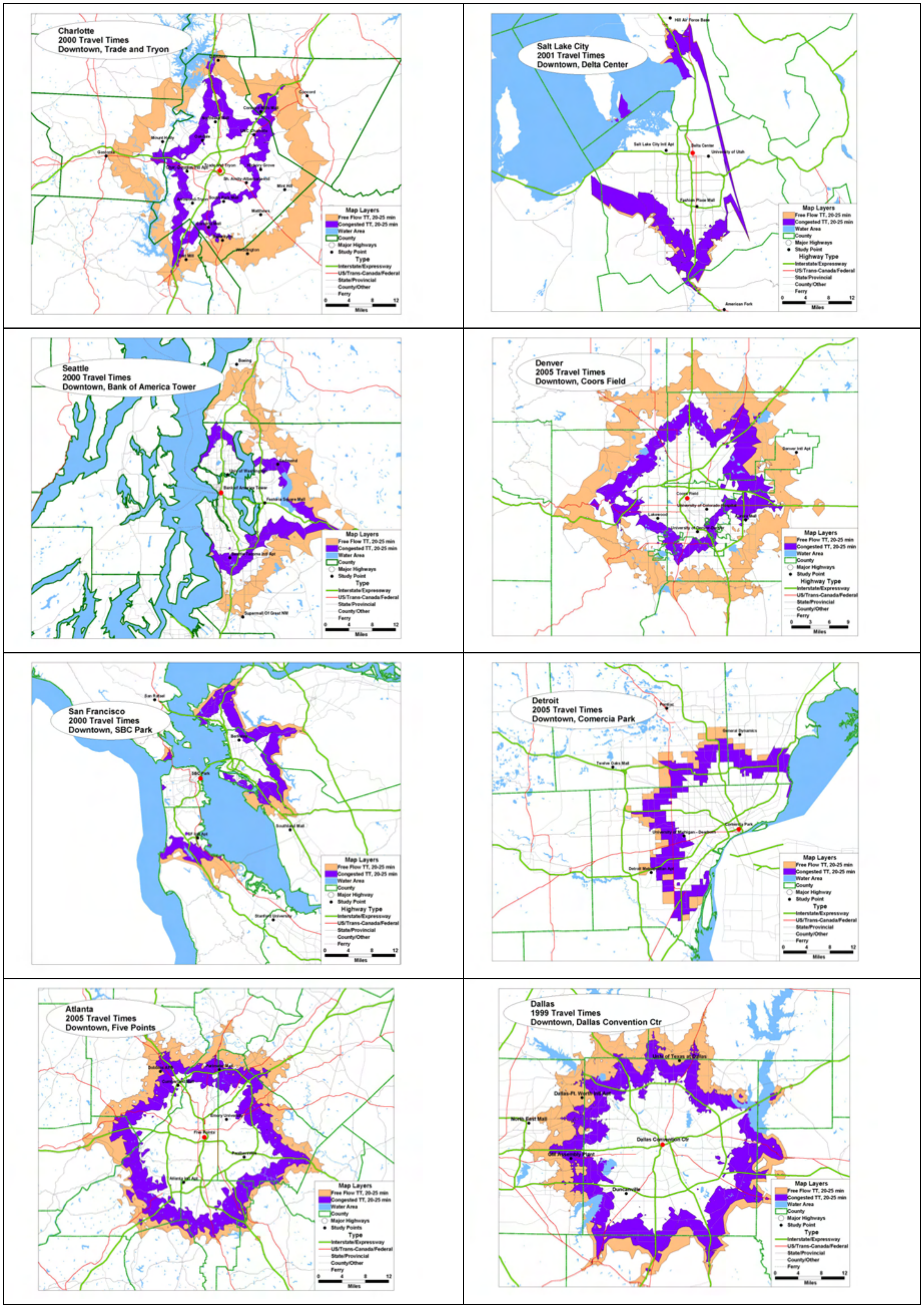
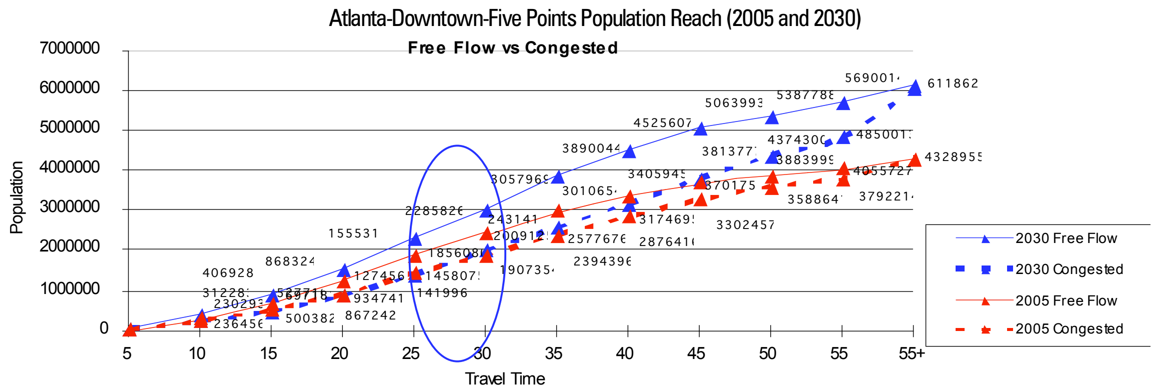


Figure A.2: Cumulative Residents and Jobs from Atlanta CBD



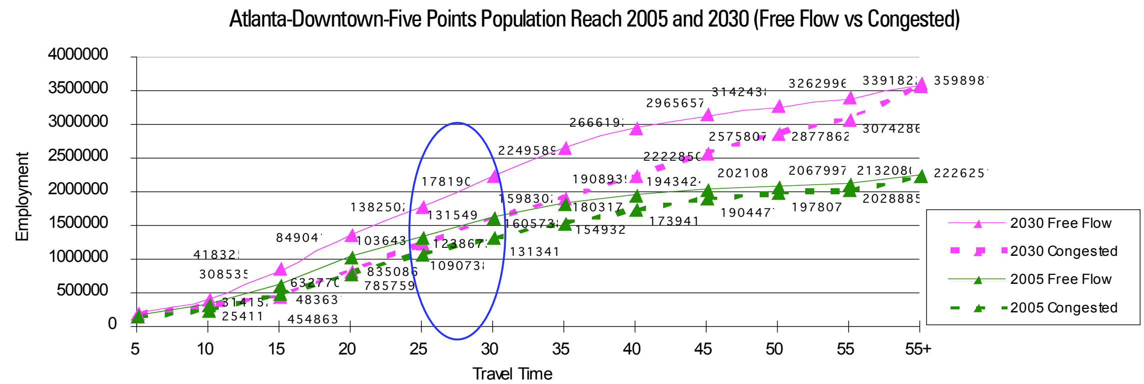


Table A.4: Access of Atlanta CBD

Downtown- Five Points, Within 25 Minutes	# Pop	%Pop	#Emp	%Emp
2005 Cong	1458075	33.7	1090738	49.0
2005 FF	1856080	42.9	1315493	59.1
2030 Cong	1419969	23.2	1238673	34.4
2030 FF	2285826	37.4	1781901	49.5
	Ch Pop	Ch %Pop	Ch Emp	Ch %Emp
2005 vs 2030 - Cong	-38106	-10.5	147935	-14.6
2005 vs 2030 - FF	429746	-5.5	466408	-9.6
2005 Cong vs 2005 FF	398005	9.2	224755	10.1
2030 Cong vs 2030 FF	865857	14.2	543228	15.1
2005 Cong vs 2030 FF	827751	3.7	691163	0.5

Looking at the productivity relationships, the following table shows the correlations and elasticities between productivity per worker and regional accessibility, defined as the number of jobs (or population) within X minutes of the CBD, under current congested conditions. The table compares models from France and Korea, developed by Prud'homme and Lee, with models from the U.S. Although the sample sizes for the models are very small, the RSQs are reasonably strong, and the elasticities for productivity reasonably consistent.

Generally, model strength and elasticity increase as the drive time contour increases, indicating greater correlation between regional productivity and overall regional size. Also, jobs-based access seems to be more strongly correlated with productivity than population-based access. But the U.S.-based models have lower elasticities than the French or Korean models, reflecting the greater spread and auto dependence of U.S. cities, which translates into lower percentages of jobs and population within 25 minutes of the CBD.

Table A.5: Productivity Models of CBD Accessibility

Location	Time Band	Intercept (a)	t-value	Productivity Elasticity (b)	t-value	time var (c)	t-value	R sq	n
Access to Jobs vs. Productivity									
US	25	10.0	7.8	0.11	1.2	0.02	0.9	0.28	8
France	25	9.8	?	0.18	4.5	-	-	0.50	22
France	30	10.1	?	0.15	4.1	-	-	0.46	22
US	35	9.5	7.4	0.14	1.5	0.015	0.6	0.37	8
US	45	9.6	7.4	0.13	1.4	0.015	0.6	0.35	8
US	55+	9.2	9.1	0.16	2.3	0.018	0.9	0.55	8
Korea	60	7.5	17.2	0.24	4.1	-	-	0.97	3
Access to Population vs. Productivity									
US	25	10.18	7.9	0.096	1.0	0.015	0.6	0.24	8
France	25	10.10	?	0.15	4.1	-	-	0.46	22
France	30	10.60	?	0.13	3.9	-	-	0.43	22
US	35	9.7	6.9	0.13	1.3	0.011	0.5	0.32	8
US	45	9.5	6.6	0.14	1.4	0.011	0.4	0.32	8
US	55+	8.8	8.0	0.18	2.5	0.0148	0.8	0.59	8

The models of access to jobs suggest that an elasticity of about 0.11 is an appropriate estimate for the relationship between productivity and access jobs within a 25-minute drive-time of the CBD. For models relating productivity to access to population, slightly lower elasticities, on the order of 0.096, are appropriate.

Comparing results with those of Prud'homme and Lee, our 'jobs' models are weaker and have lower elasticities than the similar models from France (25 and 35 minutes), and the similar model from Korea (60 minutes). Our 'population' model is also weaker and has lower elasticities than the similar models from France (25 and 30 minutes). This might be caused by the lower density and greater sprawl of U.S. regions, and a corresponding lower influence of access on economic performance. The very small number of cases for Korea (three) should of course be discounted, but in spite of the larger number of cases from France (22), our results for the 30-minute bands are very similar to the French findings. We take this as intriguing, but not definitive evidence that the same general forces may be at work in both nations.

b. Detailed Findings for Universities

Figure A.3 below shows the 25-minute drive time contours for universities in these eight regions, with and without congestion. The following charts and tables below show the cumulative data for population and employment, by 5-minute intervals, for UNC Charlotte.

Figure A.3: 25-Min Drive Time Contours for Universities

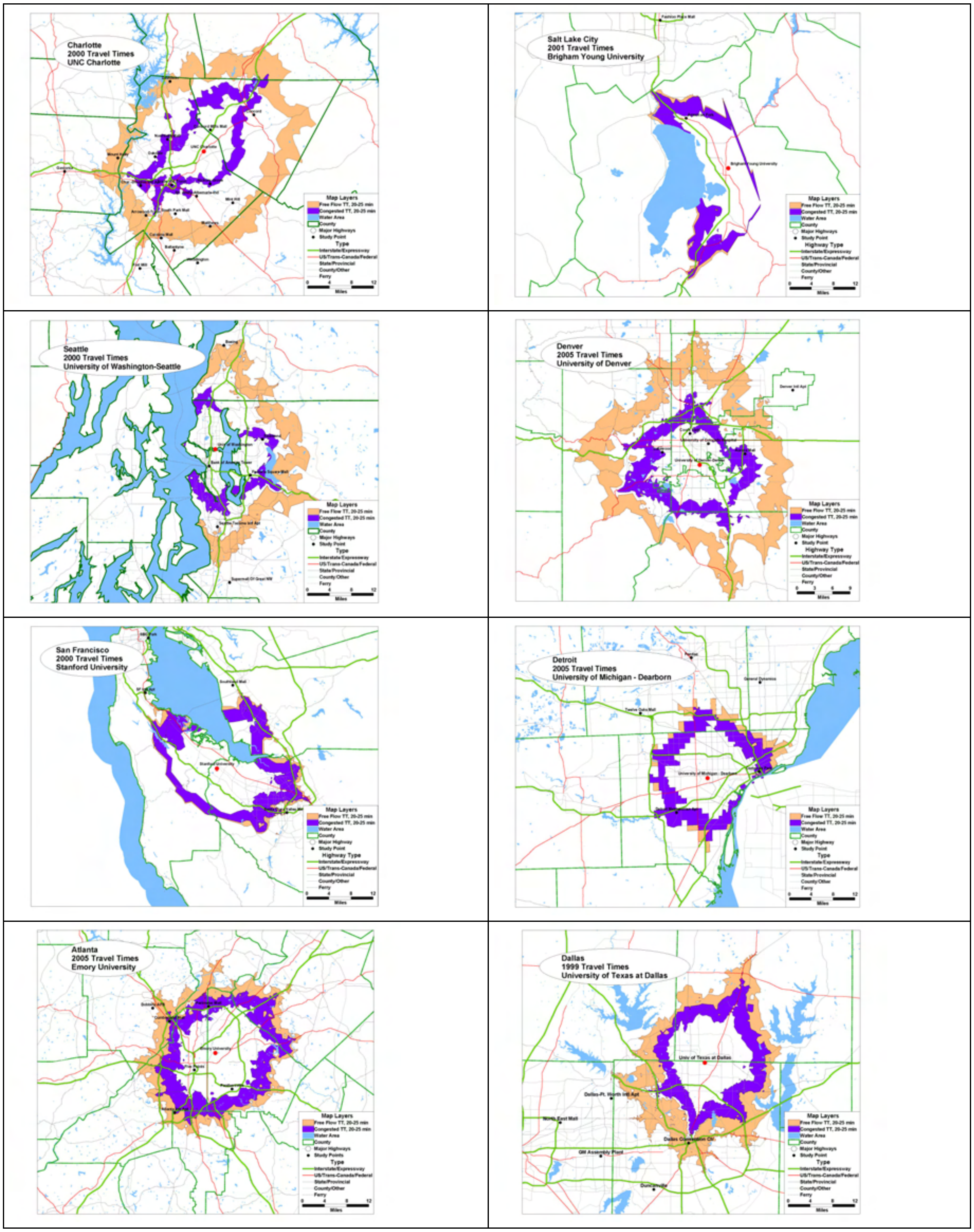


Figure A.4: Cumulative Residents and Jobs from UNC Charlotte

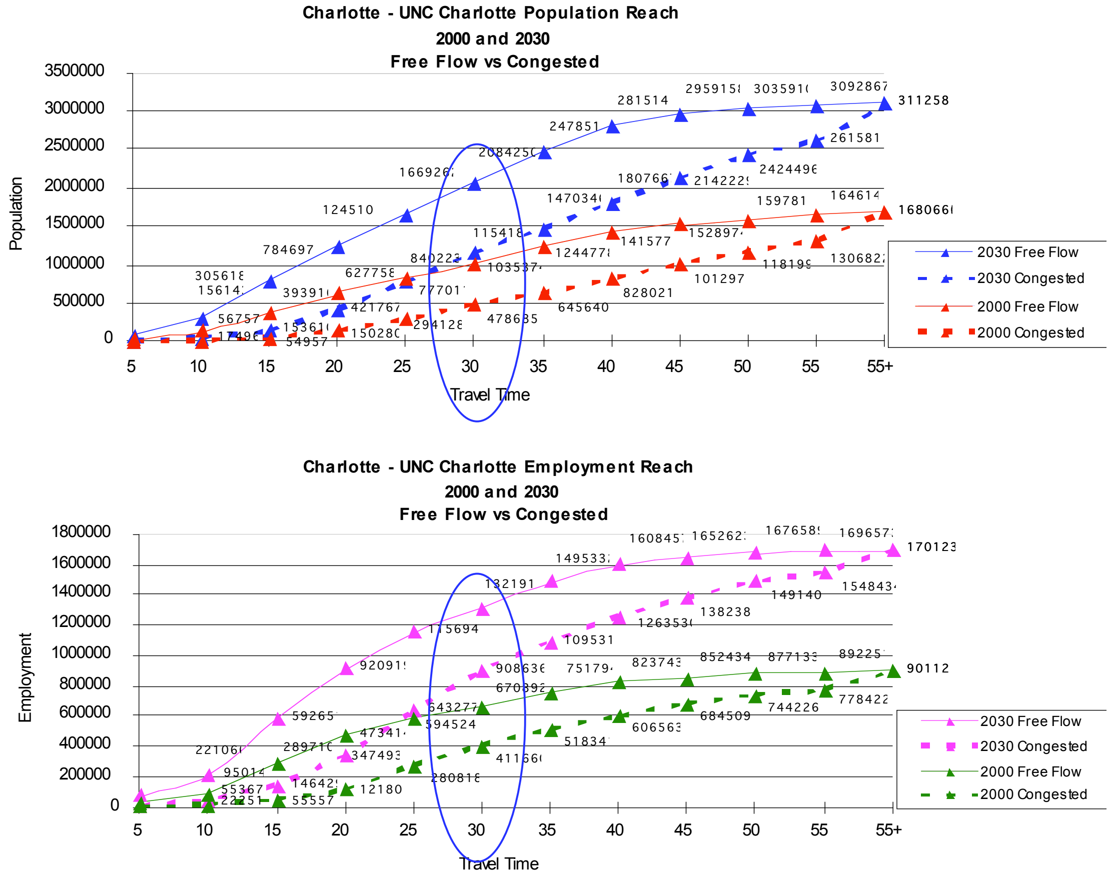


Table A.6: Access of UNC Charlotte				
UNC Charlotte, Within 25 Minutes	#Pop	%Pop	#Emp	%Emp
2000 Cong	294128	17.5	280818	31.2
2000 FF	840223	50	594524	66
2030 Cong	777011	25	643277	37.8
2030 FF	1669262	53.6	1156947	68
	Ch #Pop	Ch %Pop	Ch # Emp	Ch %Emp
2000 vs 2030 - cong	482883	7.5	362459	6.6
2000 vs 2030 - FF	829039	3.6	562423	2.0
2000 cong vs 2000FF	546095	32.5	313706	34.8
2030 cong vs 2030 FF	892251	28.6	513670	30.2
2000 cong vs 2030 FF	1375134	36.1	876129	36.8

Looking again at regional productivity models, the following table summarizes the results of log-linear models relating productivity per worker to university accessibility. We have no data for other nations, since the Prud'homme and Lee study covered only downtowns.

Table A.7: Productivity Models of University Access									
Access to Jobs vs. Productivity									
Location	Time Band	Intercept (a)	t-value	Elasticity (b)	t-value	time var (c)	t-value	R sq	n
US	25	9.2	17.1	0.18	4.3	0.003	0.2	0.81	8
US	35	9.7	16.0	0.13	3.0	0.010	0.6	0.67	8
US	45	9.4	10.2	0.15	2.3	0.010	0.5	0.55	8
US	55+	9.2	7.9	0.16	2.0	0.016	0.7	0.48	8
Access to Population vs. Productivity									
US	25	9.15	8.8	0.18	2.3	-0.003	-0.1	0.55	8
US	35	9.2	12.1	0.16	3.0	0.0002	0.0	0.67	8
US	45	9.0	8.5	0.17	2.4	0.003	0.2	0.56	8
US	55+	8.7	6.6	0.19	2.1	0.012	0.6	0.52	8

Access to universities has a generally greater correlation with productivity than access to downtowns, and a higher elasticity. As the drive time contour increases from 25 to 55+ minutes, the correlation increases, reflecting (perhaps) the increasing importance of regional campuses to regional productivity. And there is limited evidence that access to jobs is more important than access to population: RSQs are a bit higher and elasticities are also higher. This suggests that *access to major universities, particularly from job sites, may have more influence on regional productivity than access to downtowns.* Regarding the size of the elasticity, a value of about 0.18 seems appropriate for 25-minute drive time contours.

Of course these observations require some interpretation and caution. The sites chosen for our 'university' access are for major campuses within each region, not necessarily the locations of those campuses most closely aligned with the regional economy. The results are therefore highly dependent on the specific locations chosen. And access to community colleges or other important sites of job-related learning are not included. Many schools now provide substantial services over the Web or have other campus sites within a region. This reduces the need to travel to the main campus. And some of our sites are accessible by higher-speed transit services. Of course, the cost of improving road access to university sites might be more or less than the cost of improving access to downtown. The effect of these factors on our findings is unknown, but at the least the findings here generate many possibilities.

c. Detailed findings for major malls

Figure A.5 below shows the 25-minute drive time contours for major malls in these eight regions, with and without congestion. The following charts and tables show the cumulative data for population and employment, by 5-minute intervals, for Factoria Square Mall.

Figure A.5: 25-Min Drive Time Contours for Major Malls

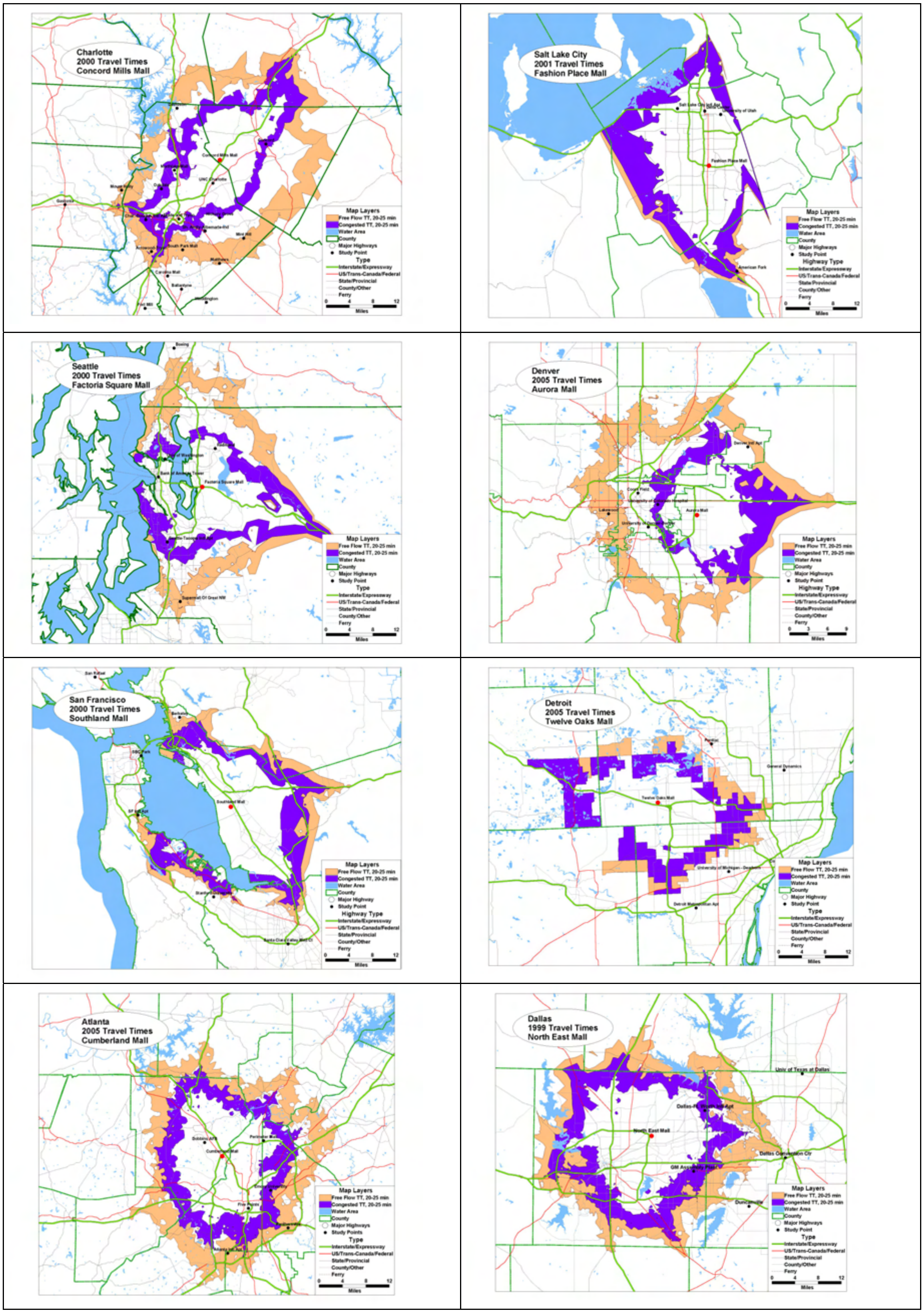


Figure A.6: Cumulative Residents and Jobs from Factoria Square Mall, Seattle

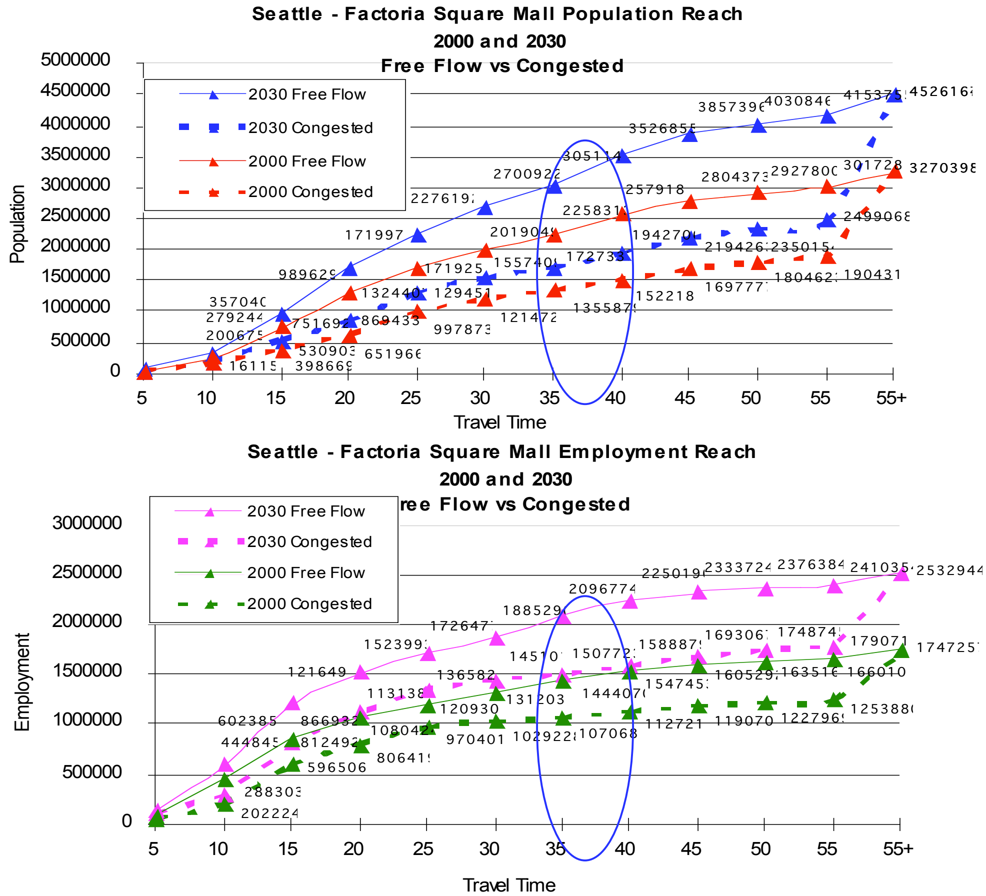


Table A.8: Access of Factoria Square Mall, Seattle

Factoria Square Mall, Within 25 Minutes	#Pop	%Pop	#Emp	%Emp
2000 Cong	997873	30.5	970401	55.5
2000 FF	1719254	52.6	1209301	69.2
2030 Cong	1294511	28.6	1365821	53.9
2030 FF	2276192	50.3	1726477	68.2
	Ch #Pop	Ch %Pop	Ch #Emp	Ch %Emp
2000 vs 2030 - cong	296638	-1.9	395420	-1.6
2000 vs 2030 - FF	556938	-2.3	517176	-1.0
2000 cong vs 2000FF	721381	22.1	238900	13.7
2030 cong vs 2030 FF	981681	21.7	360656	14.3
2000 cong vs 2030 FF	1278319	19.8	756076	12.7

Comparing productivity models, the following table shows results. Generally, the models relating regional productivity to mall access fall between the ‘CBD’ models and the ‘university’ models described earlier. The correlations (RSQs) and elasticities for these models are slightly higher than ‘CBD’ models and slightly lower than ‘university’ models. Generally, model strength and elasticity increases as the drive time contour increases, perhaps indicating the regional nature of the larger contour. And the ‘population’ models are slightly, but not uniformly, stronger than the ‘job’ models, indicating greater importance of ‘rooftops’ than jobs in retail.

These models appear to be slightly stronger (higher correlation) and have slightly steeper elasticities than the CBD models. RSQs are slightly higher and elasticities are slightly higher also. The jobs-based accessibility is also slightly stronger, and elasticities slightly higher than the population based accessibility models. On balance, they suggest that *access to major malls, particularly from job sites, may be at least as, and probably slightly more influential, in determining regional productivity than access to the CBD.*

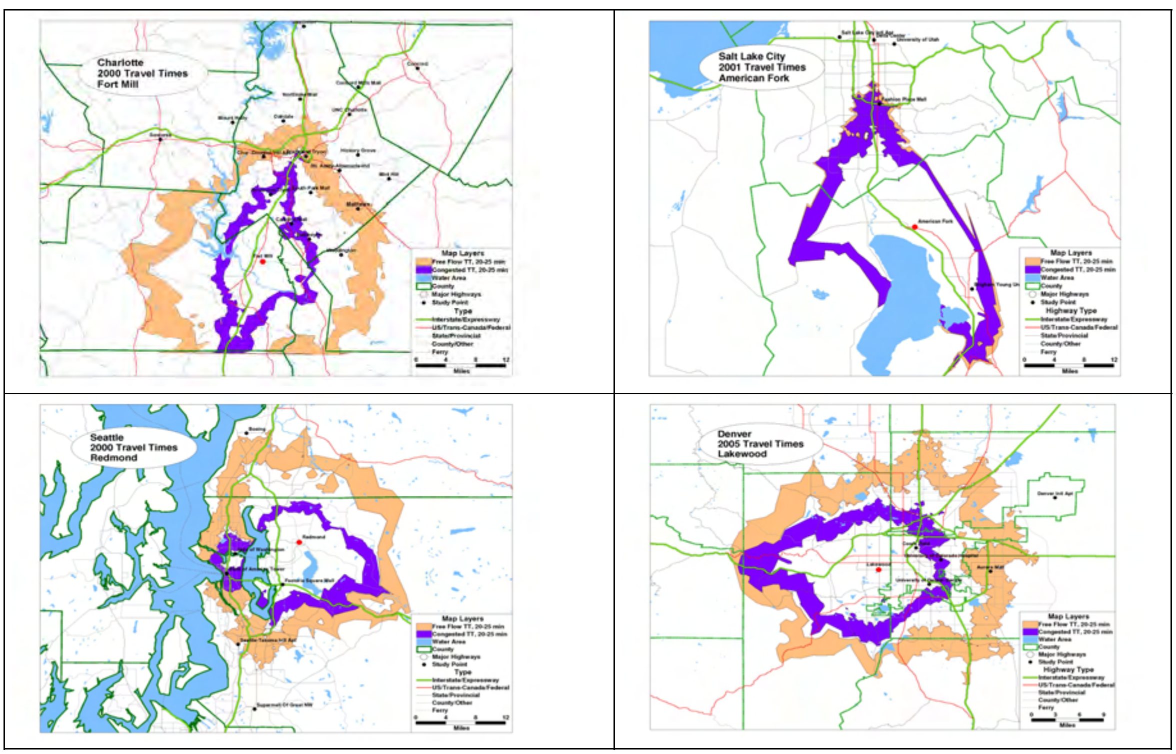
Table A.9: Productivity Models of Major Mall Access

Location	Time Band	Intercept (a)	t-value	Elasticity (b)	t-value	time var (c)	t-value	R sq	n
Access to Jobs vs. Productivity									
US	25	10.0	6.3	0.12	1.0	0.023	0.9	0.23	8
US	35	8.9	8.4	0.19	2.5	0.016	0.9	0.58	8
US	45	9.4	8.4	0.15	1.9	0.016	0.8	0.47	8
US	55+	9.2	9.2	0.16	2.3	0.018	0.9	0.55	8
Access to Population vs. Productivity									
US	25	9.5	5.6	0.14	1.2	0.021	0.8	0.27	8
US	35	9.1	6.2	0.17	1.6	0.011	0.5	0.40	8
US	45	9.2	7.1	0.16	1.8	0.011	0.5	0.43	8
US	55+	8.8	8.0	0.18	2.5	0.015	0.80	0.59	8

d. Detailed findings for major suburbs

Figure A.7 below shows the 25-minute drive time contours for major suburbs in these eight regions, with and without congestion. The following charts and tables show the cumulative data for population and employment, by 5-minute intervals, for Lakewood, CO.

Figure A.7: 25-Min Drive Time Contours for Major Suburbs



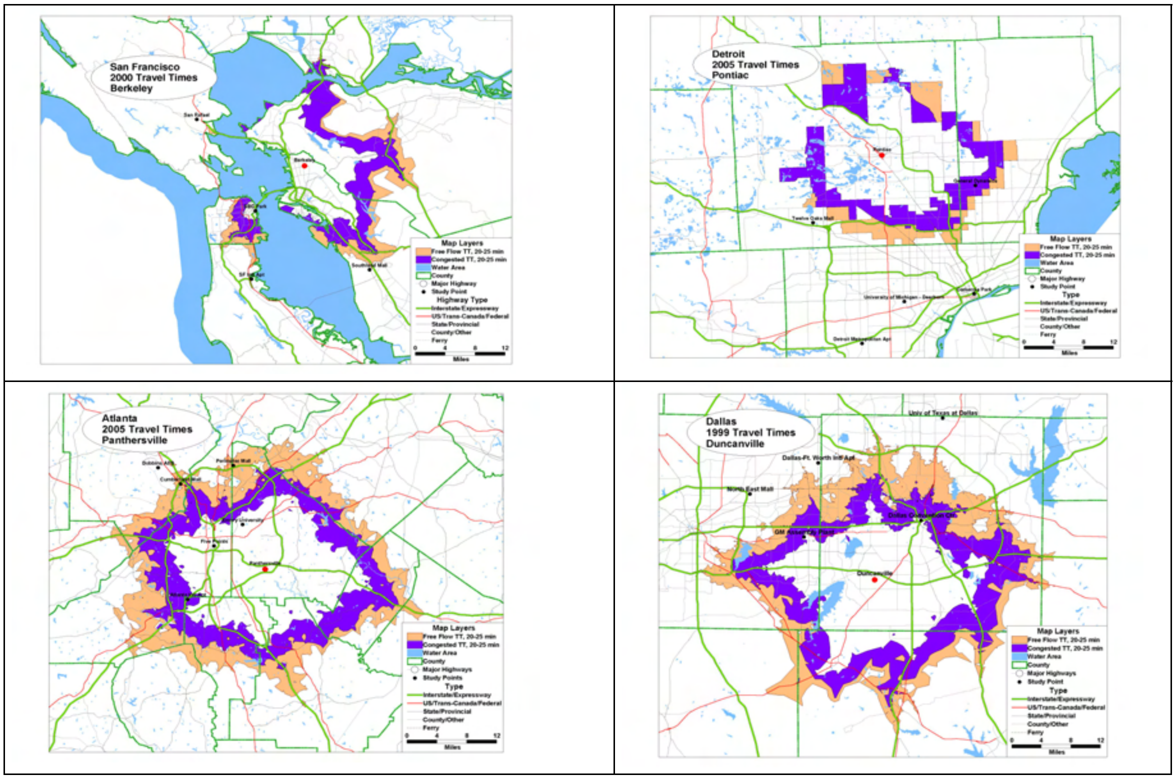


Figure A.8: Cumulative Resident and Job Access from Lakewood, CO

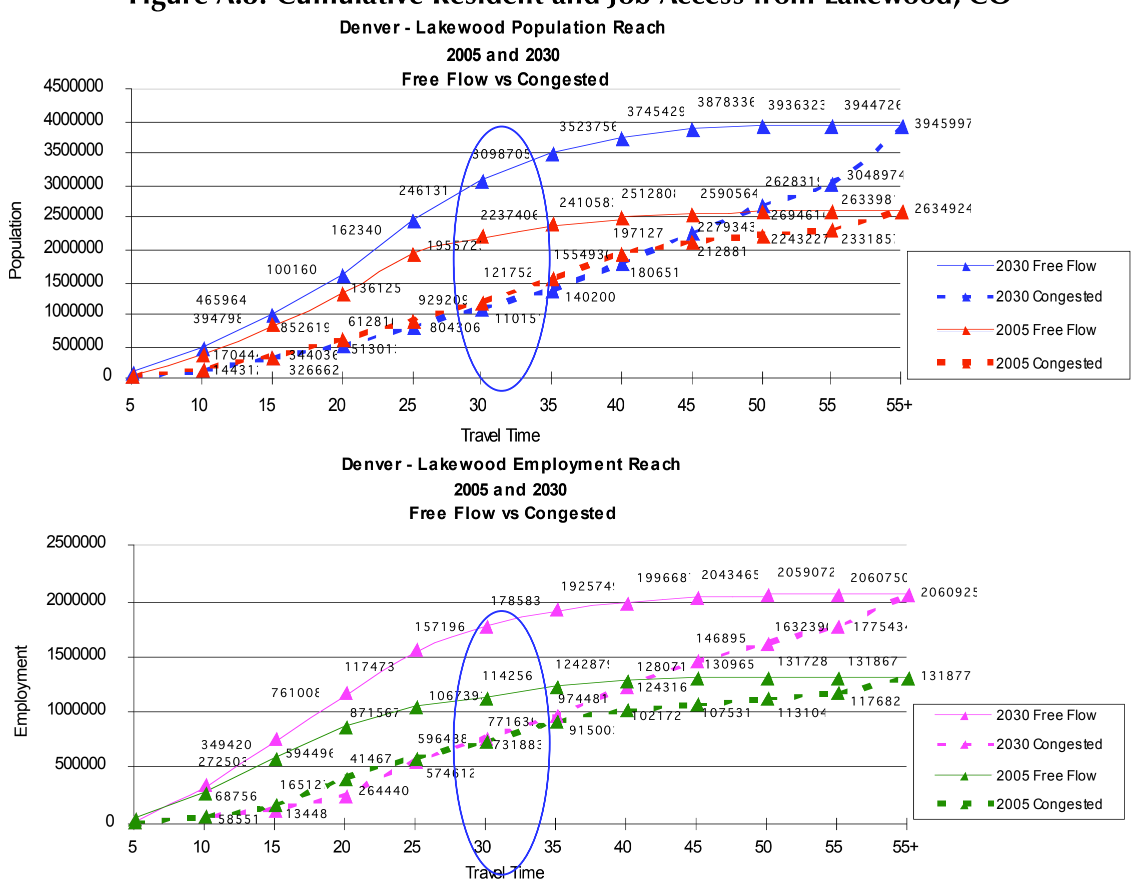


Table A.10: Access of Lakewood, CO				
Lakewood, Within 25 Minutes	#Pop	%Pop	#Emp	%Emp
2005 Cong	929209	35.3	596488	45.2
2005 FF	1955723	74.2	1067393	80.9
2030 Cong	804306	20.4	574612	27.9
2030 FF	2461317	62.4	1571966	76.3
	Ch #Pop	Ch %Pop	Ch #Emp	Ch %Emp
2005 vs 2030 - cong	-124903	-14.9	-21876	-17.3
2005 vs 2030 - FF	505594	-11.8	504573	-4.6
2005 cong vs 2005FF	1026514	38.9	470905	35.7
2030 cong vs 2030 FF	1657011	42.0	997354	48.4
2005 cong vs 2030 FF	1532108	27.1	975478	31.1

Productivity models relating regional performance to accessibility of major suburbs are summarized in Table A.12. The models are modest in strength. For the 'jobs-access' models, RSQs are actually stronger for the 25-minute time band than for larger time bands, and elasticities are in the 0.13-0.16 range, lower than for universities but higher than for CBDs and malls. For 'population-access' models, RSQs and elasticities are significantly lower, and increase with increasing time band. However the models seem to confirm notions that access from major suburbs to jobs, not population, is at least a relatively important factor in regional productivity.

Table A.11: Productivity Models of Suburban Accessibility									
Access to Jobs vs. Productivity									
Location	Time Band	Intercept (a)	t-value	Elasticity (b)	t-value	time var (c)	t-value	R sq	n
US	25	9.6	13.8	0.15	2.8	0.009	0.5	0.64	8
US	35	9.3	7.7	0.16	1.8	0.015	0.7	0.44	8
US	45	9.7	8.2	0.13	1.6	0.015	0.7	0.38	8
US	55+	9.2	9.1	0.16	2.3	0.018	0.9	0.55	8
Access to Population vs. Productivity									
US	25	10.0	10.5	0.11	1.6	0.007	0.3	0.38	8
US	35	9.9	8.2	0.12	1.4	0.011	0.5	0.33	8
US	45	9.7	7.8	0.13	1.5	0.011	0.4	0.36	8
US	55+	8.8	8.0	0.18	2.5	0.015	0.8	0.59	8

d. Detailed findings for airports

Figure A.9 below shows the 25-minute drive time contours for airports in these eight regions, with and without congestion. The following charts and tables show the cumulative data for population and employment, by 5-minute intervals, for Detroit Metro.

Figure A.9: 25-Min Drive Time Contours for Airports

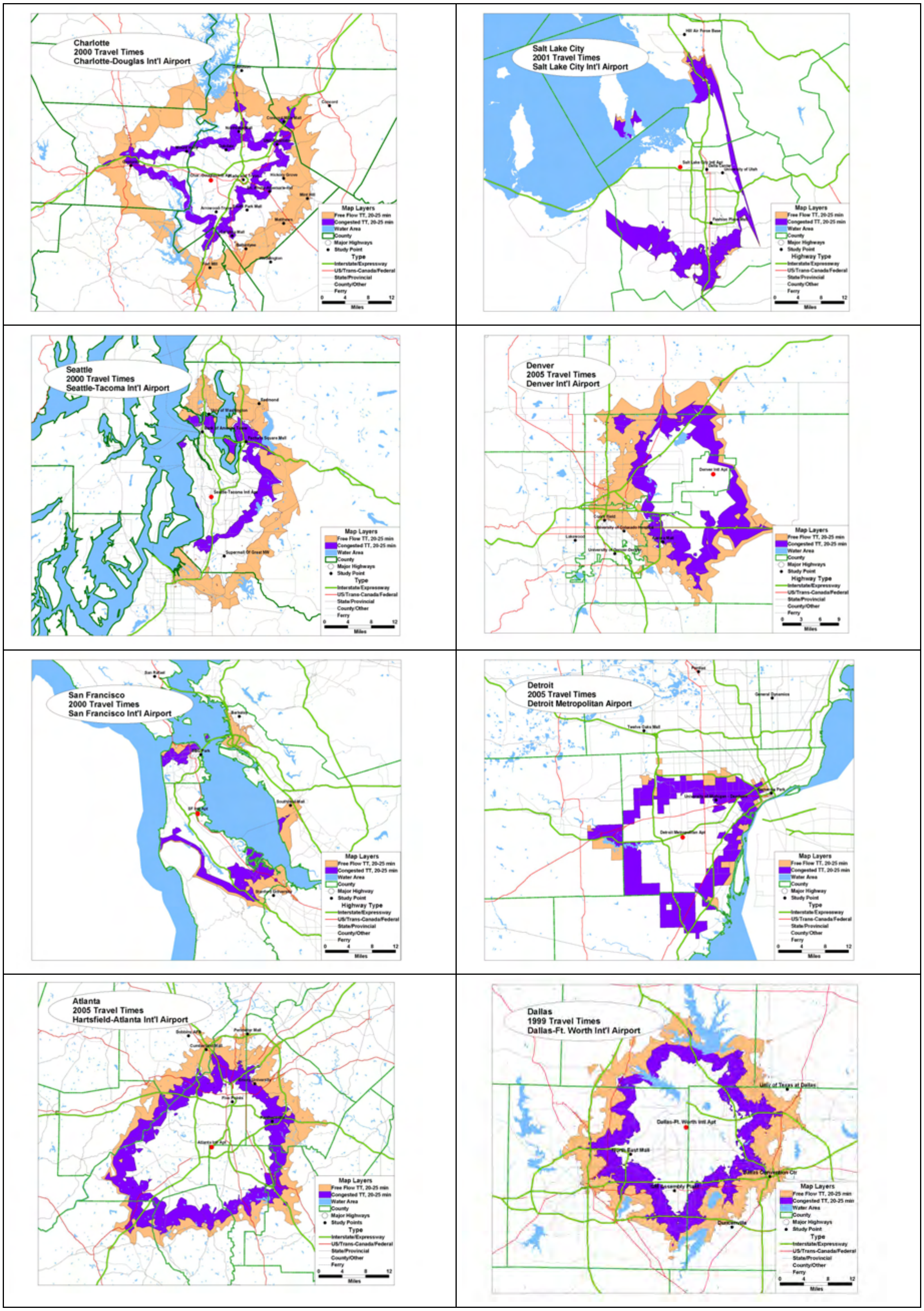


Figure A.10: Cumulative Residents and Jobs from Detroit Metropolitan Airport

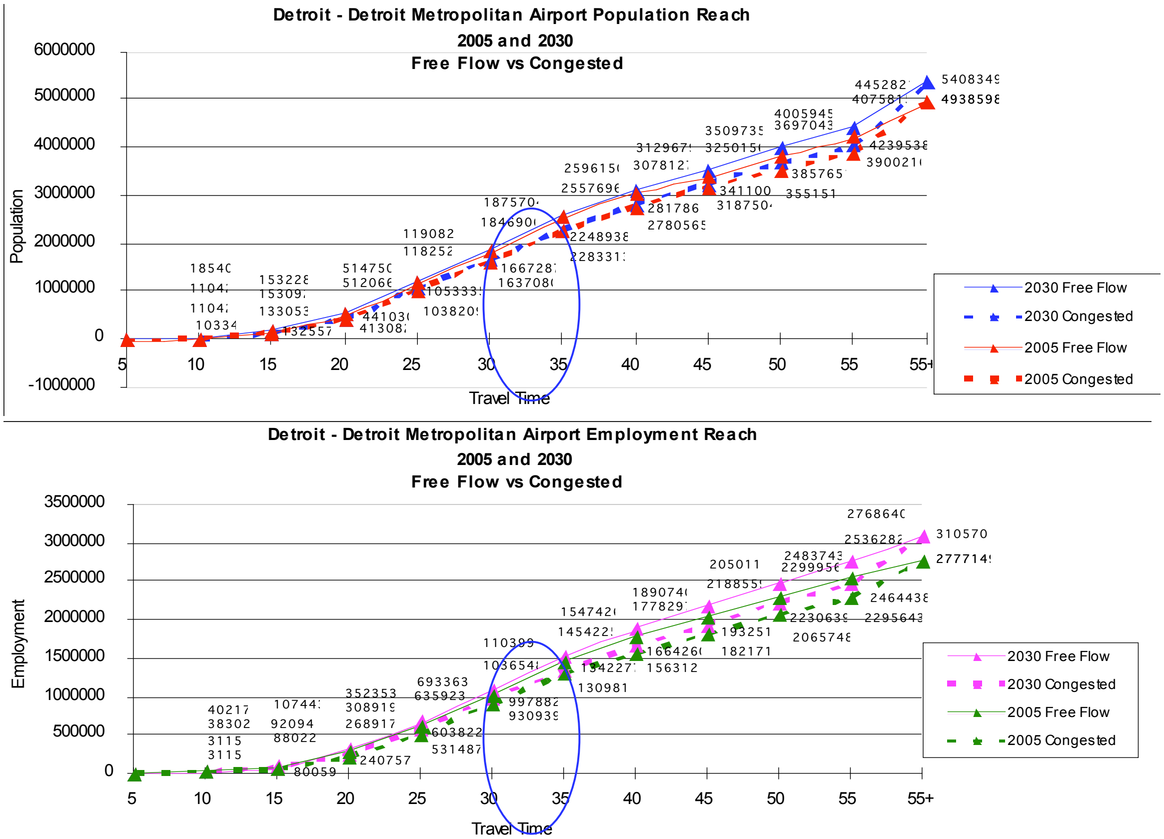


Table A.12: Access from Detroit Metropolitan Airport				
Detroit Metropolitan Airport, Within 25 Minutes	#Pop	%Pop	#Emp	%Emp
2005 Cong	1038209	21.0	531487	19.1
2005 FF	1182521	23.9	635923	22.9
2030 Cong	1053335	19.5	603822	19.4
2030 FF	1190826	22.0	693363	22.3
	Ch #Pop	Ch %Pop	Ch #Emp	Ch %Emp
2005 vs 2030 - cong	15126	-1.5	72335	0.3
2000 vs 2030 - FF	8305	-1.9	57440	-0.6
2005 cong vs 2005FF	144312	2.9	104436	3.8
2030 cong vs 2030 FF	137491	2.5	89541	2.9
2005 cong vs 2030 FF	152617	1.0	161876	3.2

Productivity models relating regional performance to airport access are summarized in Table A-14. These models are generally the weakest of the five sets we investigated. RSQs are low for medium-sized drive times, and it is only for the maximum drive time (55+ minutes) that the relationship takes on strength. Also, the elasticities of airport access to regional productivity are also low, although they do increase with increasing drive time band.

Table A.13: Productivity Models of Airport Accessibility									
Access to Jobs vs. Productivity									
Location	Time Band	Intercept (a)	t-value	Elasticity (b)	t-value	time var (c)	t-value	R sq	n
US	25	10.9	8.2	0.04	0.5	0.027	0.8	0.11	8
US	35	10.3	8.3	0.08	1.0	0.027	1.0	0.22	8
US	45	9.6	7.8	0.14	1.6	0.023	1.0	0.38	8
US	55+	8.9	10.2	0.18	3.0	0.008	0.5	0.67	8
Access to Population vs. Productivity									
US	25	11.1	8.5	0.03	0.3	0.021	0.7	0.09	8
US	35	10.0	6.5	0.11	1.0	0.020	0.8	0.23	8
US	45	9.7	6.4	0.13	1.2	0.018	0.7	0.29	8
US	55+	9.7	8.3	0.12	1.6	0.022	1.0	0.38	8

Our analysis of this data suggests that airports may not be as important to regional growth as some assert them to be; they seem to be less critical than access to CBDs or to universities, or even major malls.

Endnotes

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1 Lwellen-Davies (David Banister and Peter Hall) (2004), Transport and City Competitiveness—Literature Review, U.K. Department for Transportation document.

2 The U.S. Census Bureau has recently (October 2007) released estimates of regional metropolitan productivity per capita, for 2005. This will facilitate similar analysis in other cities.

3 In this study, *congestion* is defined as *the delay in travel caused by the presence of other vehicles.* Therefore it includes accident and capacity-related delays, but not signals that would slow even light traffic. It is estimated by comparing 'free flow' (at the speed limit) travel times with peak hour travel times that account for traffic volume.

4 This approach allows for flexible treatment of data in initially varying formats, but still yields consistent consolidated information. The use of the TransCAD methodology for building drive time contours is an important tool that allows for efficient analysis once networks have been obtained.

5 For each region, we estimated the regional productivity in terms of gross regional product/worker, corresponding to the base year of the demographic data. We estimated productivity models using log-linear regression models. See Appendix for more detail.

6 Federal Highway Administration, Highway Statistics, 2005. USDOT, Wash. DC, www.fhwa.dot.gov.

7 Daily VMT (vehicle-miles of travel) is the sum of all travel on a typical day for the urbanized area. A 'vehicle-mile' is defined as one-vehicle traveling one mile, and is a commonly used measure of traffic. AADT, average annual daily traffic, is analogous to roadside counts of vehicle volumes.

8 Regional productivity, discussed below, is defined as the gross regional product divided by the number of regional jobs. It is, of course, considerably higher than either the average wage or the per-capita productivity.

9 The TTI is an index of congestion, defined as the ratio of peak-hour travel time to off-peak travel time. Sources: David Hartgen and Gregory Fields, *Building Roads to Reduce Traffic Congestion in America's Cities: How Much and at What Cost?*, Reason Foundation Policy Study No. 346, (Los Angeles: Reason Foundation, August 2007), and long-range plans for each city.

10 Ibid.

11 Hartgen and Fields *Building Roads to Reduce Traffic Congestion in America's Cities.*

12 Within each region the transportation planning agency (the "metropolitan planning organization") maintains 'base year' and 'future year' computerized road networks for use in planning. 'Congested' networks typically contain peak-hour travel times that account for delay caused by the presence of traffic and are 50-100 percent longer in time than uncongested ('free

flow') travel times. These travel times are estimated by equilibrium-delay equations and are then verified in the field with speed runs.

13 While in previous like studies of France and Korea researchers Prud'homme and Lee used more distant time bands (60 minutes for France), the use of larger bands for the U.S. analysis would overstate the practical labor shed for most of our regions.

14 Even with these features, the models do not account for all of the new travel that will occur because congestion is reduced which would have some effect on the total capacity ultimately needed.

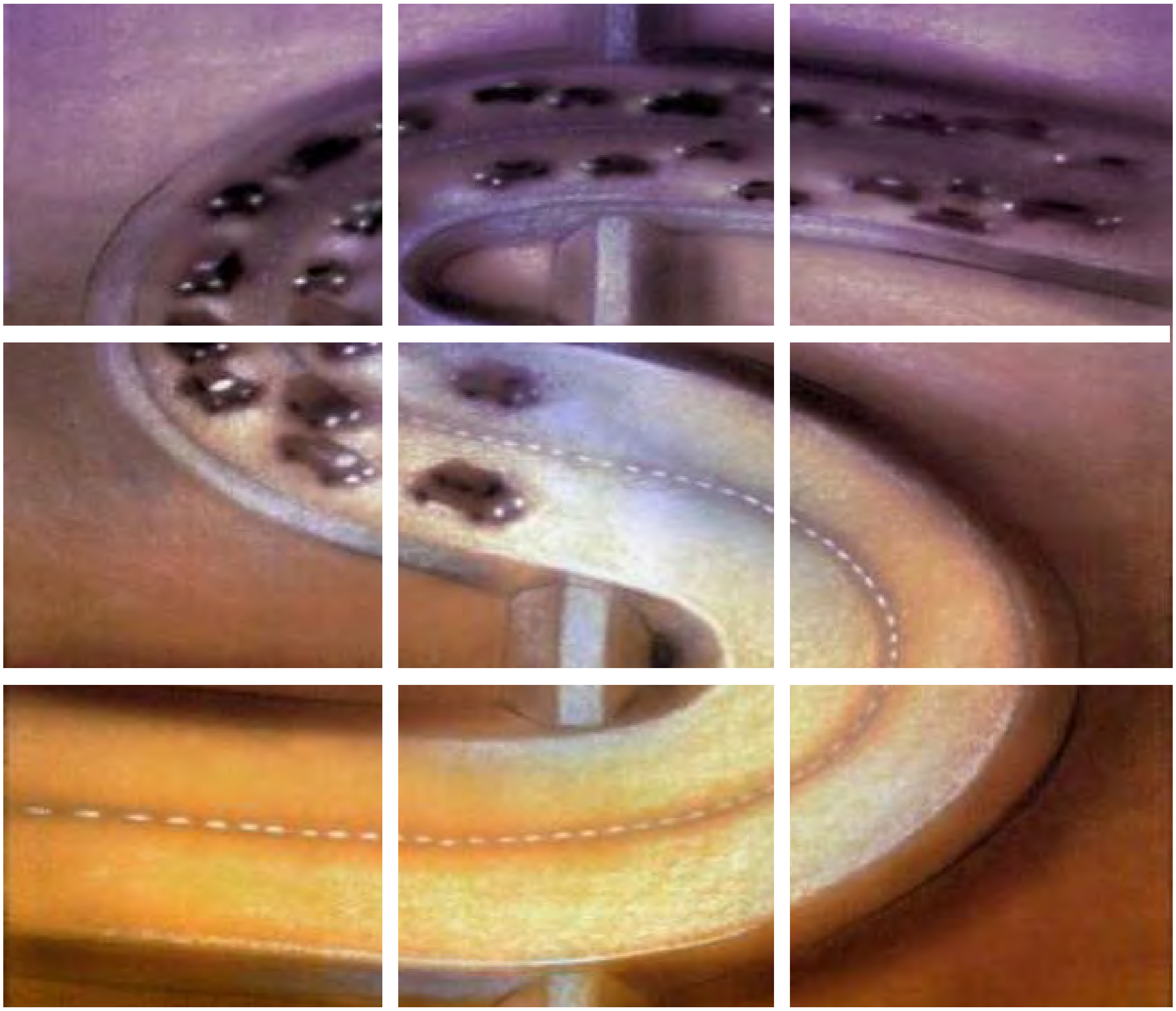
15 U.S. Census Bureau, Metropolitan Gross Domestic Product, 2005. Available at www.demographia.com . Average wages and *per capita* productivity are of course much lower. The U.S. Census Bureau has recently released estimates of metropolitan gross regional product and productivity per capita. Models of regional productivity are extensions of the classic 'production' model from economics, in which the product (output) of a firm is theorized to depend on inputs of capital, labor, materials, etc and prices. In the regional extension, the 'product' (output) of a city or region is theorized to depend on its size, capital investment, labor, competitive pricing, and other factors. Regional product*ivity,* literally the product divided by the number of workers or per capita, is related to these and other factors such as accessibility, tax rates, crime, education, and other features. In the regional extension, the 'product' (output) of a city or region is theorized to depend on its size, capital investment, labor, competitive pricing and other factors.

16 R Prud'homme and C.W. Lee, "Size, sprawl, speed and the efficiency of cities," Urban Studies 36:11, 1949-1858, 1999.

17 R. Cervero, Efficient urbanization: economic performance and the shape of the metropolis", Urban Studies, 38:10, 1651-1671, 2001.

18 In its log-linear form the model is: Ln(P/w) = ln(a) + b Ln(X/w) + c Ln(Y/w) + …..

19 By definition, elasticity is (dy/y)/(dx/x). Therefore, the form of the forecasting model is: (P/w)' = (P/w)[1 + e * (Pct change in X)], where (P/w) is the present productivity per worker, empirically defined as the gross regional product divided by the workforce, and (P/w)' is the revised productivity, adjusted for the change in X.



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