Estimating Economic and Development Impacts of Transit Investments

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ABSTRACT

Although economic and development impacts are frequently included as positive objectives of major transit investments, the issues, methods, and results of actual impact analysis remain rather crude and are sometimes misleading. Reported in this paper is an empirical analysis of economic and development impacts from a study of major transit investment for the Seattle area, using state-of-the-art econometric and spatial interaction models. Economic impacts are found to be quite sensitive to assumptions on financing local shares of transit investment, although project financial planning and economic impact analysis have rarely been considered together. Development impacts, in terms of both job and household locations, are modest overall and are concentrated in the vicinity of the central business district that was to be the focus of the transit service, despite the magnitude of the investment involved. The research findings are somewhat tentative, but do suggest directions for applied research in quantitative analysis with operational models to the end of clarifying for policy purposes the potential impacts of major investment projects.

Economic and development impacts are only indirect effects of major mass transit investments, but they are widely discussed and highly touted features of constructing or expanding a large-scale transit system. The American Public Transit Association has asserted that "it is clear...that transit investments have important jobs-creation potential...and (are) highly beneficial to the local, regional, and national economy" (1). On the development side, the U.S. Department of Transportation has in the past made intra-regional impacts an important transit objective: "Rail transit can be a supportive tool of urban revitalization...rail investment can help rejuvenate declining core areas, increase the city's tax base, create a more attractive investment climate, and promote a more efficient, livable urban environment" (2). When guidelines for analysis and planning for transit investments are published, they invariably place economic and development impacts as important components (3).

Good intentions aside, many empirical questions have certainly arisen, and remain, on the rationales, issues, methods, and results of analysis of economic and development impacts of transit investments (4,5). There are questions as to whether these are important matters to be investigated seriously (compared with benefits and costs of transportation), and even if they are, questions remain as to whether the methods and results to date show anything worthy of interest. Economic and development impacts usually rank low in any listing of transit project objectives (6), and the results of impact analysis for recent rail transit projects have been rather predictable and unexciting (7,8).

In any major public investment project, the economic and development impact analysis (if any) occupies an ambiguous role. On the one hand, it is at the least essential information to bring to bear on the public decision-making process, and, as noted previously, may even be project objectives. But, on the other hand, such impacts are rarely the central issues in that process. Public investment decisions, and especially transit investment decisions, are made for a number of diverse reasons, not all of which are economic (or should be). But the economic impacts and implications of the decision alternatives should be clear and known, even if not in a consistent benefit-cost framework with other objectives.

There are many economic and development issues related to major transit investment projects. For example, it is widely assumed that large public investments at least have significant economic benefits during the construction phase because of the outside grants involved, the multiplier effects of capital spending on the regional economy, and the sales and business tax revenues that accrue (1). But what about the local tax dollars that match the federal grants, and get spent for support and peripheral purposes? It is naturally assumed that investment in heavily capitalized transportation facilities results in operating efficiencies and lower long run costs (9). But do these necessarily produce economic benefits for the region? Finally, as indicted earlier, a major impetus for development of the transit projects is to ensure the continued growth and fiscal vitality of the urban cores, especially in light of suburbanization pressures and declines of central business districts (4). But what impact does transit development actually have on the spatial structure of urban areas? Does it significantly improve accessibility and transit ridership, and does it have an impact on locational decisions and patterns of jobs and households?

These are the types of questions that were investigated in the research reported in this paper. In this research, state-of-the-art econometric and spatial interaction models were used to explore economic and development impacts of several alternative transit investments for the Seattle area. The research was carried out as well to develop quantitative analytic techniques that could address the economic and development impact issues more effectively than the methods previously used in comparable transit planning studies. Some reasonable results were obtained, but they are far from definitive. In some respects, they raise more questions than they answer.

In the next section of this paper the transit investment project is described along with its setting and its alternatives. The economic impact empirical work is presented, both for construction and operations and maintenance costs, along with previous methods, the methods and data used in this research, and results under differing assumptions. Finally, the development impact empirical work, its models, methods, assumptions, and results, is described.

PROJECT BACKGROUND

The Puget Sound Council of Governments (PSCOG) and the Seattle Metro conducted a study of long-range transportation investment alternatives for a corridor north from the Seattle central business district (CBD) to suburban Snohomish County. This corridor had previously been selected as the highest priority for study among several radiating outward from the Seattle CBD to rapidly growing suburban areas. Staffs and consultants analyzed in detail several alternatives for this corridor, funded to date primarily by the Urban Mass Transit Administration (UMTA), and overseen by a committee of elected officials from local government jurisdictions.

Seattle is a medium-sized metropolitan area of about 2.4 million people that has been growing at moderate but uneven rates during the past two decades. It has a strong economy based in durable manufacturing (aerospace and others) and very rapidly expanding service sectors. The Seattle CBD has captured a significant portion of this service growth and has been experiencing an unprecedented boom in office development. However, access to the Seattle CBD is constrained by bodies of water, hills, and a large industrial area, and is mainly served by two bridges and a single north-south freeway corridor. Forecasts of the long-term future of the region and the CBD show continuing growth in jobs, particularly the types of jobs usually associated with office building uses. The region has been projected to gain about 500,000 additional jobs between 1983 and 2000, of which some 70 percent are to be in private nonmanufacturing, which includes mainly trade and services sectors. Jobs in the Seattle CBD are projected to increase by almost 50 percent, or 60,000, during the same period; virtually all of these jobs are to be in services sectors (10).

Meanwhile, forecasts show the greatest residential growth in the region occurring in northern King County and southwestern Snohomish County. Therefore, the need for the transportation alternatives study was derived from the concomitant projected increases in automobile work trips in the north corridor over the next 10 to 20 years, which, in the absence of any major transportation improvement projects for the corridor that could accommodate the increased traffic loads, will lead to sharp rises in peak-hour automobile and transit travel times and decreased accessibility of the CBD and other large Seattle job centers. The focus of the study was on transit development alternatives that could increase transit ridership sufficiently to reduce projected peak-hour automobile traffic in the corridor to within capacities of existing facilities. In the study, a number of alternatives were evaluated, ranging from a do-nothing, No-Build alternative, to the already programmed transportation system management (TSM) package of minor improvements, to a set of major investment alternatives involving advanced technology buses or a full light rail transit system for the corridor (both with a tunnel beneath downtown Seattle).

For purposes of this research, the wide variety of alternatives were grouped into three major distinct types: (a) No-Build, a no-major-investment alternative, which did, however, contain some costly additions and replacements while maintaining the existing bus system; (b) Advanced Technology Bus/Tunnel (ATBus/Tunnel), which included the downtown Seattle tunnel, a set of new technology buses, and a package of already programmed TSM improvements and other bus system expansions; and (c) an 18-mi Light Rail Transit (LRT) system for the north corridor to Snohomish County, including the Seattle tunnel, the TSM improvements, and the other bus expansions.

ECONOMIC IMPACT ANALYSIS

The standard approach to transit project economic impact analysis in recent applied literature consists of defining capital and operating costs, specifying those costs incurred within the region under study, and applying some relevant income and job multipliers to estimate total (direct plus indirect plus induced) impacts of expenditures, usually in comparison with some baseline alternative (No Build). Most major transit planning and evaluation work in recent years has followed this approach, with more or less care in defining regional expenditure shares, the multipliers to be used, the disaggregation of the affected industry or household sectors, and the fiscal implications for state and local governments. None of these has introduced local financing assumptions or experience as a prior input into the estimation of economic impacts.

The APTA demonstration report suggested methods for defining regional capital and operating expenditures and the use of RIMS II multipliers specific to the region under study (11), but assumed away the financing issue (1). The BART and Buffalo LRT studies made broad assumptions about regional expenditure shares and used their own regions' input-output model income and job multipliers. The BART study analyzed project financing impacts in detail, but did not introduce this into the economic impact analysis (12). The Baltimore north corridor impact study used multipliers assumed from a cross section of other region analyses (7).

In the sections that follow the empirical analysis carried out for the Seattle transit alternatives study is described, first for the regional economic impacts of project construction, and second for economic impacts of operations and maintenance costs. In each section, the cost data and their preparation are discussed, assumptions are described, the models used in analysis are introduced, and results of the empirical analysis are presented. In both cases, the analysis is conducted for the three alternatives defined previously.

Construction Expenditures

In this section the empirical analysis for the economic impact of the project construction phase is described. This analysis was assumed to begin in 1984 and was assumed to contain some expenditures in all years up to 2000, though the bulk of the investment would be completed by 1990. The objective of the analysis was to develop multipliers for the capital expenditures to be made in the metropolitan region, and thereby to estimate the total dollar and job impact of the construction phases of the various alternatives on the regional economy.

The actual capital cost estimates for each of the project's alternatives were developed and refined by the Seattle Metro staff and consultants (13). These were available for detailed expenditure categories within the three capital cost types: (a) major investment (vehicles, guideway, stations, propulsion, etc.); (b) transportation system management projects (high-occupany vehicle lanes and ramps, signals); and (c) other capital costs (buses, bases, park-and-ride lots on other components of the transit system). The latter two varied among the different alternatives because of the differential impacts of the alternative investments on the nature and performance of the balance of the transit system. Capital cost data for specific purposes within each of these types were available for each year from 1984 and 2000. These capital costs were in constant 1983 dollars and were intended to be inclusive of all capital costs for each alternative.

The most important adjustment that needed to be made was to estimate the proportion of each capital expenditure category that would be incurred within the metropolitan region. This determination was made by Metro engineering consultants on the basis of actual experience in other metropolitan regions. The results are given in Table 1. Obviously, the magnitudes of capital costs, particularly within the major investment category, vary tremendously across the various alternatives, ranging from zero major investment defined for the No-Build alternative, to very large costs for every detailed purpose for the ATBus/Tunnel and LRT alternatives (at least for the main construction years).

TABLE 1 Regional Allocation of Capital Cost Estimates

Cost Category	Local Labor (%)	Local Materials (%)	Non-Local Materials (%)
Major investment			
Site modifications	40	30	30
Guideway	60	40	0
Stations	40	50	10
Yards and shops	35	35	30
Trackwork	50	0	50
Power distribution	50	30	20
Communications	50	0	50
Fare collection	50	0	50
Train control	50	0	50
Vehicles	5	0	95
Engineering and management	100	0	0
Right of way[a]			
Other	60	40	0
Transportation system Management projects	50	30	20
Other capital costs			
Buses	5	0	95
Bases	35	40	25
Other	50	40	10

[a]Right-of-way costs not included in impact analysis.

The capital costs in each category as developed for the project were therefore modified by these percentages as an estimate of the actual capital expenditure that would be made in materials and labor within the metropolitan region. The regional capital costs, in constant 1983 dollars, were then summed for each year and transformed into constant 1972 dollars using a state and local government transit deflator.

These annual capital expenditures for each alternative were then entered into the PSCOG STEP83 regional econometric model as additional construction output for each year. The STEP83 model is a long-term forecasting and simulation model of the Glickman (14) type for the Seattle-Tacoma-Everett metropolitan area, developed and maintained by the PSCOG. It predicts output, jobs, income, and demographic variables, with considerable disaggregation, on an annual basis to the year 2000, and is described in more detail in a technical documentation report (15). The STEP83 model calculated the jobs (or job-years) supported by the direct regional construction expenditures, based on output-per-job projections in the model, and estimated the total output gain, and total job-years gain, from each alternative's expenditures, on an annual basis over the future period. Summed over the 1984-2000 period, the total output gain and the total job-years gain divided by the direct capital expenditures and the direct job-years, respectively, provide an estimate of the construction cost multipliers, which along with the total impacts estimates, were the items of primary interest in this part of the analysis.

The results of this impact analysis are given in Table 2. Direct expenditures are the expenditures for construction, labor, and materials that are expected to be made within the metropolitan region for each alternative. Direct jobs are defined as job-years, or one job (on average) for one year, and are based on labor productivity estimates and projections for construction projects. Total expenditures is the total dollar output, and includes the direct expenditure, plus indirect sales resulting from purchases of contractors from other firms in the region, plus induced sales resulting from the respending of labor income. The expenditure multipliers calculated over the 1984-2000 period in the STEP83 model are in the 2.0 to 2.1 range, or roughly two total dollars (constant) for each dollar of direct investment in the project. Similarly, total jobs (job-years) include the direct jobs, plus jobs due to the indirect sales, plus jobs due to the induced sales. The job multipliers from this analysis are in the range of 2.6 to 2.7 total job-years for each direct job (including the direct job).

TABLE 2 Regional Economic Impact of Capital Expenditures, No Local Share Assumption, 1984-2000

Alternative	Expenditures[a] Direct Regional ($)	Expenditures[a] Total Impact ($)	Jobs[b] Direct	Jobs[b] Total
No Build	159.4	326.8	1.9	5.1
Advance Technology Bus/Tunnel	554.2	1108.4	6.8	17.6
Light Rail System	980.1	1989.6	11.8	30.9

[a]Millions of 1983 dollars.
[b]Thousands of job-years.

All of these multipliers are dynamic multipliers derived from the STEP83 regional econometric model. The dynamic multipliers generally are somewhat higher than static input-output multipliers (16), the type estimated in most previous transit project studies. For the purpose of comparison, the same analysis was carried out on the capital costs using the Washington Projection and Simulation Model, a large state-level input-output econometric model (17). The same multipliers were calculated from the Washington Projection and Simulation Model (WPSM) and were considerably higher. The expenditure multipliers were in the 2.6 to 2.7 range, and the job multipliers were between 3.5 and 3.8. It should be noted that WPSM is estimated for the entire state of Washington, not just the central Puget Sound region (which contains about 60 percent of the state's economic activity) as for STEP83, and possesses a more completely specified government sector, both of which characteristics would tend to produce higher multipliers.

But the analysis described to this point is only the first step. The total impacts and multipliers in Table 2 are based on the assumption that all of the capital costs to be expended within the region during these years would be new funds granted from outside. That is clearly not the case with the alternatives being analyzed here. Even under favorable assumptions, no more than about one-half of the total project costs would be covered by federal grants. The balance would have to be financed more or less locally, through the use of the transit sales tax or the issuance of debt. In general, capital costs funded through local taxes (including costs for debt service) would have negative as well as positive economic impacts because personal income would have to be drawn to pay the local share.

Therefore, the capital costs economic impacts were analyzed again with some assumptions concerning the financing arrangements for each of the alternatives. For the No-Build alternative, it was assumed that no federal grants would be available for the stream of capital costs projected for that alternative. This is not altogether realistic because there have been substantial grants for the purchase of buses, a major capital cost for future years in that alternative, but it serves as a useful benchmark for the analysis. For the Advanced Technology Bus/Tunnel and Light Rail Transit alternatives, it was assumed that 50 percent of the total capital costs would be covered by federal grants, and that the balance would have to be raised locally. This assumption was applied to the capital costs for each year, even though the federal grants might or might not be made in the amounts of each year's capital costs (the same would be true of local debt service payments compared with each year's capital expenditures). In addition, it was assumed that the capital expenditures for materials within the region would generate some tax revenue, amounting to 8 percent on an assumed 50 percent for materials.

The income removed from the regional economy to finance the local shares of the project alternatives would be expected to lower by a considerable amount the positive economic impacts of capital expenditures that were presented earlier in this section. In general, this income "lost," or leaked, from the economy represents opportunity costs of funding this construction instead of regional consumption and investment. (This is in addition to the considerable leakage of regional personal income for non-project-related imports into the region, which is accounted for under both sets of assumptions.) Some of the income actually is lost, as the tax money pays for vehicles and other equipment manufactured outside the region. The effects of including this lost income in the analysis are given in Table 3.

The No-Build alternative, which was assumed to be financed entirely from local sources, is now projected to have a negative impact of almost $600 million and 16,300 job-years, mostly because the preponderance of capital costs is for buses, which are essentially imported into the region. The ATBus/Tunnel alternative shows a total economic impact of less than the direct regional investment, though still positive. The lost income financing out-of-region purchases offsets the indirect and induced effects of the actual transit capital expenditures in the region. Only the LRT alternative has total dollar impacts greater than the direct regional investment, though greatly reduced by the local share financing.

As shown in Table 3, the total investment even in the No-Build alternative is substantial, but only a small portion of the investment is incurred locally. Overall, some 35.2 percent of the No-Build expenditures are to be made within the region, versus 56.6 percent of the ATBus/Tunnel, and 67.0 percent of the LRT investment. That part of the overall expenditure that is funded regionally but spent elsewhere is an opportunity cost that has a multiplier effect as foregone regional output. This effect is strongest for the No-Build alternative, but is significant in all three.

As demonstrated by the results given in Table 3, the negative economic impact of removing income from the regional economy to finance capital costs incurred out of region is very strong, and largely offsets the positive stimulus of the capital expenditures within the region. In many cases the greatest economic impact is gained from putting (or leaving) money in consumers' pockets rather than in public investment projects. It is important to note, however, that these results were obtained with one set of crude and generalized assumptions about financing the project alternatives. The economic impacts of the construction expenditures in the region appear to be very sensitive to the particular financing assumptions used in the analysis.

Operations and Maintenance Costs

Estimating the comparative impacts of the operations and maintenance expenditures for each alternative over the future period presented a somewhat different problem. Estimates of the projected costs for each alternative were available from the Seattle Metro staff and consultants. But because of efficiencies gained through the greater capitalization of the so-called major investment alternatives (the advanced technology bus/tunnel and the light rail system), their operations and maintenance costs were to be somewhat lower than for the No-Build alternatives, though not by much. The total annual operations and maintenance costs in the year 2000 are estimated to range from $67.1 million for the No-Build alternative to $64.6 million for the ATBus/Tunnel alternative to $63.9 million for the full LRT system alter-

TABLE 3 Regional Economic Impact of Capital Expenditures with 100-50-50 Local Share Assumption, 1984-2000

	Expenditures[a]			Jobs[b]	
Alternative	Everywhere ($)	Within Region ($)	Total Impact ($)	Direct	Total
No Build	452.7	159.4	583.9	1.9	-16.3
Advance Technology Bus/Tunnel	979.7	554.2	397.2	6.8	-0.4
Light Rail System	1462.2	980.1	996.6	11.8	6.3

[a]Millions of 1983 dollars.
[b]Thousands of job-years within region.

native. Consequently, the economic impacts derived from a typical analysis are likely to be (a) very small and (b) negatively related to the size of the capital expenditures.

But, as with the capital cost analysis, there is a revenue side as well. In the absence of federal or state operating subsidies, the public transit costs for operations and maintenance are funded from the fare box and the transit shares of the local sales tax and the state motor vehicle excise tax. Lower costs, coupled with the higher levels of ridership on the more heavily capitalized transit alternatives, would tend to lower the transit operating deficit, which is largely financed from the taxes. Consequently, lower operating costs could be assumed to return to regional residents as higher disposable income. Much of this income would go into regional consumption and investment, the effects of which would offset at least some of the loss in incomes and sales resulting from lower transit expenditures and jobs. The question then is whether any differences among the project alternatives would remain.

Because the differences among the alternatives even in total annual operations and maintenance expenditures was not great to begin with, it was expected that the offsetting effect described earlier would all but negate any economic impact. Nevertheless, simulation analysis was attempted, this time using the WPSM. The advantage of using this state-level model was that it contains fully developed final demand sectors, including explicit consumption functions and local government expenditure equations.

The results were as expected. Using the No-Build alternative as a baseline case, the decrease in transit expenditures from alternative to alternative for any given year between 1990 and 2000 was almost entirely offset by the corresponding increase in disposable personal income. The total output impact averaged about $1 million (1972) lower, and the total job impact averaged about 300 jobs per year lower, between the No-Build and the LRT alternatives. The effect of the lower transit expenditures is slightly greater than that of the higher disposable income because a portion of the former is used for purchases of materials locally, which eventually multiplies into more total personal income available for consumption and saving.

The analysis of the impact of the operations and maintenance expenditures is less subject to the assumptions applied than was the capital cost analysis. Without federal transit operating subsidies, the entire expenditure amount for each alternative can safely be assumed to be funded from local sources. The results summarized earlier, therefore, strongly indicate that the differences among the alternatives in the impacts of operations and maintenance costs are minimal and are of little consequence for decision making.

DEVELOPMENT IMPACT ANALYSIS

For purposes of this paper, development impacts of transit investment projects are macro-level, intra-regional location shifts by households and businesses (in the aggregate) induced by the introduction of the transit facility. This definition then excludes station-area development effects and micro-behavioral changes.

There is no apparent standard approach to development impact analysis in transit project studies. Some planning studies have used qualitative assessment only, others have applied various types of urban activity models for quantitative analysis. Ex-post studies have included attitude surveys, evaluation of new development activity, and land price analysis. Urban activity models have never been applied on a widespread basis for transit impact assessment, perhaps because relatively few have been conveniently calibrated and available for use, perhaps because of suspicion concerning their nature and worth, and perhaps because the results from utilizing them have not been very striking. Models have been applied to analyze development impacts of Bay Area Rapid Transit (BART) (18) and of the Buffalo LRT (19).

Findings on development impacts of transit investment projects have been mixed at best, regardless of method. A summary of earlier studies throughout North America and Europe indicated that major transit investments did tend to stimulate CBD development, but not necessarily under conditions of overall urban economic decline or disinvestment, and mostly when coordinated with other public investment (20). The study also found that major transit projects had induced some development shifts beyond the CBD, but usually in cases where favorable local economic and public policy conditions existed. Development impact studies on BART have consistently found few shifts either between suburban and CBD office centers or among household areas, although the existence of BART was frequently cited by households in survey responses (21). Similar findings were obtained for the Lindenwold transit line in Philadelphia (5). On the other hand, ex-post studies of the Washington Metro have indicated residential development shifts, particularly in the vicinity of stations, because of the transit line, but this effect could be mostly a relocation of new development within suburban subareas rather than significant intra-regional shifts (22). In any event, little evidence has been produced to date that strongly endorses the objectives of transit investment as effective land use policy, other than in supporting the vitality of the CBD.

Empirical Analysis

In this section the application of an urban activity model system for analysis of development impact questions related to the Seattle transit investment alternatives study is described. The PSCOG maintains a set of urban activity models (DRAM/EMPAL) that are used for forecasting population, households, and employment in zones throughout the metropolitan area, and for simulation analysis on transportation and land use issues. The DRAM and EMPAL models, which in various forms have been described elsewhere (23), have been significantly restructured by the PSCOG (24), but retain essentially the same transportation core. The models contain, among other data, zone-to-zone travel times (as impedances) that are calibrated as accessibility variables for each household type and job sector in the models. Changes in accessibility can be simulated for their impacts on the locations of households and jobs in any and all zones.

Travel forecasts had been prepared for each alternative under analysis in the study, using previously adopted (May 1982) PSCOG forecasts of households and jobs by zone. These forecasts had been made through the conventional set of transportation models. From the travel forecasts could be derived estimates of peak-hour, zone-to-zone travel times for both the transit vehicles under the various alternatives and for the highways with various degrees of congestion alleviated by the transit development, along with estimates of the work-trip mode splits for each alternative. These travel times associated with each alternative were then used to make adjustments in the baseline travel times in the DRAM and EMPAL models in order to approximate the changes in overall accessibility that would be introduced by each alternative. The models could then make estimates of the household and job locational distribution that each level of accessibility would support, given adjustments for aggregate mode choice. Differences in distributions among the various alternatives could then be quantified and some conclusions about their economic and fiscal impacts could be drawn.

As discussed earlier, three types of alternatives were evaluated for such impacts: (a) No-Build, (b) ATBus/Tunnel, and (c) full LRT system. The ATBus/Tunnel alternative, as considered here, is kind of a hybrid investment, consisting of the Seattle CBD tunnel, some newer technology buses, and the TSM improvement projects. A major problem in this intraregional location analysis was that the tunnel, once constructed, is to serve buses (and thus work trips) not only from the north corridor under analysis, but also from the east and south of Seattle, and all to important advantage. On the other hand, the LRT alternative under analysis, would serve only the north corridor, and thus would potentially influence the locations of only a fraction of households from all three corridors to be affected by the ATBus/Tunnel alternative. The analysis, as a consequence, could not be expected to show as great an impact for the LRT alternative as if it were to be developed in all corridors served by the tunnel. It should also be noted that the travel forecasts for the LRT alternative probably understate the demand because of an inability to include intangible variables, which from experience elsewhere, are believed to influence rail ridership.

The point of time at which the location impact analysis was to be made was the year 2000. Obviously, there will be more households and jobs in the north corridor (and elsewhere) in the year 2000 than there are currently, but the question was one of differences due to different types of transit systems in place and operating at that time. Certain expectations on location impacts of the transit alternatives could be identified from urban economic theory. These are discussed next for various subareas of the region.

Expected Impacts

Improved accessibility from city and suburban areas, especially for peak-hour work trips, should benefit the Seattle CBD job levels (and other economic and development activity). Because of projected growth in the region, the CBD is likely to reach effective limits on the number of vehicles that can access and move about it, regardless of highway and parking improvements, due to high levels of congestion and parking costs. Under the No-Build alternative scenario of no major investment in transit development, the growth in the CBD's economic activities--the destinations of vehicular trips--would likely taper off, and employment expansion would occur elsewhere in the region. Under the investment alternatives, transit improvements are implemented that make access to and mobility within the CBD better and quicker and allow higher capacity. The effect over the long run would be to permit more growth in CBD economic activities than otherwise would be the case. Similar reasoning would also apply to the activity areas adjacent to the CBD, which also are subject to extreme congestion and are within walking distance of the CBD.

The balance of the north corridor, including southwestern Snohomish County, contains most of the corridor population and a substantial amount of economic activity, much of it concentrated in several major activity centers. Except for the fringes of southwestern Snohomish County, this corridor is virtually fully developed already and protected by zoning so that population and households, and their high transit ridership, will probably not change much in the long-term future under any transportation alternative scenario, including the No-Build alternative. Conversely, in the rapidly growing Snohomish County fringes, considerable growth in population and households, with low transit ridership, is virtually certain, regardless of the magnitude of transit investments in the north corridor.

As for job locations, growth in economic activity in all parts of the north corridor would be supported by the transit investment alternatives, though not necessarily in competition with the Seattle CBD. In other words, all of the corridor, city and suburbs, might benefit from increased accessibility to job locations within it.

Other parts of the region would also be affected. Suburban Eastside King County is more directly competitive with Seattle CBD jobs, and it would stand to grow more if the Seattle CBD grew less as a result of the No-Build alternative. Households, on the other hand, would have better accessibility to Seattle CBD jobs under the ATBus/Tunnel alternative, and thus the number of households could be higher even with more Seattle jobs. For these other subareas, therefore, the expectations are more ambiguous.

The location impacts of the various alternatives were analyzed by adjusting the zone-to-zone travel times within the DRAM and EMPAL models to approximate the accessibility effects of the transit alternatives over a 1990 to 2000-period simulation. The magnitudes of the adjustments were around 5 min less for the ATBus/Tunnel than the No-Build (out of about 40 min peak-hour time from Snohomish County to the Seattle CBD), but only about 1 to 2 min were saved by the LRT system compared with the ATBus/Tunnel (which uses freeway express and HOV lanes). Also, the ATBus/Tunnel time adjustments were made in all three major corridors, whereas the LRT applied only to the north corridor.

Results

A summary of the results of this analysis is given in Table 4, which shows the job and household differences for the ATBus/Tunnel and LRT alternatives compared with the year 2000 No-Build alternative as a baseline condition. The overall projected change in jobs and households for 1990 to 2000 for the various geographic subareas is also given. In general, the results tend to conform to the expectations outlined previously. The magnitudes of the job and household differences among the alternatives are relatively small and are much greater between the ATBus/Tunnel and the No-Build alternatives than between the LRT and the ATBus/Tunnel alternatives. The only significant impacts are on the Seattle CBD and adjacent Central Seattle. Everywhere else, the locational impacts of the project alternatives are 2 percent or less of the projected 1990 to 2000 growth. First, for the location of jobs in the region,

1. The impact on job locations does appear to be significant in the Seattle CBD, at least for the ATBus/Tunnel. Almost 3,000 jobs, or close to 10 percent of the projected growth, would be added to the CBD by the full implementation of this alternative (other factors remaining the same). But, no further net addition of jobs would be associated with the rather small improvements in accessibility that the LRT system would supply on top of this bus/tunnel system. Although the Seattle CBD is the primary

TABLE 4 Location Impacts of Transportation Investments, Year 2000

	Total Change 1990-2000 (No-Build)	Impact No-Build	Compared with ATBus/Tunnel	No-Build LRT System
Total Jobs				
King County	+194,500	0	+1,700	+1,850
Seattle	+69,800	0	+3,900	+4,300
Seattle CBD	+31,600	0	+2,900	+2,900
Central Seattle	+8,800	0	+850	+800
North Seattle	+15,900	0	0	+400
Eastside	+55,600	0	-900	-1,000
Other King	+69,100	0	-1,250	-1,450
Snohomish County	+38,100	0	-650	-750
Pierce County	+50,100	0	-750	-750
Total Households				
King County	+151,500	0	+900	+1,100
Seattle	+13,600	0	+1,600	+1,900
Seattle CBD	+1,300	0	+300	+300
Central Seattle	+1,600	0	+1,100	+1,100
North Seattle	+8,000	0	+200	+550
Eastside	+58,000	0	-250	-300
Other King	+79,900	0	-450	-500
Snohomish County	+51,900	0	-300	-350
Pierce County	+53,400	0	-500	-550

destination beneficiary of both investment alternatives, the additional accessibility resulting from the LRT system is concentrated in one corridor only, and the LRT occupies the downtown tunnel to the exclusion of buses from the other corridors. The positive and negative effects appear to offset one another for the CBD.

2. The Central Seattle zones also show a significant increase in jobs from the ATBus/Tunnel alternative, also around 10 percent of the projected growth. Closer examination indicates that all of this job impact occurs in the activity centers that are directly adjacent to the defined Seattle CBD. This impact thus can be construed as a spillover effect resulting from increased Seattle CBD accessibility, which once again shows no additional improvement (actually slight decrease) due to the LRT alternative.

3. As for the job impact on other subareas, the balance of Seattle, the rest of King County, and the adjacent counties of Snohomish and Pierce all have a zero or slightly negative impact (all less than 2 percent of the 1990 to 2000 growth projection) on job locations due to the ATBus/Tunnel alternative. When the LRT system is added, North Seattle turns slightly positive, as expected from the concentration of investment in the north corridor, and the other King, Snohomish, and Pierce areas are slightly more negative. It might be noted that most of the job location shifts indicated in this analysis are in retail trade and services sectors, which are the most sensitive sectors to household accessibility and concentrations of employment activity.

On the residential side, the results of the analysis are somewhat more mixed:

1. Only the Seattle CBD and Central Seattle areas show significant impacts of the investment alternatives when compared with the projected 1990 to 2000 growth magnitudes. The very large change in Central Seattle, which is entirely in the zones adjacent to the CBD, can be explained first by the spillover effect from the CBD, and second by the high accessibility of these zones to the now increased number of jobs in the CBD and Central Seattle (as a result of the project alternatives). The household change is concentrated in low-income households, which are particularly sensitive to job accessibility (retail and services sector growth in the CBD) and to multifamily housing concentrations near the CBD. Once again, the LRT alternative has almost no additional impact on households, largely because it leads to no extra jobs in the CBD or adjacent areas.

2. In other areas of the region, the residential location impacts of the investment alternatives are minimal. Suburban Eastside King County, the remainder of King County, and Snohomish County all show slightly negative impacts of the ATBus/Tunnel and the LRT, despite the expectation that increased accessibility to Seattle CBD jobs could cause some dispersal of households to those areas. Any such effect, however, is minimized by the factor observed earlier that Seattle residential areas are fully developed and will change only slightly no matter what, and that suburban areas will grow fast in any event (and have low transit ridership). In addition, those suburban areas show a decrease in jobs as a result of the ATBus/Tunnel and LRT alternatives, a change that has a negative influence to offset the increased accessibility to more distant job centers.

3. Finally, once again, the North Seattle zones are positively affected by the LRT system alternative, relative to the ATBus/Tunnel, because of the concentration of facility investment in that corridor under that alternative.

The foregoing results should be viewed as somewhat tentative and preliminary. The impact magnitudes were in most cases very small, which may be a statement about the true effects of small savings in transit travel times, but it could also be reflecting deficiencies in the urban activity modeling system and data. The travel impedances applied to this analysis are based on solid projections from the alternatives project, but are nonetheless somewhat artificial and arbitrary because they lack real transit and highway cost components. As noted earlier, the ATBus/Tunnel and LRT alternatives are not exactly comparable, and some important intangibles regarding the transit alternatives are not included. And the DRAM and EMPAL models may not be accurately measuring true shifts that would occur as a result of the transit investment alternatives. Despite numerous tests of transportation facility impacts on households and jobs using DRAM and EMPAL (25), Boyce (5) has argued that no currently operational activity model can pick up the rather subtle effects on households and firms that occur as accessibility and land prices change. (It should be noted, however, that other recent PSCOG applications of DRAM and

EMPAL for transportation accessibility or cost impact analysis have demonstrated the models to be sensitive to relatively modest input changes.) Finally, the development impact results were not iterated with the transportation models to find an equilibrium household-job and work-trip distribution. However, with the rather small impacts found, this step might not add much insight.

But, on the other hand, it may be a true finding that the job and household location impacts of transit facility investments are not very great, even for CBD areas. Congestion effects under the No-Build alternative may not be great enough to induce much change in the transit mode choice. Accessibility from the developing suburbs under the transit investment alternatives changes little--less than 10 percent--from the current levels (though somewhat more from the year 2000 No-Build). In other words, transit investments are essentially maintaining a constant level of accessibility to the Seattle CBD over time, while the No-Build scenario permits it to deteriorate somewhat. The largest gains in accessibility under the transit investment alternatives are from fully developed residential areas to the CBD and from all areas to the University District, which is projected to show little growth in jobs. Relatively small improvements in work trip times, introduced into rather small progressive deteriorations in accessibility over the years, may not in themselves be sufficient to induce significant shifts in households and jobs.

CONCLUSIONS

In the preceding sections of this paper the results of three almost separate pieces of research on impacts of transit investment alternatives on the economy and locational structure of the central Puget Sound region have been reported. The primary objective of this research was to use available economic and location models to assess in a quantitative manner the impacts of the various alternatives. The models and the techniques of analysis are not yet perfectly developed or adapted for this purpose, but their use in this research was intended to further this development. The PSCOG and Metro are embarking on additional study of the transit alternatives, this time covering the north, east, and south corridors together, and this economic impact research will serve as a point of departure for analyzing these wider impacts.

Regional econometric and urban activity models have been in widespread use for forecasting purposes, and for some simulation applications, but have not received frequent application in transit investment analysis studies. The research reported here concludes rather optimistically on the potential for use of these types of models as part of the planning process. Economic impact analysis can benefit from regional econometric models if they are developed with fiscal components and are used along with the project financial planning. In other words, economic impact and project financing should be considered inseparable. Intra-regional development impacts appear to be amenable to analysis with urban activity models, even when not fully integrated with transportation planning models. There may be limitations to the types of location shifts that can be measured by these models, but only through such models can the masses of data and complexity of relationships be organized sufficiently to assess development impacts at all in an ex-ante situation.

If anything, this research suggests an agenda for applied research in analysis with operational models. Regional econometric and urban activity models can be useful additions to transportation investment project analysis, but only if applied in conjunction with other planning analysis and with assumptions consistent with other project components. Further development or adaptation of models could be along the lines of (a) inclusion of explicit fiscal components, both at the regional and local levels; (b) integration of financial planning and economic impact analytic models, so that economic impacts could be reflected in financing plans, and financing alternatives could be directly evaluated for economic impact; and (c) integration of urban activity and transportation models, especially mode split and assignment models with fully consolidated highway and transit networks or composite cost impedances. Most important, this type of research needs to be carried out in project planning settings, where operational and result imperatives require pragmatic adaptations and developments to existing analytic tools.

The actual results obtained here must be viewed with some caution, particularly because of the rather arbitrary assumptions applied, for example, to the local share funding in the construction impacts. The results indicate that the economic impact of various alternatives is very sensitive to such assumptions, so that before finalized impact estimates are made these assumptions should be much more closely specified according to project financial analysis. Similarly, the transit travel times for the various alternatives in the location analysis should be more carefully developed and adapted for input into the activity models, which could affect the locational impact results obtained.

But the results described appear in general to be reasonable, given the assumptions and inputs, which offers encouragement on this type of quantitative impact analysis. These tentative results also shed some interesting light on the nature of economic impacts of the transit development projects. The usual capital cost multiplier analysis and its total economic impacts was shown to be extremely sensitive to the local share funding assumption, whatever that might be. Negative regional economic impacts of transit investment are entirely possible. The best economic impact may be gained from putting money in consumers' pockets, not in public investment. The operations and maintenance cost efficiencies from the transit investment alternatives have negative economic impacts that are just about offset by the increased disposable income thereby available to regional residents. And, finally, the effects of transit development on job and household locations within the region may be rather weak, with the possible exception of downtown and central Seattle, despite the widespread belief in its long-term benefits (fiscal and otherwise) for the city.

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