Estimating Important Transportation-Related Regional Economic Relationships in Bexar County, Texas

by

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Executive Summary

Background

Analysis of transportation cost, and comparison of cost across modes, are popular activities in transportation economic research. While possible exceptions exist, studies of automobile transportation, at least in the last two decades, generally focus on the total social cost of automobile travel, with an emphasis on external costs, such as air and water pollution, noise, accidents, and congestion, among others [Cipriani, et al. (1996); Miller and Moffet (1993); Burrington (1994); Newman and Kenworthy (1999)]. A relative lack of emphasis has been placed on the more mundane aspects of automobile transportation, direct operating costs incurred by the automobile user.

Transportation economic analysis of motor bus transit systems is much more focused on the internal system costs and questions about input substitution, input demand elasticity, and scale economies. The primary method of these studies is econometric estimation of cost functions [e.g., Viton (1981); Berechman and Guiliano (1984); Obeng (1984,1994)].

With respect to regional economic impact analysis of transportation policy, the literature concentrates primarily on the effect of infrastructure investment on regional growth and form [e.g., Reitveld (1989); Deno and Eberts (1991); Garcia-Mila and McGuire (1992)]. To our knowledge, no studies exist on the comparative regional economic impact of transportation operating expenditures, by travel mode, and the regional impacts of an auto-to-bus mode switch.

Summary of Our Findings

Of particular interest in this research is the relative expenditure leakage and multiplier effects of autos versus buses. In order to estimate these effects, we develop a complex set of three interconnected models. One model translates a reduction in private automobile vehicle-miles into reductions in regional jobs and income. A second model translates increased bus ridership into increases in jobs and income. A third model translates consumer savings from reduced driving into spending on bus fares and general consumer goods, and, in turn, their effects on jobs and income.

In order to preserve the integrity of our assumption of constant average cost of expansion of bus operations, our specific mode switching scenario is a relatively modest reduction of 1% in annual weekday auto vehicle-miles. Using the models described above, we estimate the following direct expenditure effects shown in the first line of each specific impact category in Table ES1: Roughly $14 million less spent on auto-related goods and services, $ 4.5 million more on bus operating expenditures, $5.9 million in added transit capital expenditures, and about $3.5 million additional general consumption expenditures.

Note that the net regional impacts from the mode switch are positive. We estimate the net increase in regional value added, a measure of regional income, to be $2.9 million. Our corresponding estimate of gains in regional employment is 226 jobs. Total auto-vehicle miles switched under our particular scenario are 52.7 million. Dividing $2.9 million net regional impact by 52.7 million VMT, yields about 5 cents per reduced auto vehicle-mile.

Our estimate of positive net regional impact from an auto-to-bus mode switch does not include the positive net regional effect of increased capital spending on the purchase of additional bus vehicles or related fixed capital. This is in spite of the fact that our model estimates a sizeable incremental transit surplus, i.e., changes in transit revenue exceed changes in mileage-sensitive operating expenditures. Such spending might be expected to have a positive, yet relatively small effect on jobs and income, as the leakage of regional spending on purchase of bus vehicles is likely high. While no buses are produced in Bexar County, possible direct impacts could occur through effects on transportation (of vehicles) and wholesale trade.

An important facet of this project was to consider the relative regional economic leakages of auto travel versus bus transit. The right-most column of Table ES1 addresses this issue. For every million dollars of reduced auto expenditures, Bexar County loses approximately $307 thousand in regional income and 8.4 jobs. This same million spent on bus operations will generate nearly $1.2 million in regional income and 62.2 jobs. The difference reflects the fact that auto expenditures tend to leak out of Bexar County more than bus expenditures do. Note also that non-auto personal consumption multipliers are also higher than those for auto expenditures, with $526 thousand in regional income and 17 jobs per million dollars in expenditure. The greater multiplier effect of bus and non-auto consumption expenditures (reflecting less leakage) result in the positive net regional economic impacts from the auto-to-bus mode switch.

Table ES1
Summary of Regional Economic Impacts of an Auto-to-Bus Mode Switch in Bexar County, Texas

	Regional Effect Total	Regional Effect Multiplier*
Auto-Related		
Change in Direct Auto-Related Expenditures	-$13,967,877	
Regional Change in Value Added (Income)	-$4,284,000	$306,704
Regional Change in Employment (Jobs)	-117	8.4
Transit-Operations		
Change in Direct Bus System Operating Expenditures	$4,564,636	
Regional Change in Value Added (Income)	$5,362,000	$1,174,683
Regional Change in Employment (Jobs)	284	62.2
Transit-Capital Account		
Change in Capital Expenditures	$5,938,877	
Regional Change in Value Added (Income)	-	-
Regional Change in Employment (Jobs)	-	-
General Household Consumption		
Change in Direct General Consumption Expenditures	$3,464,364	
Regional Change in Value Added (Income)	$1,823,000	$426,215
Regional Change in Employment (Jobs)	59	17.0
Net Total		
Regional Change in Value Added (Income)	$2,901,000	NA
Regional Change in Employment (Jobs)	226	NA

* Multipliers show change in regional value added, and employment, plus $1 million change in direct expenditures.
NA = not applicable

Introduction

Analysis of transportation cost, and comparison of cost across modes, are popular activities in transportation economic research. While possible exceptions exist, studies of automobile transportation, at least in the last two decades, generally focus on the total social cost of automobile travel, with an emphasis on external costs, such as air and water pollution, noise, accidents, and congestion, among others [Cipriani, et al. (1996); Miller and Moffet (1993); Burrington (1994); Newman and Kenworthy (1999)]. A relative lack of emphasis has been placed on the more mundane aspects of automobile transportation, direct operating costs incurred by the automobile user. In spite of the large amount of research on the cost of driving, little consensus on magnitude or method has emerged. Indeed, Murphy and Delucchi (1998), in an excellent review of forty-six such studies conclude, "Thus, with a few exceptions, the recent literature on national social costs in the United States, taken at face value, is of little use (p.38)." Murphy and Delucchi are less negative about analysis of particular costs in particular local case studies.

Transportation economic analysis of motor bus transit systems is primarily focused on the internal system costs and questions about input substitution, input demand elasticity, and scale economies. The primary method of these studies is econometric estimation of cost functions [e.g., Viton (1981); Berechman and Guiliano (1984); Obeng (1984,1994)].

With respect to regional economic impact analysis of transportation policy, the literature concentrates primarily on the effect of infrastructure investment on regional growth and form [e.g., Reitveld (1989); Deno and Eberts (1991); Garcia-Mila and McGuire (1992); Berechman(1994)]. To our knowledge, no studies exist on the comparative regional economic impact of transportation operating expenditures, by travel mode.

Purpose of Project

The purpose of this project is to estimate the mileage-related operating expenditures on public bus transit and automobile travel in Bexar County, Texas, and to compare the relative regional economic impact of these expenditures. The comparison of relative economic impact stems from a mode switching scenario, where we assume an amount of automobile travel is switched to bus transit in Bexar County. The resulting expenditure changes are entered into an input-output model of Bexar County in order to calculate changes in regional jobs and income.

While the project is embedded in a broader project evaluation context, such as benefit-cost analysis [see, e.g., Nash (1993); Small (1999)], or, alternatively, total cost analysis [DeCorla-Souza, et al. (1997)], we do not perform such analysis, per se. Our departure from these more comprehensive approaches is one of method as well as scope. Our concern is with regional impacts, and these are driven by explicit expenditures, not by economic notions of opportunity cost. And within the realm of expenditure analysis, our scope is narrow. We consider only mileage-related operating expenditures. We elaborate briefly on these two points in the following.

Transportation Costs and Expenditures

In an economic sense, the true measure of the cost of an action is the value of the next best opportunity foregone when that action is undertaken, its opportunity cost. This opportunity cost can be further defined as explicit (pecuniary or out-of-pocket) or implicit. Expenditure on gasoline by an automobile traveler is an explicit cost. The value of a traveler's time on a trip is an implicit cost. In this project, we estimate expenditures only, so we are definitely in the explicit realm.

But explicit and implicit opportunity cost to travelers is only a portion of the cost of a trip, the internal portion. Driving an automobile creates opportunities foregone for people other than the travelers in the vehicle. Costs from pollution, congestion, accidents, and noise, among others, are legitimate components of cost [Cipriani, et al. (1996); Miller and Moffet (1993); Burrington (1994); Newman and Kenworthy (1999)]. These are external costs, one-way effects transmitted outside a market mechanism.

The right-hand side of Figure 1 summarizes our economic cost classification for automobile transportation. The arrow indicates that our expenditure measurements are explicit, internal opportunity costs. Neither external opportunity costs nor sunk costs are considered. Implicit opportunity cost, such as the cost of travel time, is also beyond the scope of this research.

Figure 1 **Automobile Transportation Costs and Expenditures**

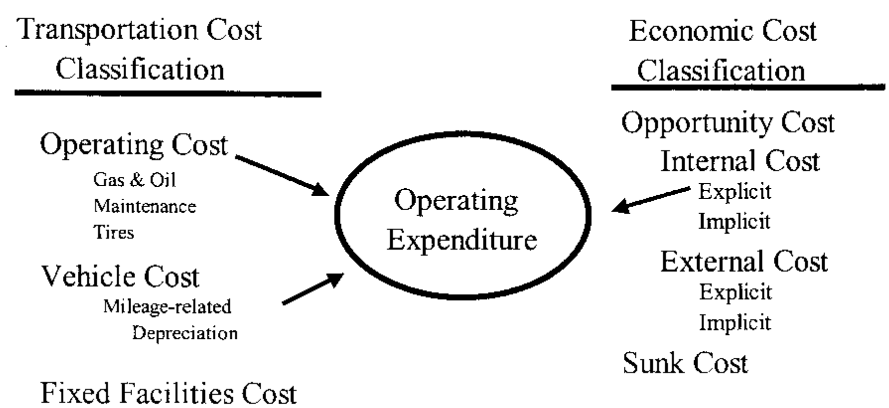


Figure 1 also summarizes our transportation cost classification. Ours is that of Boyer (1998), but is by no means an "industry standard." Examination of a review article such as Murphy and Delucchi (1998) gives ample evidence of the variety of cost taxonomies in the literature. Mackensie et al. (1992) divide cost into market and external categories. Miller and Moffet (1993) have the categories, personal, government subsidies, societal and un-quantified. Apogee Research (1994) divides costs into the categories of user, governmental, and societal. Levinson et al. (1996) use the categories, infrastructure, external, and user, with the latter broken into fixed + variable, and time classifications. The closest relative to our taxonomy is Litman (1996), who uses a three-way taxonomy, internal-external, market-nonmarket, and fixed-variable.

Two arrows on the left-hand-side of Figure 1 show the types of transportation costs which we measure as expenditures. The arrow from the operating cost category indicates the standard relationship between gas, oil, maintenance and tires expenditures and the number of vehicle-miles. The arrow from the vehicle cost category indicates mileage-related depreciation. In the taxonomy, it is usually considered a vehicle cost, but it does contribute to mileage-related expenditures for auto travel, so we include it as an operating expenditure. In an economic sense, we are considering a time period between the short run and the long run, where the number of vehicles is variable, but where facilities are fixed.

Auto-Bus Mode-Switching and Regional Economic Impacts

Figure 2 is a similar taxonomy for bus transit. The right-hand-side is the same as in Figure 1, indicating that we are considering only explicit opportunity costs. The left-hand-side of Figure 2 indicates that the operating costs under consideration are those related to vehicle- miles traveled. Our initial assumption is that only part of transportation administration and support is variable, while all of ticketing and fare collection, vehicle operations, and vehicle maintenance are variable costs related to vehicle-miles. Our implicit assumption here is that the bus system operates at constant average cost over the relevant range of our simulation. The arrow from vehicle cost to operating expenditure indicates that we consider as a cost of operating the bus system the mileage-related depreciation of vehicles. The arrow is dashed, however, as measurement of the magnitude of this expenditure is beyond the scope of this research. Exclusion of this expenditure makes our estimate of the regional economic impact of our mode-switching scenario more conservative. Including this magnitude would increase the net regional impact on jobs and income, as more buses are purchased for the system. Some small part of this expenditure would have a positive regional economic impact through spending on, say, transportation and wholesale trade.

Figure 2 **Bus System Transportation Cost and Expenditure**

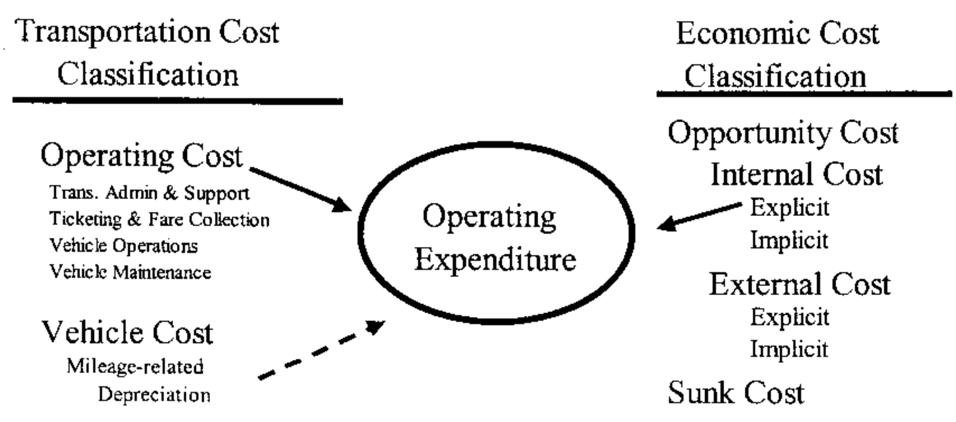


Figure 3 is a graphical representation of the scenario we examine in this research. The initial shock to the system is a switch of automobile trips to bus trips. This action is represented by the two rectangles at the left of the diagram. Fewer automobile trips have two effects on regional expenditures. The money saved from less driving will have the effect of reducing regional expenditures on automobile operations. This is represented by the middle oval in the diagram. Reduced regional spending is not the only result, however, as we assume households spend their auto expenditure savings on general consumption goods. This is represented by the top oval in the middle of Figure 3. The final change in regional spending occurs through the bus system, as VIA Metropolitan Transit spends to accommodate the increased ridership from the mode switch. These three general expenditure changes are fed into an input-output model for Bexar County (Rutgers University, 1998), and the net regional economic impacts are calculated.

Figure 3 **Mode Switiching and Regional Economic Impacts**

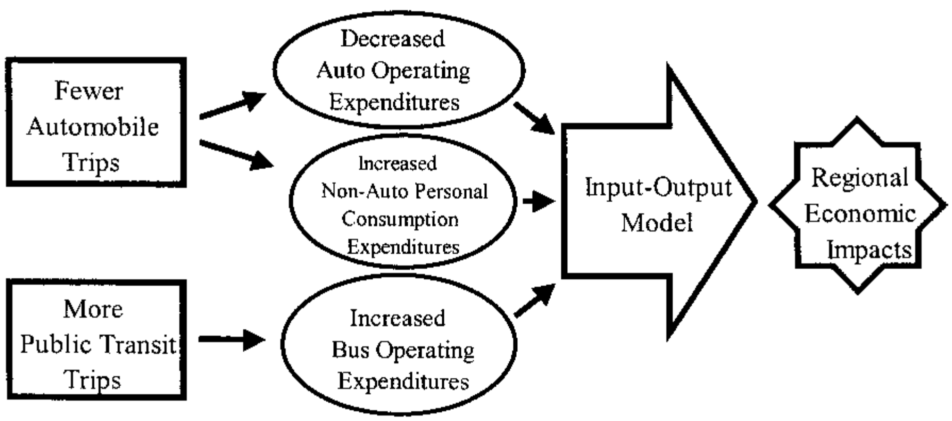
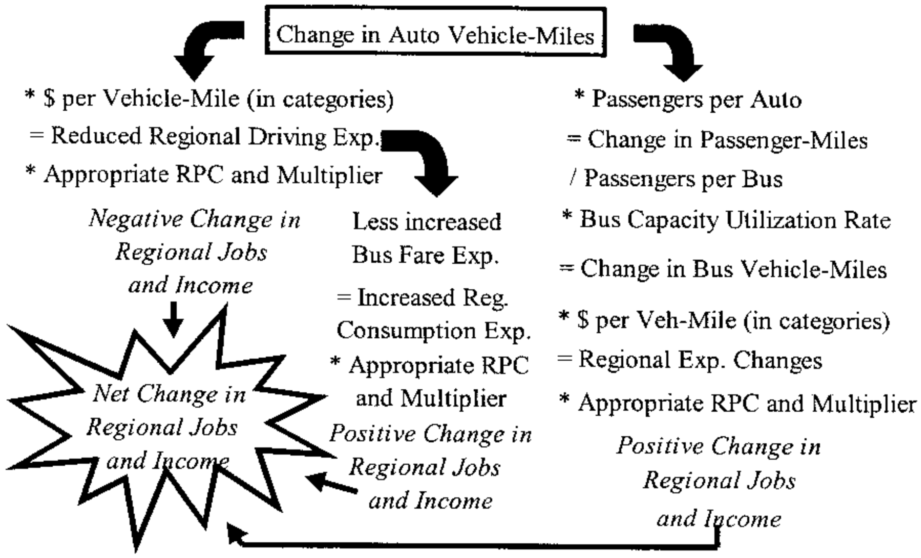


Figure 4 is a more detailed description of the methods and model components used in the analysis. The three general effects on regional spending are indicated by the three solid arrows. The arrows coming out of the change in auto vehicle-miles box at the top of the figure represent the transfer of trips from auto to bus. On the left-hand side we see that we multiply the change in vehicle-miles times the expenditures per vehicle mile in the different expenditure categories.

These disaggregated expenditures are the “bridges” to the appropriate sector in the input-output model. They are multiplied by a regional purchase coefficient (RPC) to determine the leakage of spending from the regional economy, and then by the appropriate regional multiplier for that sector. Performing these calculations yields the negative effects on the regional economy from reduced auto spending. RPC’s for affected sectors appear below, in the first horizontal sections of Tables 8 and 9.

Figure 4 **Methods and Model Components**



The arrow coming out of the right of the auto vehicle-miles box at the top of the diagram represents the transformation of auto vehicle-miles into bus vehicle-miles, through several intermediate steps. While not shown in Figure 4, this process is broken down into peak and off-peak components. Reduced auto vehicle-miles times vehicle occupancy yields the number of passenger miles coming to the bus system. Dividing this number by passengers per bus and multiplying it by the bus capacity utilization rate yields the increase in bus vehicle-miles. This change is then multiplied by the expenditure per vehicle-mile for the appropriate bus expenditure category. These expenditures are then “bridged” to the appropriate sector in the IO model, where they are multiplied by the sector-specific RPC and multiplier to yield the increase in regional jobs and income from the larger bus system.

The middle arrow of Figure 4 represents the increased general consumption expenditures stemming from the decreased auto expenditures (net of bus fares), “bridged” to the IO model and then multiplied by their appropriate RPC and the household consumption multiplier. The three effects, one negative and two positive are combined to form the net change in regional jobs and income stemming from our mode switching scenario.

Detailed Documentation of Key Calculations and Components of the Model

Mileage-sensitive Automobile Expenditures

Table 1 contains estimates of expenditures per vehicle-mile on gasoline and oil, maintenance, and tires for 1995-1999. These figures come from the American Automobile Association (1999, pp. 6-7) and the American Automobile Manufacturer's Association (1998), and represent expenditures for a common intermediate size vehicle. For our purposes here we average the expenditures over a five year time period.

Table 1 **Estimates of Mileage-Sensitive Expenditures on Driving** (in cents per vehicle mile)
Passenger Car Expenditures on Gas and Oil, Maintenance, and Tires, 1995-1999

Model Year	Gas & Oil	Maintenance	Tires	Total
1999	5.7	3.4	1.6	10.7
1998	6.3	3.1	1.4	10.8
1997	6.6	2.8	1.4	10.8
1996	5.9	2.8	1.4	10.1
1995	6.0	2.6	1.4	10.0
1995-1999 Average	6.10	2.94	1.44	10.48
Passenger Car Mileage-Sensitive Deprecation, 1999				16.0

Sources: American Automobile Association for 1999; American Automobile Manufactures Association for 1995-1998

The mileage-sensitive depreciation figure also comes from the AAA (1999, pp. 6-7) and is the added depreciation cost per mile for cars driven over 15,000 miles per year. We are careful here not to include any "ownership costs" not sensitive to miles driven, such as insurance, license, registration, and taxes. The 16 cent figure has some intuitive appear. Suppose one purchases a car for $19,200 and drives it 120,000 miles. The value of the vehicle will be close to zero at that time. $19,200 divided by 120,000 miles is 16 cents per mile.

Mileage-sensitive Bus Operating Expenditures

Table 2 contains our estimates of mileage-sensitive bus operating expenditures for VIA Metropolitan Transit. The information comes from VIA Metropolitan Transit (1999a). Our goal is not to include expenditures which are not related to vehicle-miles. We allocate no general administration and support and non-vehicle maintenance to our variable expenditure, and only half of the transportation administration and support.

Table 2 Variable Motor Bus Operating Expenditures in Bexar County, Texas: Annual and Per Vehicle-Mile

Expenditure Category	Trans. Admin. & Support (1)	Ticketing & Fare Collection	Vehicle Operations	Vehicle Maintenance	Total Annual	Per V-M (2)
Salaries & Wages	$1,400,207	$227,098	$19,632,421	$5,753,363	$27,013,089	$1.46034
Fringe Benefits	$550,279	$89,265	7,614,777	$2,260,902	$10,615,223	0.57386
Services	$11,938	$25,825	-	$12,227	$49,990	0.00270
Fuel & Lubricants	-	-	$2,923,755	$61,723	$2,985,487	0.16140
Tires & Tubes	-	-	$813,789	$2,267	$816,056	0.04412
Other Mat. & Sup.	$11,759	$930	-	$3,195,297	$3,207,986	0.17342
Taxes		-	$1,084,681	$16,000	$1,100,681	0.05950
Misc. Expen.	$705	$91	$180	-	$976	0.00005
Grand Total	-	-	-	-	$45,789,488	$2.47539

Notes: (1) All categories, 50% of Form (301) value.
(2) Vehicle miles are calculated as the sum of peak and off-peak weekday vehicle miles, times 260 weekdays.

The operating function categories appear as columns in Table 2, and the detailed expenditure categories appear as rows. Expenditures are summed for each expenditure category across the various operating functions to yield the number in the second column from the right in Table 2. For example, salary and wage expenditures are summed across operating functions to yield an annual figure of $27,013,089. This figure is then divided by total annual weekday vehicle-miles (18,497,856) to yield the figure $1.46 per vehicle-mile, the figure in the rightmost column. The expenditure category detail is helpful for the input-output model component of the model, as well, as the expenditure detail provides clues to important sector information.

When we run the mode-switching scenario through the model, we assume that expenditures in all categories of vehicle operations, vehicle maintenance, and ticketing and fare collection are linearly related to vehicle-miles at their current average expenditure per vehicle-mile. Note that the grand total of expenditures per vehicle-mile, $2.47, is less than the amount appearing in, say, the National Transit Database, as the latter includes in operating cost expenditures which are not variable with respect to vehicle-miles.

Change in Automobile Vehicle-Miles and Bus Passenger-Miles

Table 3 represents the initial mode-switching component of the model. The first line of Table 3 is an estimate of average daily vehicle-miles in Bexar County (VMT, 1999a). As we will be using estimates of vehicle occupancy on home-based work trips in the calculation of peak vehicle-miles, and these trips are primarily weekday trips, we multiply daily trips by the number of weekdays in a year, 260, the number appearing on the second line of Table 3. This yields annual weekday automobile vehicle-miles.

Table 3 **Annual Decrease in Automobile Vehicle-Miles and Increase in Bus Passenger-Miles**

Average Daily Vehicle-Miles	20,287,992
Weekdays Per Year	260
Annual Weekday Vehicle-Miles	5,274,877,920
Peak %	52%
Annual Weekday Peak Vehicle Miles	2,742,936,518
Peak Passengers Per Vehicle	1.084
Annual Weekday Peak Auto Passenger Miles	2,973,343,186
Off-Peak %	48%
Annual Weekday Off-Peak Vehicle-Miles	2,531,941,402
Off-Peak Passengers per Vehicle	1.402
Annual Off-Peak Auto Passenger Miles	3,549,781,845
% Decrease in Peak Auto Vehicle-Miles	1%
% Decrease in Off-Peak Auto Vehicle-Miles	1%
Annual Decrease in Peak Auto Vehicle-Miles	27,429,365
Annual Decrease in Off-Peak Auto Vehicle-Miles	25,319,414
Annual Total Decrease in Auto Vehicle-Miles	52,748,779
Annual Increase in Bus Peak Passenger-Miles	29,733,432
Annual Increase in Bus Off-Peak Passenger-Miles	35,497,818

Some differences in reported vehicle-miles exist in our information received from VIA Metropolitan Transit. In another correspondence (VMT, 1999c), weekday vehicle-miles are estimated at nearly 33 million. The actual, precise number of vehicle-miles is not as crucial as it might seem initially, as our mode-switching scenario transfers only a small amount (1%) from autos to buses. The purpose of the small mode switch is to not overwhelm the bus system, as roughly 90% of peak trips are by auto. A 10% mode switch would nearly double the size of the bus system at peak, and would stretch the credibility of the fixed average cost per bus vehicle-mile we use here. So a 1% mode switch, from any estimate of automobile vehicle-miles that is in the ballpark will accomplish our purposes here.

In the fourth line of Table 3 we show the percent of vehicle-miles occurring in our definition of the peak (7:00 - 10:00 a.m., and 4:00 - 7:00 p.m.) Multiplying the peak percentage times total weekday vehicle-miles gives the next figure, annual weekday peak vehicle-miles. The next line in Table 3 is passengers per vehicle in the peak period, 1.084, the estimate for home-based work trips.

Multiplying vehicle-miles by passengers per vehicle yields the next line of Table 3, annual weekday peak auto passenger-miles. This same procedure is followed for off-peak vehicle use in the next four lines of Table 3. The next two lines shows the 1% figure mentioned above, the percent change in vehicle and passenger-miles. The lines of Table 3 show the numbers which will drive the remainder of the analysis, the annual decrease in automobile vehicle-miles, and annual increase in annual peak bus passenger-miles, and the annual increase in off-peak bus passenger-miles. The decrease in auto vehicle-miles will drive the reduction in auto expenditures, and the increase in peak and off-peak bus passengers will be converted to a change in bus vehicle-miles, and this will drive the bus expenditure change component of the model.

Change in Bus Vehicle-Miles

As the bus-related output of the automobile vehicle-miles component of the model, shown in Table 3, is in units of passenger-miles, and our expenditure change estimates for the bus system are based on bus vehicle-miles, we must convert bus passenger-miles to bus vehicle-miles. This is shown in Table 4.

Table 4 **Increase in Annual Bus Vehicle-Miles**

Annual Increase in Bus Peak Passenger-Miles (Table 3)	29,733,432
Annual Increase in Bus Off-Peak Passenger-Miles (Table 3)	35,497,818
Passengers in Full Bus	50
Bus Utilization Rate at Peak	90%
Passengers per Bus at Peak	45
Increase in Peak Bus Vehicle-Miles	660,743
Bus Utilization Rate Off-Peak	60%
Passengers per Bus at Off-Peak	30
Increase in Off-Peak Bus Vehicle-Miles	1,183,261
Increase in Total Annual Bus Vehicle-Miles	1,844,004

The first two lines of Table 4 are the annual increases in peak and off-peak bus passenger-miles, from Table 3. Next, we assume full buses contain 50 passengers, the number in the third line of Table 4. Buses don't run at 100% capacity, however, so we estimate what we call the bus utilization rate for both peak and off-peak periods. Here we use the peak and off-peak utilization rates provided to us by VIA Metropolitan Transit (VMT, 1999c). To these figures (80% peak and 50% off-peak) we add ten percentage points. This is to account for the fact that the increase in bus passengers in our mode switching scenario would likely increase the utilization rate. This assumption has the effect of damping the regional economic impacts of the mode-switching scenario, as fewer vehicle-miles are need to accommodate new passengers when buses run at higher capacity. The numbers for the lines of Table 4 labeled passengers per bus are calculated as full bus capacity multiplied by the bus utilization rate.

Dividing annual passenger-miles by passengers per bus gives the peak and off-peak figures, which are summed in the last line of Figure 4 to yield the total increase in bus vehicle-miles. This figure will drive the bus expenditure changes described in Table 6, below.

Change in Automobile Expenditures

We show the decrease in automobile expenditures in Table 5. The first line of Table 5 is the total decrease in annual auto vehicle-miles from Table 3. The expenditure categories and expenditures per vehicle-mile come from Table 1 discussed above. The figures in the rightmost column of Table 5 are the product of the decrease in vehicle-miles and the expenditures per vehicle-mile, by category. These numbers, then, will drive the auto-related component of the regional impact analysis in the input-output model.

Table 5 **Annual Decrease in Auto Expenditures by Category**

Annual Change in Auto Vehicle-Miles (from Table 3) -52,748,779

Expenditure Category		Expenditures per Vehicle-Mile	Decrease in Expenditures
Gas & Oil		$0.0610	$3,217,676
Maintenance		$0.0294	$1,550,814
Tires & Tubes		$0.0144	$759,582
Auto Dealers		$0.1600	$8,439,805
	Totals	**$0.2648**	**$13,967,877**

Change in General Consumer Expenditures

As shown in Figure 3 and discussed above, we assume savings in automobile expenditures are spent in two ways, on bus fares and on general consumer expenditures. Calculation of these two components of increased spending is accomplished in Table 6. To calculate the increase in spending on bus fares, we need to estimate the increased number of trips generating these fares. We do this for both peak and off-peak bus trips in Table 6, by dividing peak and off-peak passenger-miles by peak and off-peak trip length, respectively. Peak and off-peak trip lengths are calculated by dividing passenger-miles by the ridership (VIA Metropolitan Transit, 1999a).

The peak and off-peak trips, calculated in this manner, are summed in Table 6 to yield the total increase in trips. This number is multiplied by the average fare, 50 cents (VIA Metropolitan Transit, 1999b), to give the annual increase in bus fares. This number is then subtracted from the money freed up from decreased automobile expenditures to yield the increase in general consumption expenditures on the last line of Table 6. This number will drive the household consumption multiplier component of the input-output model.

Table 6 **Annual Increase in General Consumer Expenditures**

Annual Increase in Peak Bus Passenger-Miles (Table 3)	29,733,432
Average Peak Trip Length (Miles)	3.57
Annual Increase in Peak Bus Trips	8,328,692
Annual Increase in Bus Off-Peak Passenger-Miles (Table 3)	35,497,818
Average Off-Peak Trip Length (Miles)	2.8
Annual Increase in Off-Peak Trips	12,677,792
Annual Total Increase in Trips	21,006,485
Average Fare	$0.50
Annual Increase in Bus Fare Expenditures	$10,503,242
Annual Decrease in Auto Expenditures (Table 5)	$13,967,877
Annual Change in General Consumption Expenditures	$3,464,634

Change in Bus System Expenditures

Table 7 contains calculations for the bus system analogous to those for automobiles in Table 5. Here, the annual change in bus vehicle-miles (from Table 4) is multiplied by the expenditures per vehicle-mile of Table 2. The rightmost column of Table 2 contains estimates of increased bus system expenditures in the categories that will be bridged to the input-output model.

Table 7 **Annual Increase in Bus Expenditures, by Category**

Expenditure Category	Expenditures per Vehicle-Mile	Increase in Expenditures
Salaries & Wages	$1.460336	$2,692,865
Fringe Benefits	$0.573862	$1,058,204
Services	$0.002702	$4,983
Fuel & Lubricants	$0.161396	$297,615
Tires & Tubes	$0.044116	$81,351
Other Mat. & Sup.	$0.173425	$319,796
Taxes	$0.059503	$109,724
Misc. Expen.	$0.000053	$97
Totals	**$2.475394**	**$4,564,636**

The Bexar County Input-Output Model

Input-output models are often constructed for the type of analytic problem examined in this project. Input-output modeling is one of the most accepted means for estimating economic impacts. This is because it provides a concise and accurate means for articulating the interrelationships among industries. The models can be quite detailed. For example, the current U.S. model currently has more than 500 industries representing many four-digit Standard Industrial Classification (SIC) codes. The Bexar County PC I-O model used in this study has 463 sectors. Further, the industry detail of input-output models provides not only a consistent and systematic approach, but also more accurately assesses multiplier effects of changes in economic activity. Research has shown that results from more aggregated economic models can have as much as 50 percent error. Such large errors are generally attributed to poor estimation of regional trade flows resulting from the aggregation process.

The limitations of input-output modeling should also be recognized. The approach makes several key assumptions. First, the input-output model approach assumes that there are no economies of scale to production in an industry; that is, the proportion of inputs used in an industry's production process does not change regardless of the level of production. This assumption will not work if the technology matrix depicts an economy of a recession economy (e.g., 1982) and the analyst is attempting to model activity in a peak economic year (e.g., 1989). In a recession year, the labor-to-output ratio tends to be excessive because firms are generally reluctant to lay off workers when they believe an economic turnaround is about to occur. This is not a problem in our analysis of Bexar County.

A less-restrictive assumption of the input-output approach is that technology is not permitted to change over time. It is less restrictive because the technology matrix in the United States is updated frequently and, in general, production technology does not radically change over short periods.

Finally, the technical coefficients used in most regional models are based on the assumption that production processes are spatially invariant and are well-represented by the nation's average technology. In a region as large and diverse as Bexar County, this assumption is likely to hold true. Further detail on the mathematics and general workings of input-output models are readily available in a variety of textbooks dealing with regional economics and analysis, e.g., Miller and Blair (1985).

Our first input-output task in this project was to select the best model for the analytic problem. In the United States there are three major vendors of regional input-output models. They are U.S. Bureau of Economic Analysis's (BEA) RIMS II multipliers, Minnesota IMPLAN Group Inc.'s (MIG) IMPLAN Pro model, and Regional Science Research Corporation's (RSRC) PC I-O model. For our analysis of transportation issues in Bexar County, we obtained a recent (1997) PC I-O model. The PC-IO model had distinct advantages over the other model choices. A further discussion can be found in Brucker, Hastings, and Latham's article in the Summer 1987 issue of *The Review of Regional Studies* entitled "Regional Input-Output Analysis: A Comparison of Five 'Ready-Made' Model Systems."

PC I-O "regionalizes" the U.S. national I-O technology coefficients table at the highest levels of disaggregation (more than 500 industries). Since aggregation of sectors has been shown to be an important source of error in the calculation of impact multipliers, the retention of maximum industrial detail in these regional systems is a positive feature that they share. PC I-O is unique in its approach to regionalization, differing from other models in the manner of estimating regional purchase coefficients (RPCs), which are used to regionalize the technology matrix. An RPC is the proportion of the region's demand for a good or service that is fulfilled by the region's own producers, rather than by imports from producers in other areas. Thus, it expresses the proportion of the purchases of the good or service that do not leak out of the region, but rather feed back to its economy, with corresponding multiplier effects. Thus, the accuracy of the RPC is crucial to the accuracy of a regional I-O model, because the regional multiplier effects of a sector vary directly with its RPC.

The technique for estimating RPCs used by RSRC and MIG in their models are theoretically more appealing than the location quotient (LQ) approach used in RIMS II. This is because the former two allow for crosshauling of a good or service among regions, and the latter does not. Since crosshauling of the same general class of goods or services among regions is quite common, the RSRC-MIG approach should provide better estimates of regional imports and exports. Statistical results reported in Stevens, Treyz, and Lahr (1989) confirm that LQ methods tend to overestimate RPCs. By extension, inaccurate RPCs may lead to inaccurately estimated impacts.

Further, the estimating equation used by RSRC to produce RPCs should be more accurate than that used by MIG. The difference between the two approaches is that MIG estimates RPCs at a more aggregated level (two-digit SICs, or about 86 industries) and applies them at a disaggregated level (over 500 industries). RSRC both estimates and applies the RPCs at the most detailed industry level. The application of aggregate RPCs can induce as much as 50% error in impact estimates (Stevens and Lahr, 1990).

Although both PC I-O and IMPLAN use an RPC-estimating technique that is theoretically sound, and update it using the most recent economic data, some practitioners question their accuracy. The reasons for doing so are three-fold. First, the observations currently used to estimate their implemented RPCs are based on 20-year old trade relationships—the Commodity Transportation Survey (CTS) from the 1977 Census of Transportation. Second, the CTS observations are at the state level. Therefore RPCs estimated for substate areas are extrapolated. Hence, there is the potential that RPCs for counties and metropolitan areas are not as accurate as might be expected. Third, the observed CTS RPCs are only for shipments of goods. The interstate provision of services is unmeasured by the CTS. IMPLAN replies on relationships from the 1977 US Multiregional Input-Output Model, which are not clearly documented. PC I-O relies on the same econometric relationships that it does for manufacturing industries, but employs expert judgment to construct weight/value ratios (a critical variable in the RSRC RPC-estimating equation) for the nonmanufacturing industries.

The fact that BEA creates the RIMS II multipliers gives it the advantage of being constructed from the full set of the most recent regional earnings data available. BEA is the main federal government purveyor of employment and earnings data by detailed industry. It therefore has access to the fully disclosed and disaggregated versions of these data. The other two model systems rely on older data from *County Business Patterns* and Bureau of Labor Statistic's ES202 forms, which have been "improved" by filling-in for any industries that have disclosure problems (this occurs when three or fewer firms exist in an industry of a region).

Specific Input-Output Calculations

Reduced Expenditures on Autos. Table 8 shows detailed calculations from the input-output analysis of the effect of decreased automobile expenditures. The general procedure is to allocate an expenditure item among trade, transportation and producing sectors, account for out-of-county leakage, and multiply the remainder by appropriate multipliers, value added and employment.

For example, lets examine the gas and oil column of the table. For every dollar of spending on gas and oil, about 32 cents goes to wholesale and retail trade sectors in Bexar County. Likewise, a little over 2 cents goes to transporters. Of that spending on trade and transportation, some remains in the county and some is spent outside the county. The RPC numbers for trade and transportation are 0.97 and 0.61, respectively. Ninety-seven percent of the money spent on retail trade margin is generated in Bexar County, but only 61% for transportation. The "RPC Produced" row is for the production of gas and oil, and indicates that only 8.35 cents per dollar of spending on gas and oil goes to gas and oil producers in the county.

Margins and RPCs for maintenance, tires, and automobiles have similar interpretations. Note there is no trade margin on maintenance, as we assume that is a service directly sold to the customer. The RPC for maintenance, 0.789, indicates that the model says nearly 79% of the auto maintenance is purchased in Bexar County. Note that the RPC for automobile production is zero, indicating no auto production in the county.

The remaining row sections show the value added and employment multipliers for the different sectors to which expenditures are bridged, and the final multiplier calculations.

Table 8 Input-Output Parameters for Automobile Expenditures

Expenditure Category	Gas & Oil	Maintenance	Tires & Tubes	Automobiles
Trade Margin	0.31800000	-	0.43900000	0.19700000
Transportation Margin	0.02300000	-	0.13800000	0.01900000
RPC Transportation	0.61264565	-	0.65721535	0.55327047
RPC Trade	0.97153500	-	0.88013850	0.97153500
RPC Produced	0.08350000	0.78874200	-	-
Value Added Multipliers				
Transportation Multiplier	0.82517391	-	0.87775362	0.86994737
Trade Multiplier	1.02900000	-	0.95150000	1.02900000
Gas & Oil Multiplier	0.42600000	-	-	-
Maintenance Multiplier	-	0.87400000	-	-
Tire Mfg. Multiplier	-	-	0.66100000	-
Automobile Mfg. Multiplier	-	-	-	0.35600000
Employment Multiplier				
Transportation Multiplier	0.025443478	0	0.036294203	0.026605263
Trade Multiplier	0.0256	0	0.02725	0.0256
Gas & Oil Multiplier	0.0042	0	0	0
Maintenance Multiplier	0	0.0289	0	0
Tire Mfg. Multiplier	0	0	0.0111	0
Automobile Mfg. Multiplier	0	0	0	0.0066
Total Value Added ($1,000)				
Transportation Multiplier	$37	-	$60	$77
Trade Multiplier	$1,023	-	$279	$1,662
Gas & Oil Multiplier	$74	-	-	-
Maintenance Multiplier	-	$1,069	-	-
Tire Mfg. Multiplier	-	-	-	-
Automobile Mfg. Multiplier	-	-	-	-
Total Employment				
Transportation Multiplier	1	-	3	2
Trade Multiplier	25	-	8	41
Gas & Oil Multiplier	1	-	-	-
Maintenance Multiplier	-	35	-	-
Tire Mfg. Multiplier	-	-	-	-
Automobile Mfg. Multiplier	-	-	-	-

Expanded Bus Transportation. Table 9 is the counterpart to Table 8. This time the input-output margins and multipliers refer to those pertaining to the increase in bus expenditures. Salaries and fringe are multiplied by the Bexar County input-output model's household consumption multipliers. Other multiplier calculations are direct parallels to those in Table 8.

Table 9 **Input-Output Parameters for Bus Expenditures**

	Salaries & Fringe	Services	Fuel & Lubricants	Tires & Tubes	Other Maint. & Supplies	Taxes	Misc. Expenditures
Household Consumption	-	-	-	-	-	-	-
Transportation Margin	-	-	0.02300000	0.13800000	0.00700000	-	0.00700000
Trade Margin	-	-	0.31800000	0.43900000	0.39600000	-	0.39600000
RPC Transportation	-	-	0.61264565	0.65721535	0.65721535	-	0.65721535
RPC Trade	-	-	0.97153500	0.88013850	0.88013850	-	0.88013850
RPC Produced	-	0.95517200	0.08350000	-	0.20290000	-	0.20290000
Value Added Multipliers							
Household Consumption	1.35534475	-	-	-	-	-	-
Transportation Multiplier	-	-	0.82517391	0.87775362	0.87775362	-	0.87775362
Trade Multiplier	-	-	1.02900000	0.95150000	0.95150000	-	0.95150000
Fuel & Lubricants Multiplier	-	-	0.42600000	-	-	-	-
Maint. & Sup. Multiplier	-	0.92300000	-	-	-	-	-
Tires Mfg. Multiplier	-	-	-	0.66100000	-	-	-
Taxes Multiplier	-	-	-	-	0.63500000	-	-
Misc. Expenditures Multiplier	-	-	-	-	-	-	0.63500000
Employment Multipliers							
Household Consumption	0.07375424	-	-	-	-	-	-
Transportation Multiplier	-	-	0.02544348	0.03629420	0.03629420	-	0.03629420
Trade Multiplier	-	-	0.02560000	0.02725000	0.02725000	-	0.02725000
Fuel & Lubricants Multiplier	-	-	0.00420000	-	-	-	-
Maint. & Sup. Multiplier	-	0.03610000	-	-	-	-	-
Tires Mfg. Multiplier	-	-	-	0.01110000	-	-	-
Taxes Multiplier	-	-	-	-	0.01930000	-	-
Misc. Expenditures Multiplier	-	-	-	-	-	-	0.01930000
Total Value Added							
Household Consumption	$5,084	-	-	-	-	-	-
Transportation Multiplier	-	-	$3	$6	$1	-	-
Trade Multiplier	-	-	$95	-$30	$106	-	-
Fuel & Lubricants Multiplier	-	-	$7	-	-	-	-
Maint. & Sup. Multiplier	-	$4	-	-	-	-	-
Tires Mfg. Multiplier	-	-	-	-	-	-	-
Taxes Multiplier	-	-	-	-	$25	-	-
Misc. Expenditures Multiplier	-	-	-	-	-	-	-
Total Employment							
Household Consumption	277	-	-	-	-	-	-
Transportation Multiplier	-	-	0.1	0.3	0.1	-	-
Trade Multiplier	-	-	2	1	3	-	-
Fuel & Lubricants Multiplier	-	-	0.1	-	-	-	-
Maint. & Sup. Multiplier	-	0.2	-	-	-	-	-
Tires Mfg. Multiplier	-	-	-	-	-	-	-
Taxes Multiplier	-	-	-	-	1	-	-
Misc. Expenditures Multiplier	-	-	-	-	-	-	-

Increased Personal Consumption Expenditures. A movement of a given number of passenger-miles from private auto to bus transpiration saves the public money. Our analysis assumes consumers devote these moneys to added consumption spending.

Our input-output model is equipped with a set of personal consumption expenditure coefficients, showing the allocation of the average dollar of consumption spending in Bexar County. Of course the consumption spending coefficients include expenditures on personal auto travel. And it would make little sense to move people from cars to bus, and then have them spending some of the money saved on auto expenditures. Accordingly, we factored out auto expenditure items, including appropriate trade and transportation margins, from the vector of personal consumption expenditures, and then re-normalized the vector. This vector is then applied sector-by-sector to appropriate RPCs, and this in turn to employment and value added multipliers. The results appear in Table 10, as the "household employment and value added multipliers per expenditure."

Table 10 **Increase in General Household Expenditures From Switching Transportation Modes**

Increase in Household General Consumer Expenditures	$3,464,634
Household Value Added Multiplier per Expenditure	0.526301
Household Employment Multiplier per Expenditure	0.017153
Total Value Added	$1,823,441
Total Employment	59

Beyond formation of the household multipliers, the calculations in Table 10 are straightforward. The result is that an increase in non-auto personal consumption expenditures (estimated at $3.5 million, see Table 6) creates $1.8 million in regional value added, and 59 jobs.

Conclusions

As noted at the beginning of this report, our purpose is to compare the relative regional economic impact of an incremental switch in weekday travel from automobiles to buses. Of particular interest is the relative expenditure leakage and multiplier effects of autos versus buses. In order to estimate these effects, we had to develop a complex set of three interconnected models. One model translates a reduction in private automobile vehicle-miles into reductions in regional jobs and income. A second model translates increased bus ridership into increases in jobs and income. A third model translates consumer savings from reduced driving into spending on bus fares and general consumer goods, and, in turn, into their effects on jobs and income.

In order to preserve the integrity of our assumption of constant average cost of expansion of bus operations, our specific mode switching scenario is a relatively modest reduction of 1% in annual weekday auto vehicle-miles. Using the models described above, we estimate the following direct expenditure effects: $14 million less spent on auto-related goods and services, $4.5 million more bus operating expenditures, and $3.5 million additional general consumption expenditures. We run these negative and positive expenditure changes through our regional I-O model to determine the net effect on the regional economy. While the negative direct expenditure reduction, $14 million less auto-related spending, is greater than the direct positive effect of increased bus and general consumer spending, $4.5 million and $3.5 million respectively, the overall effect on the regional economy, after accounting for regional leakage and multiplier effects, is strongly positive. We estimate a net increase in regional income of $2.9 million, and a gain of 227 jobs. The results are reported in Table 11.

Table 11 **Summary of Regal Value Added and Employment Changes**

	Value Added ($1,000)	**Employment**
Regional Losses from Decreased Automobile Expenditures	-$4,284	-117
Regional Gains from Increased General Household Consumption Expenditures	$1,823	59
Regional Gains from Increased Bus Expenditures	$5,362	284
Total Net Gain from Mode Switching	$2,901	227

Our estimate of positive net regional impact from an auto-to-bus mode switch is likely conservative, as we do not include the positive net regional effect of increased spending on additional bus vehicles. This is in spite of the fact that our model estimates a sizeable increase in bus fare revenue. On the other hand, such spending might be expected to have a relatively small effect on jobs and income, as the leakage of regional spending on bus vehicles is likely high.

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