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Estimating Economic and Development Impacts of Transit Investments

W. T. WATTERSON

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

	Local		
Cost Category	Labor (%)	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

	Expenditures[a]		Jobs[b]	
Alternative	Direct Regional ($)	Total Impact ($)	Direct	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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Highway Investment as a Regional Development Policy Tool

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ABSTRACT

A technique was developed to estimate the regional development effects of highway investment. The study area was the Province of New Brunswick, Canada. A weak relationship between highway investment and regional development was found to exist. The results indicate that the hypothesis of saturation and shift may be occurring. As it becomes saturated, the highway network exhibits less of a developmental effect and begins to act as an agent to increase personal mobility. The results of the models indicated that highway investment was related to increased mobility in one of the five test regions. No relationship was evident in the other four economic regions in the study area. The analysis also indicated that highway development in New Brunswick progresses through three phases. In the first phase the highway network is not developed to a level at which it is capable of encouraging regional development. In the second phase the network acts as an agent for regional development, whereas in the third phase it becomes an agent for personal mobility.

It is generally believed that in order to reduce regional disparities, government action is required. In 1957 the Gordon Commission on Canada's Economic Prospects indicated that an improved highway network would encourage regional development. This argument has been prevalent in the justification of most, if not all, of the future federal-provincial agreements that provide federal funds to assist regional highway improvements in Canada.

In recent years, the validity of this argument has come under question. It has been suggested that the construction of highway infrastructure does little to encourage regional development.

The hypothesis that a transport system can be saturated to the point where there are diminishing benefits to a regional environment was outlined by Meier (1). In general form the hypothesis states that

> The incidence of the transport system on the socio-economic development of regional environments is becoming increasingly saturated at the present time and is shifting to other civilisatory and cultural aspects.

The hypothesis was examined in Western European industrialized nations in a comparison of the nations' own history and a simultaneous comparison with countries in Europe and the Third World that have a lesser developed economic structure. Meier (1) concluded that evidence from Switzerland suggests that the hypothesis is correct; in Switzerland, transport systems were switching from a development asset to a mobility asset.

Historically, it has been assumed that highways have an interregional effect. They serve as a means of transporting people to other regions. This function is giving way to more local influences, providing better access within the region.

The level of effects is also changing. In the past, highways have had effects on the whole society. The hypothesis suggests that the effects of highways are changing so that it is the individual who is benefiting from highway construction. Thus transport facilities are losing their importance as a development tool. However, they are increasing in importance as an agent of personal mobility.

RESEARCH METHODS

In order to test the hypothesis of saturation and shift from development functions, a model was developed to identify the variance in a region's economy, which can be explained by investment in the region's highways. The model also estimates the magnitude of the effect of highway investment.

For the purpose of this research, the basic observation unit is the economic region. Following World War II, Canada was divided into a series of 68 economic regions. These regions were subprovincial units with similar characteristics that could be used for estimating the impact of changing economic conditions.

The study area, the Province of New Brunswick, Canada, was divided into five economic regions, with the boundaries falling on county lines. Each region is identified by the major city in the region; namely, Saint John, Moncton, Fredericton, Edmundston, and Bathurst. Although most of the socioeconomic and highway data are recorded as a provincial total, some of the socioeconomic data and all of the highway data can be disaggregated to the regional level. These disaggregated data will be used in the analysis.

The model takes the form: $Y_t = a + bX_t + r$

where Y_t is the economic indicator that measures the performance of a region's economy at time t, X_t is the highway development variable that is a measure of the investment in a region's highways, and r is the residual.

In this model, b represents the magnitude of the effect highway investment has on the economic indicator. To accurately estimate the effects of highway investment, the proper lag period between investment and economic development should be used when entering the highway development variable into the model.

In this study the correct lag period will be determined by altering the model to include a range of lags.

A review of previous research on highway impact analysis revealed that employment within a region is primarily used as the indicator of regional development. For this research the use of employment as the dependent variable is not possible. Neither the employment by industrial classification nor the total employment is available at the New Brunswick regional level throughout the study period.

As a proxy for total regional employment, the per capita income from wages, salaries, and commissions will be used to indicate regional development. Statistics Canada's all-item consumer price index for Saint John was used to deflate the per capita wages, salaries, and commissions into 1971 dollars.

Because highway investment is a regional factor, only that part of the dependent variable that is affected by regional factors should be entered into the model. Shift-share analysis was used to divide the change in socioeconomic activity into two components (2). The aggregate growth component measures the change in a region's socioeconomic activity as the rate of change in the analysis area (the province in this research).

The second component, the competitive component, is actually a measure of the economic activity of a region based on changes particular to that region. If the region grows at the same rate as the province, the region's competitive component will be zero.

The highway development variable will be represented by monetary expenditure on highways that will provide many benefits not realized in other methods such as the use of dummy variables (3) or accessibility measures (4). The history of highway development in New Brunswick is characterized by continuous improvements to the existing infrastructure. Unlike other variables, expenditure on highway construction has the ability to determine the magnitude of these continuous improvements. The New Brunswick Highway Construction Cost Index was used to eliminate the effects of inflation.

HIGHWAY INVESTMENT IN NEW BRUNSWICK

The total expenditure on highway construction in New Brunswick appears to be directly related to the amount of funding available from the government of Canada. Areas designated by federal assistance programs received a relatively high proportion of the construction, whereas capital construction in other areas did not increase as rapidly.

Since 1951 the Province of New Brunswick has entered into 23 federal cost-sharing agreements under 8 programs. The programs under which these agreements operated are as follows:

1. Trans-Canada highway agreements,
2. Roads to resources programs,
3. Atlantic Development Board (ADB) agreements,
4. Northeast New Brunswick federal-provincial rural development agreements,
5. Department of Regional Economic Expansion (DREE) special areas and highways agreements,
6. Community Improvement Corporation (CIC) agreements,
7. Department of Regional Economic Expansion General Development Agreements (GDA), and
8. Canada-New Brunswick Highway Strengthening/ Improvement (MOT) agreement.

The time frame of each of these agreements is shown in Figure 1.

The fiscal year 1951-1952 was selected as the first year of the study mainly because the construction of the Trans-Canada Highway through New Brunswick was beginning at that time.

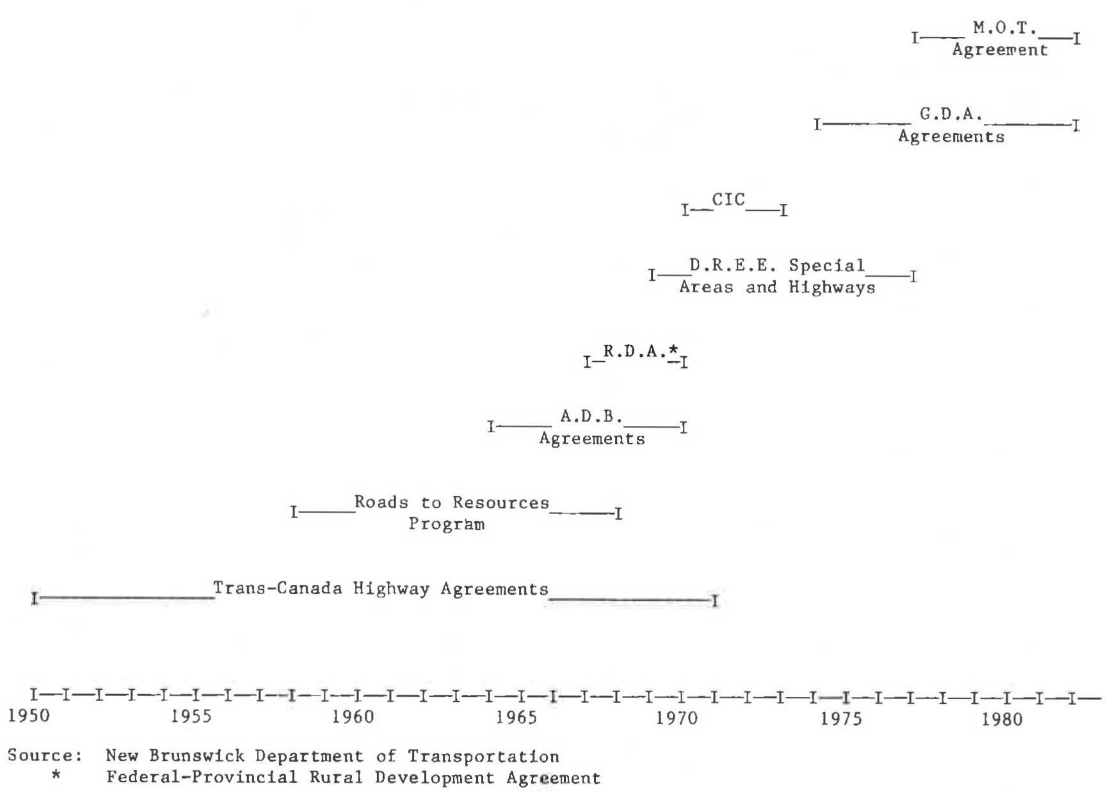

FIGURE 1 Federal cost sharing programs.

DATA ANALYSIS

The magnitude of highway investment for each year of the 31-year study period (1951-1982) was available for each region. The magnitude of the per capita wages, salaries, and commissions was not available for the entire study period. In 1957 the Department of National Revenue changed its publishing format to include more statistics. Before 1957, the value of per capita earnings is not published at the regional level. Because of a delay in the publishing process, the 1980 calendar year is the most recent year for which statistics are available. Thus a value for per capita wages, salaries, and commissions can only be determined for 24 years.

With 23 years of economic data (1 year is lost in the shift-share analysis) and 31 years of highway investment, the maximum number of observations possible in the time series is 23.

The data in Table 1 present the calibrated regional development models. In these models the competitive component of the share of per capita earnings is denoted [SWS]. HILAG4 is the magnitude of highway investment 4 years before the increase in earnings, in constant 1971 dollars.

TABLE 1 Regional Development Models

Regional Model	n	F-value of model	t-value of Regression Coefficient	r^2
Fredericton				
SWS = -50.8 + 14.1 (HILAG4 ÷ 10^6)	21	6.03	2.45	0.24
Moncton				
No significant model				
Saint John				
SWS = -24.8 + 8.9 (HILAG4 ÷ 10^6)	21	5.02	2.24	0.21
Edmundston				
No significant model				
Bathurst				
No significant model				

As outlined in Table 1, models were developed for only two economic regions: Fredericton and Saint John. No significant model was developed for the Moncton, Edmundston, or Bathurst regions.

The model developed for the Fredericton region indicates that an investment in highway construction has a positive effect on the regional economy 4 years later. The magnitude of this effect is that for every $1 million invested in Fredericton's highway network, there is an increase of $14.1 in Fredericton's share of per capita earnings. Thus as highway investment increases in the Fredericton region, the earnings of the region will rise relative to the provincial average.

The model also indicates the influence of factors other than highway construction. If no money was invested in highways, the residents of the Fredericton region would incur a relative loss in earnings of $50.8 per person. Thus $3.6 million of investment are required to maintain the provincial average rate of increase of earnings.

The results in the Saint John region are similar in concept but are different in magnitude. In Saint John, as in Fredericton, an investment in highways has an effect on the region's earnings 4 years later. For every $1 million invested in highway construction in Saint John, there is a relative increase of $8.9 in per capita earnings. Due to the influence of other factors, an investment of $2.8 million is required to maintain the provincial average rate of increase of earnings.

These numbers should not be accepted as exact figures, but should be considered approximations. If more explanatory variables were available to be included in the model, the estimated magnitude of the effects of highway investment would change.

No significant models would be developed for three regions. This may be the result of two possibilities. One possibility is that highway investment has no significant effect on the economic development of the regions. However, because the investment in highways has a significant effect on the economic development of two regions, this possibility does not appear valid. The second possibility is that highway investment does have a significant effect on highway development but this effect is not noticeable because of the absence of other explanatory variables. This possibility also appears to be invalid because of the ability to develop models in two regions. This may indicate that the function of highways is changing within the study period. In the early portion of the study period, highways may have had a substantial effect on regional development. If the saturation point is reached in the latter portion of the study period, the overall development effect of highways would be diluted.

SAINT JOHN REGION

Throughout the 1950s the magnitude of highway investment in the Saint John region remained relatively small. In 1964 a major increase in construction occurred. The construction of the region's major arterial highway from St. Stephen to Sussex resulted in a substantial investment within the region until its completion in 1972.

Subsequent to 1972, the magnitude of the investment in regional highways declined while a major portion of the total investment financed the construction of the Saint John throughway. It could be argued that an investment in the construction of the Saint John throughway, which would serve primarily to increase the ease of traveling through the city of Saint John, would have a smaller development effect than an investment in the construction of a regional highway. It would thus appear that after 1972 there was a decline in the construction of regional highways.

If this decline in the investment in highway construction was due to the approximate completion of the highway network it could be assumed that the saturation point had been reached. To test whether the Saint John regional highway network became saturated in 1972, two models were used. The models were the same as those developed in the previous section except for the time frame. One model was developed using the investment in highway construction before 1972 as the independent variable, and the second model was developed using the investment in highway construction subsequent to 1972 as the independent variable.

The dependent variable for each of the models was Saint John's share of the total per capita wages, salaries, and commissions 4 years after the highway investment was made. If the coefficient representing the magnitude of the development effects of highway investment from the pre-1972 model is statistically greater than that of the all-year model, and if the the same coefficient for the post-1972 model is statistically lower than that of the all-year model, it could be concluded that the regional highway network became saturated in 1972. Therefore, subsequent to 1972, highway investment had smaller developmental effects and the secondary function of highways was changing. If the coefficients were not statistically different it would be concluded that the saturation point of the highway infrastructure had not yet been reached and that investment in highway construction continues to provide a developmental function.

A summary of the three models is given in Table 2. In these models SWS represents the competitive component of the Saint John region's share of per capita earnings. All three models are statistically significant at a 10 percent level of significance.

TABLE 2 Model Development for the Saint John Region

Model	n	F-value of Model	t-value of Regression Coefficient	r^2
All-year				
SWS = -24.8 + 8.9 (HILAG4 ÷ 10^6)	21	5.02	2.24	0.21
Pre-1972				
SWS = -26.2 + 8.3 (HILAG4 ÷ 10^6)	17	3.31	1.82	0.18
Post-1972				
SWS = -15.0 + 9.8 (HILAG4 ÷ 10^6)	4	9.04	3.01	0.82

A Student's t-test indicated that at a 10 percent level of significance there is no significant difference between the change in the level of economic activity caused by events other than highway investment (the "a" coefficients in the models) in each of the three models. The t-test also revealed that there is no significant difference between the magnitude of the development effect of highway investment. The point of saturation of the highway network had therefore not been reached within the study period, and highway investment continued to play a small developmental role.

FREDERICTON REGION

In the Fredericton region, the increase in highway construction in the late 1950s was due to the construction of the early portion of the Trans-Canada Highway. The increase in construction in the late 1960s resulted in the virtual completion of the Fredericton portion of the Trans-Canada Highway. The increase in construction at that time was a result of the federal contribution of 90 percent of the construction costs.

Following the 1968 fiscal year there was a noticeable decrease in the money invested in the construction of highway infrastructure in the Fredericton region. Although the trend in construction subsequent to 1968 appeared to be generally increasing, this may not have been a result of the need for the investment. In every provincial election year since 1970 the investment in the construction of highways increased dramatically. This suggests that the highway network may have become saturated in 1968, and the general increases in investment subsequent to that point were due to political rather than transport or development reasons.

To test whether the saturation point was reached in the Fredericton region in 1968, two models were developed. One model examined the effects of highway investment on economic development before 1968, and the second model examined the relationship after 1968. If the effects of highway investment after 1968 are significantly lower than the effects when considering all years, it could be concluded that the Fredericton highway network became saturated in 1968.

A summary of the three models is given in Table 3. In these models SWS denotes the component of the Fredericton region's share of per capita earnings.

TABLE 3 Model Development for the Fredericton Region

Model	n	F-value of Model	t-value of Regression Coefficient	r^2
All-year				
SWS = -50.8 + 14.1 (HILAG4 ÷ 10^6)	21	6.03	2.45	0.24
Pre-1968				
SWS = -26.3 + 12.3 (HILAG4 ÷ 10^6)	15	3.77	1.94	0.22
Post-1968				
SWS = -122.2 + 25.1 (HILAG4 ÷ 10^6)	8	3.43	1.85	0.36

The three models are statistically significant at a 10 percent level of significance.

A Student's t-test indicated that at a 10 percent level of significance there was no significant difference in the level of economic activity caused by events other than highway investment in each of the three models. The t-test also indicated that there was no significant difference in the effects of highway investment on regional development in each of the time periods examined. This implies that the saturation point of the Fredericton regional highway network had not yet been reached.

MONCTON, EDMUNDSTON, AND BATHURST REGIONS

In the regions of Moncton, Edmundston, and Bathurst, no relationship between highway investment and economic development was evident. Because a relationship was found in two regions, it appears that highway investment could have an impact on regional development. This indicates that a relationship between highway investment and regional development may have existed before the study period or after the study period.

The hypothesis of saturation suggests that after a certain level of investment, additional investment will have no developmental effects but will affect individual mobility. If this level of investment was reached before the study period, a relationship between a measure of mobility and investment in highway infrastructurte should be evident. If no relationship was evident it would appear that the level of investment in highways has not yet reached a level at which it would cause economic development.

To test whether highway investment is serving to increase personal mobility in any of the three regions, the model developed in the previous section was utilized. The investment in highway construction was used as the indicator of the development of highways. As outlined before, a variety of lead and lag periods was used to determine the proper delay between cause and effect.

The ratio of the total retail sales within a region to the total income of the residents of that region was used to indicate the level of personal mobility. In the short run the average consumer was expected to spend approximately the same percentage of total income on retail goods. Thus, an increase in the ratio of retail sales to total income of a region would indicate that people were traveling to this region to purchase retail goods. Similarly, a decrease in the ratio indicates that people were leaving the region to purchase retail goods.

The results of the three models are given in Table 4. The competitive component of the ratio of total retail sales to total income (expressed as a percentage) of a region is denoted [RS/TI]. A significant relationship was evident in the Moncton region whereas no significant relationship was evident in the Edmundston and Bathurst regions (at a 10 percent level of significance).

TABLE 4 Regional Saturation Models

Regional Model	n	F-value of Model	t-value of Regression Coefficient	r^2
Moncton				
RE/TI = -3.17 + 0.51 (HILAG4 ÷ 10^6)	20	9.46	3.08	0.34
Edmundston				
No significant model				
Bathurst				
No significant model				

The model developed for the Moncton region indicated that there was an increase in the ratio of retail sales to total income relative to the provincial average of 0.51 percent 4 years after an investment of $1 million in highways. Due to external influences, an investment of $6.2 million is required to maintain the average provincial growth.

The statistical correlation between the investment in highway infrastructure and the measure of personal mobility provides evidence that the hypothesis of saturation and shift from development functions is correct. Highway investment did stimulate economic development in two regions; however, mobility was related to investment in the Moncton region. This provides evidence that highway investment in Moncton played a development role before the study period. The validity of these conclusions cannot be determined due to the unavailability of statistics before the study period.

A statistically significant model could not be developed for the Edmundston and the Bathurst regions. Because no relationship was evident between highway investment and regional development or personal mobility, it appears that the level of investment in highways had not yet reached a level at which it would cause development. In time, continued highway investment in these two regions should be correlated with increased regional development.

DISCUSSION AND CONCLUSIONS

The results presented in this paper provide some evidence to support the hypothesis of saturation and shift, and indicate that it is applicable to the study area in New Brunswick. It appears that the highway networks are developed to different levels: the highway network in the Moncton region developed before the study period, the highway network in the Fredericton and Saint John regions were developing to their full potential throughout the study period, and the highway network in the Edmundston and Bathurst regions had not yet reached a significant level of development.

After calibrating models for each of the five economic regions and examining the hypothesis of saturation and shift, several observations on the secondary function of highways can be made. Transportation improvements provide the opportunity for economic development; however, because of their individual characteristics, each economic region may react to the opportunity at different times. Some regions may react quickly, whereas there may be a considerable lag time between cause and effect in other regions. In New Brunswick the lag time between investment in highway infrastructure and the resulting effect appears to be 4 to 5 years.

The secondary effects of investment in highways appears to go through three phases. The first phase is the preliminary development of the regional highway network. At this stage limited development of the highway network has been completed. Although the highway network may adequately serve its primary function, new construction and upgrading does not have the potential to encourage development.

The second phase occurs after the regional highway network has been developed to a certain level. With a sufficient highway network in place, additional highway investment has the ability to encourage economic development.

As the investment in the highway network continues, the region becomes saturated with highways. A point is reached at which any addition to this network does not encourage further economic development. This is the third phase. Investment in the highway network no longer encourages economic development, but serves to increase the mobility of the residents.

The analysis indicated that the Edmundston and Bathurst regions were in the first phase throughout the study period. These regions of the province had been the last to receive a developed highway network, and the investment in highways in these regions was generally lower than in the other regions. With increased federal funding, especially in the Bathurst region, increased highway investment should begin to have a development effect.

The Fredericton and Saint John regions appeared to be in the second phase throughout the study period. Because Fredericton is the provincial capital and Saint John is New Brunswick's major port and largest city, these regions received relatively developed highway networks at an earlier time than the rest of the Province. By 1950 the highway network developed to the point that it could encourage economic development within the region. Throughout the study period, continued investment in highways encouraged further economic development.

Throughout the study period, the Moncton region was in the third phase of development as highways encouraged an increase in personal mobility. Throughout the history of New Brunswick, Moncton has been called the "Hub of the Maritimes." This is a result of the increased transport service activity of the area, as it is mainly a distribution center. Because of Moncton's advanced level of economic development, it would follow that the developmental stage of highways would arrive and depart relatively quickly. By 1950 highway investment had ceased encouraging economic development and had begun to act as an instrument to encourage personal mobility.

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Abridgment

Transportation Planning for Enterprise Development Areas

RONALD J. ROGGENBURK and RASIN K. MUFTI

ABSTRACT

Several states have now passed legislation creating an enterprise development area (EDA) or enterprise zone. Several more are now considering such legislation. Pennsylvania's EDA program has among its features a transportation component targeted to improved access to EDAs through highway improvements. The Pennsylvania Department of Transportation asked the Delaware Valley Regional Planning Commission (DVRPC) to undertake this component, including surveying transportation problems in the two EDAs within its jurisdiction and recommending actions leading to resolution of the problems. The commission's study of the EDA in Chester City and Chester Township in Delaware County is summarized in this paper. The study consisted of a practical application of problem identification and solution development. The centerpiece of the study was an extensive series of interviews with the managers of private firms now operating in the EDA. The recommendations made by DVRPC included permanent, long-term solutions and interim solutions that could be implemented in the short term. How effective these might be and the kinds of reactions that might be expected from shippers and local elected officials are suggested in this paper.

The enterprise zone concept is founded on the premise that relief from taxes, regulations, and other government burdens will spur the formation of new business activity, which will then create employment opportunities. The lifting of these restrictions would be limited to designated distressed areas and would offer advantages to employers not available elsewhere. Through this cooperative effort of the public and private sectors, an environment will be created in which investment in distressed areas will be rewarded. Also, traditional forms of economic development assistance will be made more effective through promises of matching investment by local government and private firms.

BACKGROUND OF ENTERPRISE DEVELOPMENT AREAS

The Pennsylvania Program

State programs, including one in Pennsylvania, have come into being while efforts at the national level to pass a law have floundered. The concept of a Pennsylvania enterprise development area program was initiated in 1982. Central to awarding enterprise development grants was the communities' desire and commitment to reverse the downward economic spiral. A strong emphasis was placed on discovering the answers through innovative projects. According to a recent state publication, enterprise development initiatives "recognize that the ultimate solution to the problems of distressed areas rests in the joint ability of the public and private sectors to create environments which increase the rewards for investment, production, and employment. . .targeted on selected areas."

The state's commitment consists largely of a promise to focus existing programs into the Enterprise Development Area (EDA). Examples cited in a recent state publication include aid to airports, a program of bridge replacements, and highway maintenance. As a part of the state commitment to revitalize the area, the Pennsylvania Department of Transportation agreed to award grants to transportation planning agencies, such as the Delaware Valley Regional Planning Commission (DVRPC), to analyze transportation problems in EDAs and to recommend actions.

The objective of this study was to determine the transportation problems that hinder the development of industry and to make recommendations for improvements that will increase the attractiveness of Enterprise Development Areas located in Chester City and Chester Township. The study focused on the Chester waterfront and the I-95 Industrial Park and sought to provide a more effective connection between these areas and landside rail and road networks. Through these improvements (and other nontransportation improvements and incentives) it is hoped that private investments will be made in industrial and commercial operations, providing jobs for local residents.

The Chester Enterprise Area

Governor Richard Thornburgh announced on August 3, 1983, the first communities to be designated as Enterprise Development Areas. A portion of Chester City and Chester Township in Delaware County, Pennsylvania, was so designated.

This EDA is well-qualified as a distressed area. The population has declined in recent years from 76,000 to 44,000. The central business district, once strong, has been decimated by the construction of four major shopping centers within a 15-min drive. Several large employers within the EDA and several more in adjacent communities have closed their facilities in recent years. Eighty percent of the residents receive some form of public assistance and 20 percent are unemployed. Although the crime rate is high, Chester laid off a quarter of its police force for lack of municipal funds.

The Chester waterfront has long been an active industrial area. At least two companies have been located on the Chester waterfront for more than 80 years. Considerable truck traffic is generated by these firms, most of which ship their products using heavy (four- or five-axle) trucks. Several companies now plan to use twin trailers, which are currently not well accommodated by the old street system. The waterfront of the Delaware River lies parallel to I-95, the major access route to Chester, but is separated by about a mile of residential and commercial neighborhoods.

A second focus of the study was a recently developed industrial park in Chester Township. The oldest companies located in the I-95 Industrial Park have only been there since 1977 when the park was opened. The park's proximity to I-95 and East Coast markets is attractive to firms, and growth has been steady. About 50 large trucks arrive and depart the industrial park each day.

Frequent contact was maintained with local officials of Delaware County, Chester City, and Chester Township. These local officials contributed much time in detailing area problems, in providing data and maps, and in carefully considering the alternatives that were studied.

PLANNING APPROACH

Overview of the DVRPC Approach

Consistent with staff discussions with county and municipal officials, DVRPC proposed the following major steps for the study:

1. View the identified Enterprise Development Areas and investigate the routes that truckers currently use;
2. On the basis of field view and subsequent analysis, propose alternative truck routes or new roads, or both;
3. Interview corporate executives to determine their specific transportation problems and the advantages and disadvantages of proposals in item 2;
4. Formulate permanent and interim strategies to address transportation problems; and
5. Propose further work to be performed next year.

Based on discussions with municipal and county officials, three major access problems were identified as critical to serving the targeted areas within the EDA. To conserve limited funds for the study, it was decided to omit all less important problems.

Development of Alternative Solutions

The site visits mentioned earlier as the first step in the process identified points of congestion, currently used truck routes, and opportunities for designating alternative routes, building new facilities, and improving existing ones.

Four alternatives were proposed to solve each of the access problems. Two of these alternatives could be implemented in the short-range future and one required enough lead time to be termed long range. A do-nothing alternative was also included, against which each of the others could be compared. It was assumed that if the long-range solution were to be selected, one of the short-range solutions or the do-nothing alternative would also be selected as an interim measure.

Survey of Current Highway Users

The central activity in this analysis was a series of extended interviews with officials of several of the companies that now operate trucks within the EDA. At each interview, two staff members spoke with one or more company representatives. Requests were made to meet with the highest ranking manager who deals with transportation problems at the subject facility on a day-to-day basis. The discussions were open-ended, encouraging candor, but prompted by a list of 33 questions. The results of these interviews are discussed later in this paper.

The survey included questions in the following four categories: growth of truck traffic, currently used routes, problems on the road, and acceptability of the proposed solutions. Responses to these topics are summarized in the following paragraphs.

Growth of Truck Traffic

In interviews, some of the firms stated their plans to expand. If two major projects revealed by the interviews are carried out, the number of heavy trucks on Chester streets would be multiplied several times and the problems cited made much worse. The solutions proposed were designed to be able to meet the eventuality of both of the new facilities coming into being.

Currently Used Routes

Most of the persons interviewed had only sketchy knowledge of the routes used by truckers. This information was supplemented by earlier observations of truck movements. Interviewers learned that truck drivers, generally, are not vocal about the problems they face on the road and circumvent obstacles with alacrity and ingenuity.

Problems on the Road

Access to the waterfront from I-95 suffers from several problems, foremost of which is the lack of clear signing. Much of Chester between I-95 and the waterfront is residential. On-street parking is permitted on most streets in such neighborhoods and restricts capacity. Railroad underpasses of the Amtrak main line, which lies between I-95 and the waterfront, are another major restricting factor. Few streets pass under the railroad with clearances over 14 ft and some are as low as 12 ft. Signs well in advance of encountering these low clearances are not posted, contributing to unnecessary truck movements. Many streets are in need of resurfacing and new traffic signals.

The major access problem between the industrial park and I-95 is the lack of a direct route. The roadway used includes a narrow, heavily traveled residential street with parking allowed on one side. Trucks must also maneuver a 135-degree turn with a small turning radius.

Acceptability of the Proposed Solutions

Responses to most of the proposed solutions were positive. Each respondent chose from among the suggestions those that were most advantageous to the operations of his firm.

Analysis and Results

Following the interviews, the staff made draft recommendations for the consideration of local elected officials. In two of the three cases, the permanent solutions involved long-range capital improvements. These were readily embraced by the officials, for they greatly relieved traffic on existing streets and involved very little condemnation. In the third case, the problem was readily eliminated through rerouting of truck traffic away from residences and through an industrial area, with only small increases in travel times.

The interim solutions, however, were far more problematic. Local officials resisted these changes to the status quo because it would cause an adverse impact, although less than the current impact, on a different group of residents who could be expected to fight the changes.

Specific recommendations can be found in the report "Chester City/Chester Township Enterprise Development Area Transportation Survey," published by the Delaware Valley Regional Planning Commission in July 1984. Copies may be ordered through the commission.

RECOMMENDATION AND CONCLUSIONS

DVRPC's final report recommended only those permanent solutions in which support could be found in all quarters. The interim solutions could not be recommended, although a few areas where significant hazards now exist have been recommended for study.

Role of Transportation Improvements in EDAs

Transportation improvement is one of many ways public entities can invest in EDAs to make them more attractive as employment locations. Other programs can focus on assembling land into packages large enough to accommodate large industrial operations or to be developed into office or industrial parks; improvements in utility infrastructure, particularly water and sewerage systems, or in other public services such as improved security or technical assistance to new businesses; direct financial assistance or low-interest loan programs for employers who locate in the zone; or acquisition of land and demolition of buildings to make reuse more attractive to developers and to enhance the visual environment.

Are highway improvements more important than any one of these alternatives? It is, of course, a subjective judgment as to which ranks highest. However, in many cases, transportation improvements are very important and the authors believe that this may be the case in Chester City and Township. Our conclusions were reinforced by the firm officers, who could not identify more pressing obstacles to doing business in the EDA.

Both municipalities have large parcels available for development with access to rail and water facilities. Today, however, the link to the Interstate highway system is critical for most industries whose flow of materials and products is significant. Although both subject areas are located within a mile of I-95, the impedance presented by the existing street network reduces this advantage greatly.

Importance of Signs

In the case of two access problems studied, permanent, major capital improvements were advisable. The interim solutions that the DVRPC staff believed were needed, however, would have improved the attractiveness of the area for firms and the shipping companies with whom they contract. The interim solutions would have designated a truck route and would have recommended signs located on I-95 and the route leading trucks to the frontage roads of all the major firms. Such signs are almost totally lacking on the routes that truckers use today. The only signs meant for truckers are those that prohibit trucks. These are located on streets where the residents have been successful in having the municipalities ban commercial vehicles.

Truck routes with signs that indicate "Chester Waterfront Industrial Area" or "I-95 Industrial Park" would eliminate residents' problems with stray trucks and save time and money for shippers and truckers. But perhaps more important, they would serve to advertise the existence of industrial land accessible from I-95. Combined with promotion of the area, the option of locating there would be kept alive in the minds of entrepreneurs and other firm executives responsible for plant location.

Resolution of Land Use Conflicts

Many of the residential neighborhoods in the EDA through which trucks must pass are badly deteriorated. It is typical for declining residential areas and industrial areas to be adjacent. The problems of one appear to create problems for the other. For example, a deteriorated neighborhood is often threatening to commuters; it may also be offensive to the company's image of itself. On the other hand, the existence of nearby vacant industrial buildings and derelict land may be a deterrent to maintaining residences. Homeowners may deter maintenance, preferring to save for a new home away from the noisy and hazardous trucks. Emphasis, therefore, was placed on separation of plant-bound traffic from residential areas. In this way, both the industries in the EDA and the residents will benefit.

Summary

Major capital improvements were found to be necessary to remove the isolation of the waterfront area that was created when I-95 was built on the far side of a residential area and further restricted by low railroad underpasses. An expensive solution was also found to be necessary to remove the adverse impact of truck traffic generated by an industrial park. The park had been built to attract I-95 users, but on land that could be reached only by narrow residential streets. Interim solutions, which would ease the situation, were resisted by local officials, thereby applying pressure to execute the permanent improvements quickly. The improvements recommended were judged by DVRPC staff to be essential to making the Enterprise Development Area attractive to potential employers.

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Transportation Planning for a High Technology Corridor in Suburban Philadelphia

DONALD S. SHANIS, RONALD J. ROGGENBURK, and RASIN K. MUFTI

ABSTRACT

A study of the new and growing high technology firms in the corridor between West Chester and Willow Grove, Pennsylvania, was conducted to develop an understanding of the locational criteria of these firms and to recommend short-range transportation improvements. Through these improvements, "high technology" firms will be encouraged to remain and expand at their current sites and the area will continue to appear attractive to new or existing firms seeking sites. The study recommendations were based on a survey of high technology and nonhigh technology firms in the corridor, and on field observations of highway problem areas identified by survey respondents. Among the findings of the survey: (a) few firms considered Center City Philadelphia as a possible location; most restricted their search to suburban sites; (b) ownership (or rental) costs, existing residence of the professional/managerial staff and the physical environment are the most important criteria for locating in the corridor; (c) access to Philadelphia International Airport is much more important to high technology firms than others and therefore interest in the completion of the rehabilitation of major access facilities is keen; and (d) the quality of airport limousine service is a concern, and many want mass transit and special transportation services improved. In a strategic plan for transportation, 12 policies have been developed that emphasize the need for increased maintenance of the transportation system, additional low cost roadway improvements, improved transit and paratransit services, and better accessibility to airports.

The Delaware Valley has long enjoyed a reputation for having outstanding centers of higher education, a well-educated and trained work force, and a pleasant quality of life. These characteristics have contributed to the startup of many technology-oriented, industrial, and business activities in the region. The emergence and special needs of those technology-based firms along US-202 and the Pennslyvania Turnpike in Chester and Montgomery counties were the subject of a special study conducted by the Delaware Valley Regional Planning Commission (DVRPC). The recommendations were intended to advance high technology business within this corridor and thus provide greater employment opportunities in the region. The corridor is located within the Delaware Valley region shown in Figure 1.

DEFINITION

Technology-oriented, technology-based, advanced technology, or high technology firms are those that have a high rate of change in processes and products and a research and development orientation. Industries such as computers, laser electronics, robotics, and biomedical equipment are examples. These firms may be characterized by their systematic use of recent scientific discoveries and knowledge and their output of high-value products. Transportation costs are typically a small portion of total production costs. The rationale for their locational decisions has not been well documented.

For analytical purposes of this study, technology-based firms have been defined by a series of Standard Industrial Code (SIC) categories. This classification is currently used by the Pennsylvania Department of Commerce.

STUDY OBJECTIVES

The literature has suggested that high technology firms require specialized transportation services and infrastructure, and value accessibility to residential areas and amenities attractive to a highly trained work force. These firms also may be able to substitute telecommunication systems for travel needs and improve communications. Because technology-based industries appear to be different from traditional firms, an understanding of the firms' operations and goals was a prerequisite for proposing modifications to the transportation system. Because a primary emphasis of this study was to identify existing and future deficiencies in the highway and transit system, it was recognized that transportation requirements must be put into perspective. Therefore, objectives of the study included obtaining a better understanding of (a) the location criteria of high technology firms in the corridor; (b) the advantages and disadvantages of the corridor as a location for high technology firms; (c) perceived problems and obstacles for future expansion of business activities and economic growth within the corridor; and (d) differences between high technology and other firms, especially with regard to transportation needs.

The transportation improvement recommendations that resulted from this study were to the ultimate purpose of stimulating the growth of jobs in the corridor through the retention of present firms and the attraction of new firms. It is in the region's best interest to develop advanced technology in the region. Not only are jobs created by the expanding high technology firms, but productivity will be improved in the region's industries that buy high-technology products, improving their ability to compete and protecting the jobs of those in nonhigh

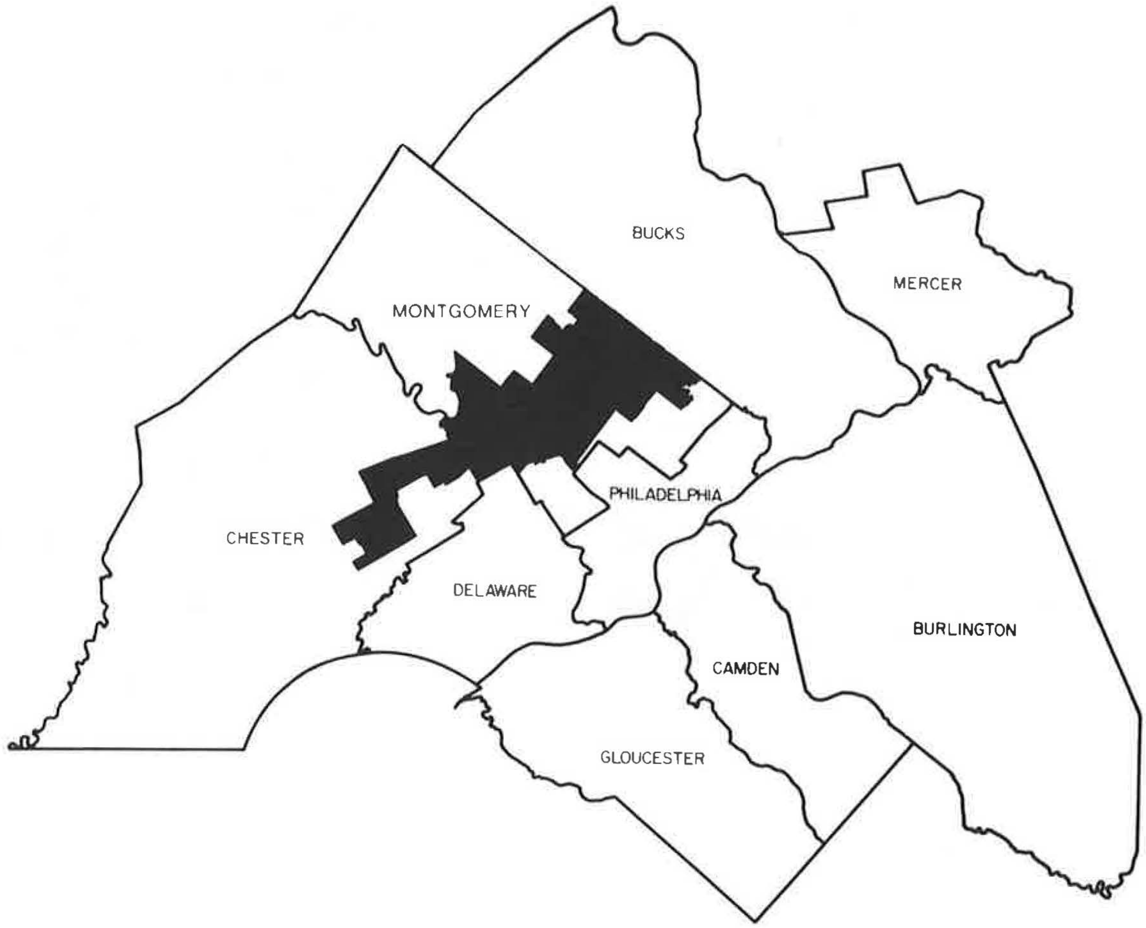


FIGURE 1 Study area within region.

technology industries. There is, in other words, a multiplier effect of establishing high technology jobs. In this way, the firms now sprouting in the US-202/Turnpike corridor can help to slow the decline of traditional manufacturing in the older areas of the region.

STUDY AREA

In cooperation with planning officials in Chester and Montgomery counties, the limits of the study area were defined. Figure 2 shows those municipalities that were included. The corridor is broader in Montgomery County because of the greater number of firms and their tendency to locate along both US-202 and the Pennsylvania Turnpike, which diverge east of King of Prussia. The firms in the corridor in Chester County are fewer and tend to be located near US-202 only.

The study area was composed of 24 municipalities that included 213 mi^2 lying between 10 and 25 mi from City Hall in Philadelphia. The total population of these minor civil divisions was 327,000 in the 1980 Census. Preliminary projections for the study area indicate the year 2000 population will be about 350,000, about 7 percent more than 1980.

In summary, the study area is a large, partly developed and affluent section of the region, which by plan and by trend should continue to grow between now and the end of the century.

HIGH TECHNOLOGY IN PERSPECTIVE

According to a study by the Massachusetts Division of Employment Security (1), there were 208,000 jobs in high technology firms in early 1981 throughout the Commonwealth of Pennsylvania. This amounted to about 4 percent of the estimated 5,500,000 jobs in all fields. DVRPC estimates that 43,000 of the current 210,000 jobs in the study area are with high technology firms, about 20 percent. So the "density" of high technology jobs is five times greater in the corridor than in the state as a whole. Also, one out of five high technology jobs in Pennsylvania is located in the corridor. No attempt was made to determine if other high concentrations of high technology jobs exist within the Pennsylvania portion of the region.

An economist with the Federal Reserve Bank in Philadelphia suggested that growth in jobs with high technology firms in the 1980s may not be more than 1 million nationwide (2). If Pennsylvania succeeds in keeping up with the national rate, about 40,000 of those jobs would be located in the Commonwealth, and if the corridor maintains its share of state jobs, 8,000 would be located in the study area.

STUDY APPROACH

A three-phased approach was used to accomplish the study objectives. In the first phase of the project,

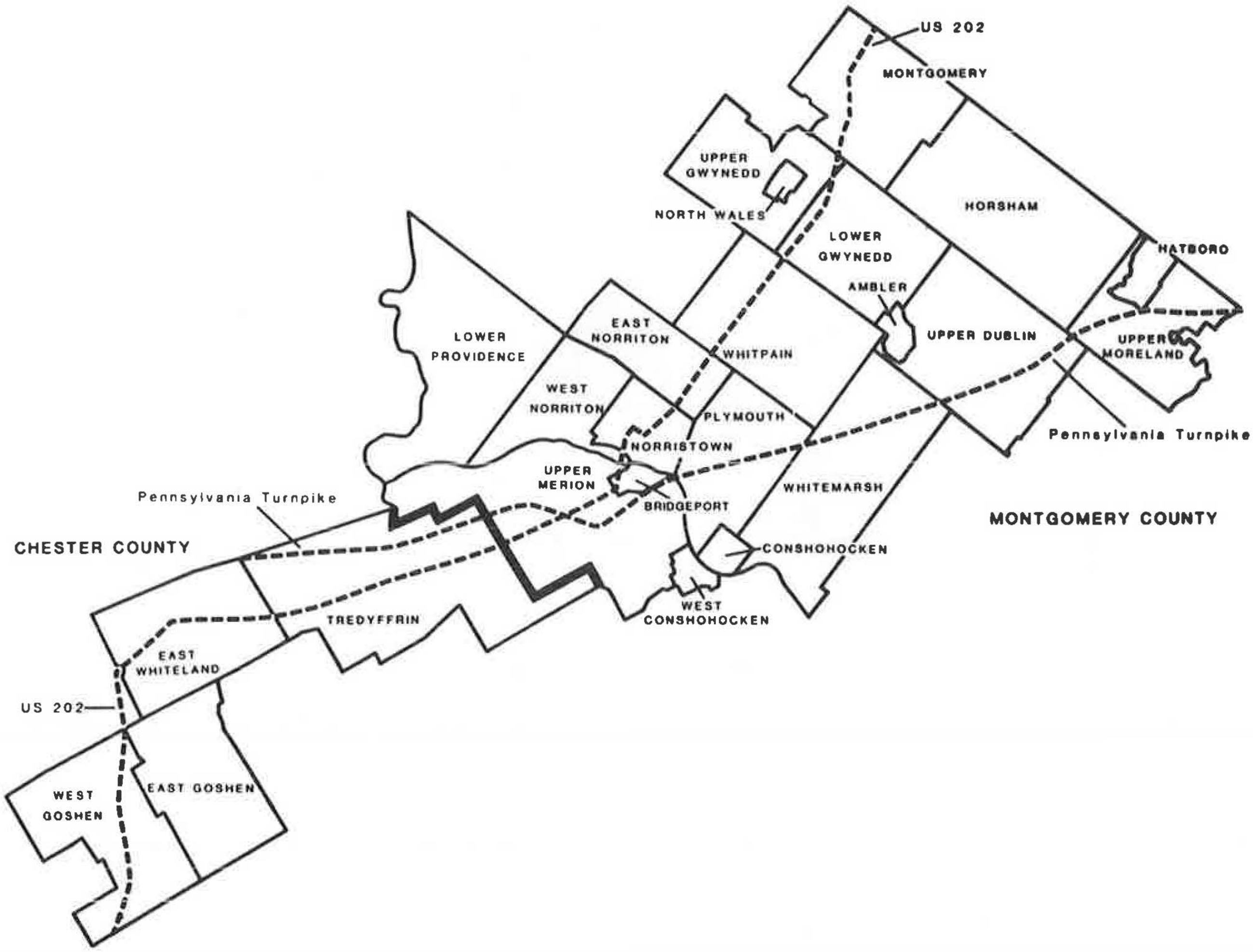


FIGURE 2 Municipalities within the study area.

staff interviews were conducted with selected executive officers, developers, and other interests in the corridor. A mail-back questionnaire was used to obtain information on location and transportation from all other technology firms that were identified in the corridor. In addition, the questionnaire was mailed to a selected sample of nonhigh technology firms for comparison.

The second phase of the study included field views and analysis of the corridor and locations with transportation problems; a review of existing studies, plans, and programs; and a general literature review. The field views included site visits and classification of the problems (or problem symptoms) that were identified during the survey and the review of past planning studies. Data about the corridor were collected in this phase to supplement the survey and to verify its findings.

The study recommendations were prepared during the final phase and are based on the results of Phases I and II. This action plan consists of a policy statement, transportation improvements, and proposed future studies.

Survey Design and Sample

The objective was to tailor the recommendations of the study to the needs and desires of the users of the transportation system--in this case the technology-oriented firms in the corridor. In this way, the corridor would continue to be an attractive location and would stimulate the development of this sector of the local economy. To learn the improvements that are desired by the client, it became necessary to conduct a survey.

Having identified 167 firms as meeting the study criteria of being high technology, it appeared reasonable to offer each the opportunity to respond to the survey. Inasmuch as it is also desirable to serve the needs of all firms in the region, it was determined that a sample of nonhigh technology firms also be surveyed. To assure adequate representation, surveys that had 12 questions about location and 14 about transportation were sent to 100 nonhigh technology firms with representation from each geographic subarea.

Executive officers from 25 of the high technology firms were asked to be interviewed. These interviews were designed to last about 1 hr and cover topics relating to location, transportation, and other issues defined by the person being interviewed. The executive officers interviewed were selected on the basis of achieving a representative sample of the size and geographic location of firms.

The 167 high technology firms employed more than 44,000 persons, accounting for approximately 20 percent of the estimated 210,000 jobs located in the study area in 1980. Figure 3 shows where the firms are located by four categories of size. The map also demonstrates that the high technology corridor contains several clusters of firms, which are circumscribed.

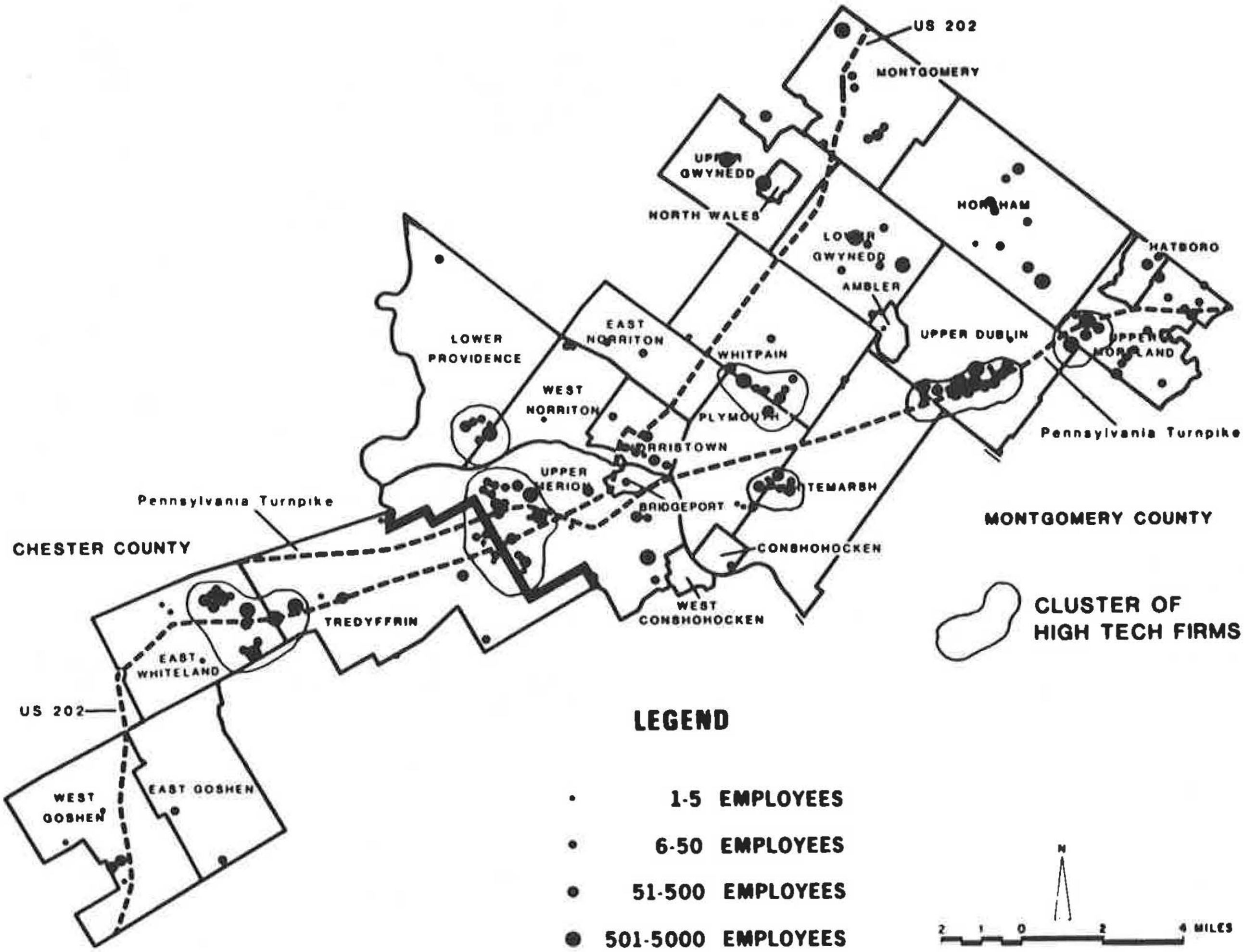


FIGURE 3 Location of high technology firms.

Transportation Problem Areas and Field Investigations

An objective of the study was to recommend transportation improvements that will support economic development and solve existing transportation problems. For this purpose, responses to a survey question were plotted on a map of the corridor to display locations with severe traffic problems. Because these responses represented perceived problems and often were only symptoms of the real problems, additional analysis was performed.

Those mapped locations that were cited more than once in the survey were aggregated into transportation problem areas based on their proximity and interrelationship to each other. The individual problem areas were then discussed with staff members of the Chester County and Montgomery County Planning Commissions to determine which areas should be addressed further in this study. Certain areas that may experience future transportation problems if development plans are implemented and problem areas outside of the corridor were not given further treatment.

To collect data on the physical and operational aspects of the transportation system in the problem areas and to determine the cause of problems, field investigations were conducted by a team of DVRPC staff. Data analysis, field reviews, and strategy assessments resulted in a number of improvement recommendations for each location or subcorridor. These recommendations include traffic flow, signing, and safety improvements.

THE SURVEY

A total of 102 firms responded out of 167 to whom the survey was distributed, about 6 out of every 10. Fifty-five out of 100 questionnaires were returned from nonhigh technology firms. No pattern was discerned in the characteristics of the firms that chose to respond, and it was assumed that the responsiveness of the person receiving the survey was the only factor at work.

Two types of high technology firms are known to be thriving in this region: pharmaceuticals and computer software developers. It was, therefore, deemed useful to separate responses from these firms from those of all others. SIC 283, including biological products, medicinals and botanicals, and pharmaceutical preparations were included in pharmaceuticals; SIC 737, including computer programming and other software services, data processing, and other computer services were included in computer services. Seven responses were received from pharmaceutical firms and 32 were received from computer service firms. A complete profile of responding firms is provided in Table 1.

Each of the newly located or newly founded firms was asked if transportation facilities played an

TABLE 1 High Technology Firms—Profile of Respondents

Standard Industrial Classification	Number
283 Pharmaceuticals	7
737 Computer services and software	32
357 Computer and calculating equipment	7
366 Communications equipment	5
367 Electronic parts including semiconductors	11
376 Spacecraft	1
381 Scientific instruments	2
382 Process instruments	12
383 Optical instruments	2
384 Medical instruments	7
386 Photographic equipment	2
739 Research and development labs	9
807 Medical labs	3
892 Noncommercial educational and scientific organizations	3
Size of firm	
1 to 5 employees	10
6 to 50 employees	38
51 to 500 employees	33
501 to 5,000 employees	16

important role in their location decision. Slightly more than 50 percent of the high technology firms answered yes but slightly more than 80 percent of the other firms agreed. This response can be traced to the fact that high technology firms are, for the most part, free of the burden of moving large quantities of raw materials to their site and moving high-volume products to market. Indeed, in the case of computer service firms, input and output may occur through telecommunications.

Location of Firm

Each respondent was asked if the firm had been located at its present site less than 10 years. If so, the respondent was asked to answer the next three questions pertaining to the firm's choice of location. Slightly more than one-half of the high technology firms were new and slightly less than one-half of the nonhigh technology firms were old. As expected, the pharmaceutical firms were well-established and the computer service firms were the youngest.

Respondents indicated the alternative sites they considered when selecting a location. Very few firms considered Center City as a possible location. In interviews, the firm official was asked: "Do you think that Center City Philadelphia is a suitable location for your firm?" In most cases, the operation could have been located in Center City, but most persons were quick to volunteer why locating there was not considered. The most often heard responses were (a) the existence of the (high) wage tax, and (b) the perception that the firm or its employees would be more likely to be victimized by crime.

Firm officers were asked if each of the following seven criteria were very important, important, somewhat important, or not important in choosing their location:

1. Existing residence of professional/managerial staff,
2. Ownership or rental costs,
3. Physical environment,
4. Highway facilities,
5. Availability of trained labor force,
6. Local taxes, and
7. Local government attitude or incentives.

This is presented in the rank order of importance expressed by high technology firms. Scores were very close for 1 and 2 and for 3 and 4; together these four criteria scored well above the last three. Both high technology and nonhigh technology firms rated most criteria similarly, including highway facilities. The most remarkable divergence was on existing residences, which were very important or important to 79 percent of the high technology respondents, but important to only 53 percent of nonhigh technology respondents. This confirms the popular notion that executives of high technology firms value accessibility to residential areas. It suggests to economic developers that the best sites to promote for high technology firms are those that are close to good housing stock.

Almost one-third found the physical environment very important among high technology firms and almost as many nonhigh technology firms.

Municipalities (or any other government entities) that are attempting to attract high technology industries should carefully monitor development of their communities so that they are assured that the visual surroundings are not degraded by development. It also means that public facilities, and particularly streets and highways, be built and maintained to high standards. Greater attention should be given to landscaping, highway fixtures, vistas, visual barriers, and so forth, if the corridor is to compete more effectively for new industry. Cooperative efforts by municipalities and county planning agencies to upgrade land development design standards are therefore encouraged.

Attributes of Region

Respondents were asked to compare the Delaware Valley Region with other metropolitan areas of the Northeastern United States and to judge a series of 14 attributes to be either assets or liabilities. Respondents could also answer "uncertain." The following list classifies the attributes. (The score is computed by subtracting the percent judging the attribute a liability from the percent judging it an asset.)

Clearly assets:	
Universities/technical graduates	85
Cultural and recreational opportunities	74
Size and skills of labor force	69
Housing costs	59
Energy reliability	55
Climate	28
Attitudes toward business	24
Neither an asset nor a liability:	
Transportation	9
Labor costs	6
Venture capital availability	4
Financial incentives	-6
Energy cost	-10
Clearly liabilities	
Local taxes (individual and corporated)	-18
State taxes (individual and corporate)	-36

The preceding results indicate that there is a positive attitude about the Philadelphia Region among the officers of technology-oriented companies. Attributes that scored highly are among those that are thought to be valued by high technology firms.

The negative scores that indicate a net liability are all fiscal attributes and one wonders if respondents may be exercising an automatic negative response, especially in the case of taxes. But note that two other fiscal attributes--labor costs, and especially housing costs--are considered assets to the region.

The most outstanding attribute of the Philadelphia region, according to the executives who completed DVRPC's survey, was its universities and their technical graduates. Not only did the largest number judge this attribute an asset but the fewest number judged it a liability; the fewest number were also uncertain.

In a study conducted recently by the Institute of Public Administration (IPA) of Pennsylvania State University and the Pennsylvania MILRITE Council, however, only 1 of the 31 firms surveyed in the corridor listed proximity to universities as important in its location decision, and in that case it was the fifth most important (3). No firm included closeness to universities as important in determining whether to expand in the region.

It appears, then, that high technology firms are happy to have access to many well-educated graduates, and to have universities nearby for continuing education. These advantages are not so important, however, to draw firms away from the benefits they find in the suburbs. Continuing education will become more important in the future as the half-life of a college degree decreases while the complexity of a technological world increases.

More than two-thirds of the high technology firms reported that they have no problem hiring professionals or persons with the skills they require. About two-thirds of the nonhigh technology firms also reported no problems. These percentages look favorable, although no comparisons with other metropolitan areas are available.

Future of the Corridor

Four questions addressed the attitude of the firm toward further growth of the corridor and its role in it. The responses from high technology firms are summarized as follows:

1. Almost one-half stated that it is an advantage to be located among other firms whose products or services, or labor requirements, are similar to their own. (Only one-third of the nonhigh technology firms considered proximity an advantage.) Only 8 percent considered it a disadvantage.
2. Seven out of every eight respondents believed that continued growth of the corridor would be good for their firm.
3. Forty-six percent asserted that they plan to expand their operations at their present location; another 13 percent preferred not to divulge this information.
4. Only seven firms indicated plans to relocate. It may be significant that three of these firms are located in King of Prussia. An officer of one such firm stated in an interview that his firm would relocate farther west on US-202 because of the almost paralyzing congestion experienced on highways in the vicinity of US-202 and the Schuylkill Expressway. Note, however, that relocation does not imply that the firms will leave the corridor.

The conclusion that must be drawn from these four points is that, given a strong economy, the corridor will continue to grow and prosper, requiring additional transportation improvements to handle the attendant traffic.

Company Practices that Affect Traffic Conditions

Almost one-half of all firms have considered the use of flexible work schedules. Apparently such schedules have been more successful at high technology firms, where one of every five respondents report their normal work hours as variable, a rate three times greater than nonhigh technology firms. Furthermore, one-half of the respondents indicated that their firm would be willing to modify their work schedule as part of a plan to decrease traffic congestion in the area.

Only 7 of the 102 firms surveyed have a shared-ride program. In interviews, several firm officers spoke skeptically of the concept of carpooling and vanpooling. Many high technology firms prefer to think of their employees as highly motivated people who leave their jobs when their work is completed and not in time to meet shared-ride schedules.

As noted earlier, these firms prefer to be located near the homes of their employees so that the employee can travel to and from his or her job easily--in the evening or on weekends as well. Such a location makes carpooling unnecessary and sometimes counterproductive in the eyes of company executives.

Transportation Needs of the Firms: Non-Highway

The survey asks the executive if his location is served by public transportation. Responses ranged from one out of three to two out of three answering yes in different parts of the corridor. The results appear to indicate that people have different ideas about what being "served" is, but also, no doubt, that many people do not know if they are served. The interviews support this contention. Public transit is not even considered an alternative to many persons working in the study area, and so there is little knowledge about routes, stops, frequencies, and destinations.

Those who stated that they are served by transit were asked to indicate which attributes of the service are most in need of improvement. Most often cited was frequency. Reliability was mentioned next most often, but only about one-half as many times. It is not known if reliability is really in need of attention in the corridor, or if it was mentioned often because it tends to be an automatic response. People appear not to easily forget an unhappy experience in using transit. In third place is information, which can be relatively inexpensive to improve.

During the testing of the draft survey, it became apparent that some dissatisfaction is felt with paratransit services--particularly taxicabs and airport limousine service--and so two questions were added. The first question elicited that only 4 out of 10 respondents were satisfied with the service offered in Upper Merion, but in other areas 6 out 10 respondents found the service adequate.

Attributes of taxicab and limousine service in need of improvement are reliability (showing up when promised), destinations served (being too limited), and vehicle qualities. This last attribute received a lot of attention in interviews, along with drivers' attitudes. At least one executive mentioned that he felt embarrassed when customers and business associates used the limousine service to the airport. Inasmuch as the survey results demonstrate that fare is not a concern to many respondents, it may be that higher fares that pay for improved service may be welcomed.

Compared to 90 percent who believe that more public funds should be spent on highway improvements, 70 percent of the respondents believed that more money should be spent on mass transportation. Less than 30 percent believed, however, that more funds should be expended for bicycle and pedestrian facilities.

Transportation Needs of the Firms: Highways

Firm officers were given six destinations and asked to indicate their relative importance to their company as high, medium, low, or none. The results point to some differences between high technology firms and other firms. The most striking of these is in access to air travel. Philadelphia International Airport was cited as a highly important destination by 60 percent of high technology firms, and of no importance to only 4 percent. For nonhigh technology firms, it was highly important to only 30 percent and not important to 20 percent.

Interviews confirmed the significance of airport access to high technology firms. The market for many technological products is nationwide and sometimes worldwide, which means a higher than ordinary rate of air travel for the executives of such firms. Perhaps even more important, these firms often produce small, high-value products (or paper) for which the cost of air freight is small relative to its value. High technology firms are frequent users of private air express services. It is interesting to note that the airport is less important to computer service and software firms than to other technology-oriented firms, perhaps because so much of their input and output is moved through telecommunications. Access to local airports and heliports is also important to high technology firms, more so than with nonhigh technology firms, but not by such wide margins as travel to and from Philadelphia International Airport.

Center City remains an important destination, being of medium or high importance to 65 percent of high technology firms and 54 percent of others. In addition to using services located in Center City--legal and financial, primarily--firms also find many of their clients in Center City.

The survey asked the executive to locate severe traffic problems in the vicinity of his firm. In each of the subareas, a majority of the respondents reported severe problems. These citations were found to be clustered into 14 problem areas with the study boundaries shown in Figure 4. Recommendations in the study primarily addressed solving problems in these areas. About 90 percent of the questionnaires returned indicated that the chief executive officers and others who completed the forms believed that more public funds should be spent on highway improvements.

Finally, the questionnaire listed six major programmed capital improvements either in or affecting the study area and asked the respondent to state which are important to the operation of his firm.

To firms in the eastern, central, and western part of the corridor, the Schuylkill rehabilitation is the most important project. The expressway forms a tether to Philadelphia, and its free flow is important to permitting Philadelphia to remain the focus of services to the corridor. As an example, some executives of high technology firms are finding Trenton and Wilmington rail stations more convenient than 30th Street, even though the over-the-road distance is greater.

The second most important project to each group is the Mid-County Expressway. This selection reflects

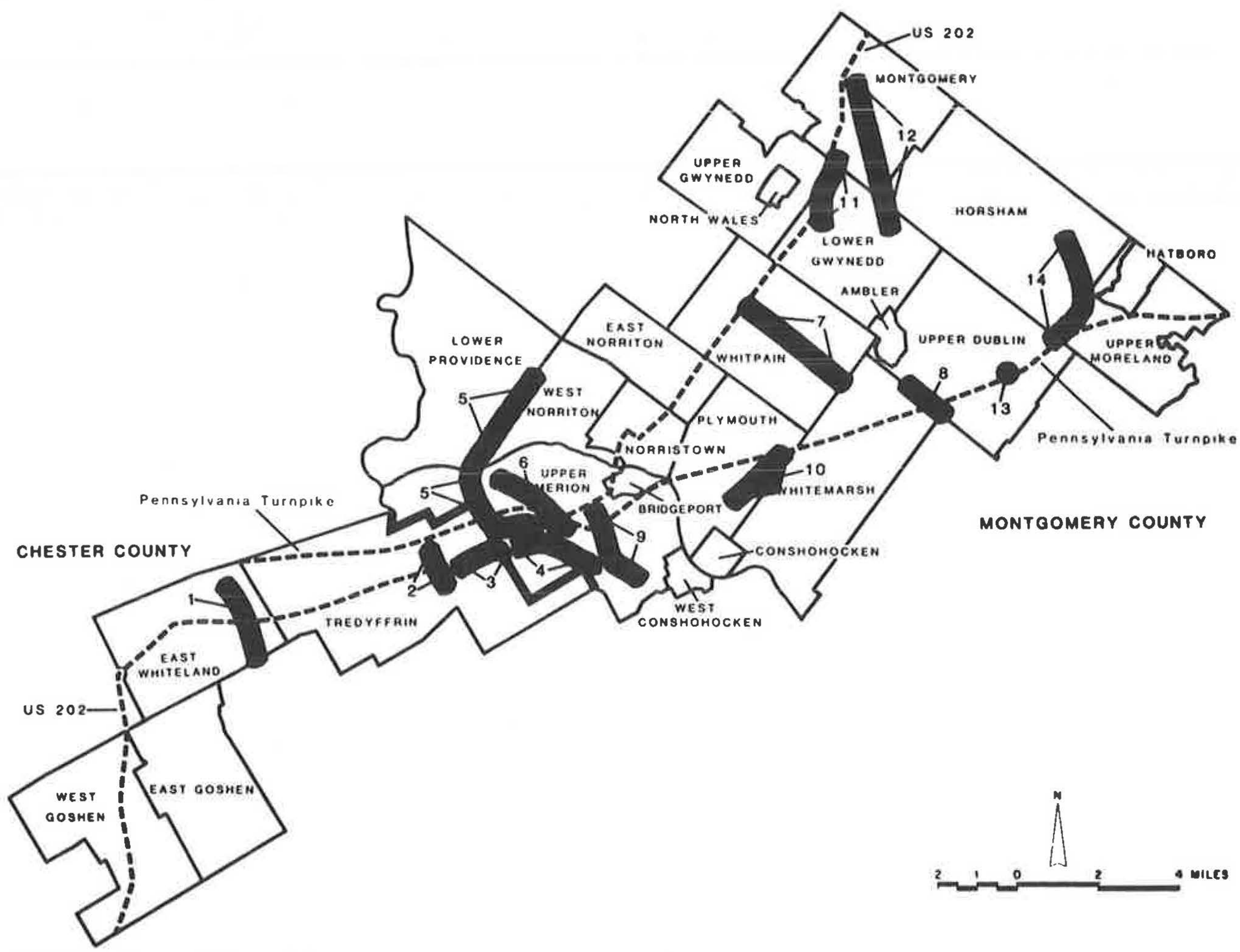


FIGURE 4 Transportation problem areas.

the importance of access to Philadelphia International Airport. Several executives were critical of the transportation bureaucracy for failing to surmount the obstacles to completion of the project. They stated that their investment in the corridor was in part predicated as the concept of a fast, direct route to the airport. After these two priority projects, the areas differed in their responses.

STRATEGIC PLAN FOR TRANSPORTATION

This section of the paper contains a summary of the study recommendations and proposed strategies for action. These recommendations were based on an evaluation of the office interviews and mailback surveys of the existing firms in the US-202/Pennsylvania Turnpike Corridor. Field views of locations with transportation problems, other studies, planned projects, and funding constraints, have been considered in this action plan. The action plan consisted of three elements:

1. Statements of policy.
2. Recommended transportation improvements.
3. Proposed studies and outstanding issues.

The policies, transportation improvements, and proposed studies contained in the plan have been coordinated with the current plans of the member governments, the transportation operators, and local businesses. Simultaneous and continuing action by the municipalities, counties, state, and the private sector is required to maximize the effectiveness of these concepts and proposals.

Policy

To foster economic growth and the location of technology-oriented firms in the corridor, the existing and future needs of business must be satisfied. These needs are complex, changing, and require continuous attention. Generally, this broad-based effort must involve the maintenance and upgrading of a total environment and many quality-of-life considerations.

The policies discussed below address the most important areas of concern expressed during the corridor study. As a guideline for decision makers, these transportation policies should provide overall direction for planning activities.

1. Support the increased use of taxicabs, limousines, and other private transportation services to assist in meeting the corridor's travel demand and the special needs of the technology-oriented firms.
2. Preserve rail corridors within the corridor for possible transportation uses in the future.
3. Provide for convenient and safe local airport and heliport facilities to meet the increasing air transportation needs of the corridor.
4. Pursue transportation improvements that increase accessibility to the Philadelphia International Airport.
5. Support the advancement of telecommunication services to augment transportation facility improvements.
6. Gradually convert transit vehicles to the most appropriate sizes and types to better meet the needs of the corridor.

In addition, six additional policies, which apply throughout the region, were recommended to receive special attention in the corridor. The policies focused on increasing maintenance on the existing network, spreading the peak periods, staging implementation plans, environmental quality, minimizing travel requirements, and encouraging transit.

Transportation Improvements

Transportation improvements recommended for completion during the next 5 years were outlined. Each set of improvements was based on a description of the problem area and the transportation deficiencies that were observed. As shown in Figure 5, a schematic of the street system indicating the location of problems, proposed improvements, and cost estimates for planning purposes was prepared.

The recommended improvements primarily addressed deficiencies and problems cited in the survey of firms in the corridor and the followup field investigations. The region's Transportation Improvement Program, Year 2000 Transportation Plan, Transportation System Management Plan, and the ongoing planning efforts of local governments were considered in the development of these recommendations.

The proposed transportation improvements did not represent a complete response to all problems that exist or that will occur in the corridor. Other traffic studies should be integrated into these recommendations. Continuous monitoring of corridor growth and traffic was also encouraged to enhance and modify the set of projects. Additional evaluation may be needed to assign a priority to improvements and to stage implementation activities.

Transportation improvements in other parts of the region are also required. For purposes of improving the attractiveness of the corridor to advanced technology, the projects should focus on improving accessibility to critical destinations of technology-oriented business. Included among these important locations are the Philadelphia Central Business District, the Philadelphia International Airport, cultural and recreational areas in the region, and suburban residential locations.

Outstanding Issues

This study recognized that many issues and transportation problems could not be adequately addressed. Implementation of transportation policies and facilities require detailed project studies. A commitment to investigate problems and undertake such studies was, therefore, an important part of the plan.

IMPLEMENTATION

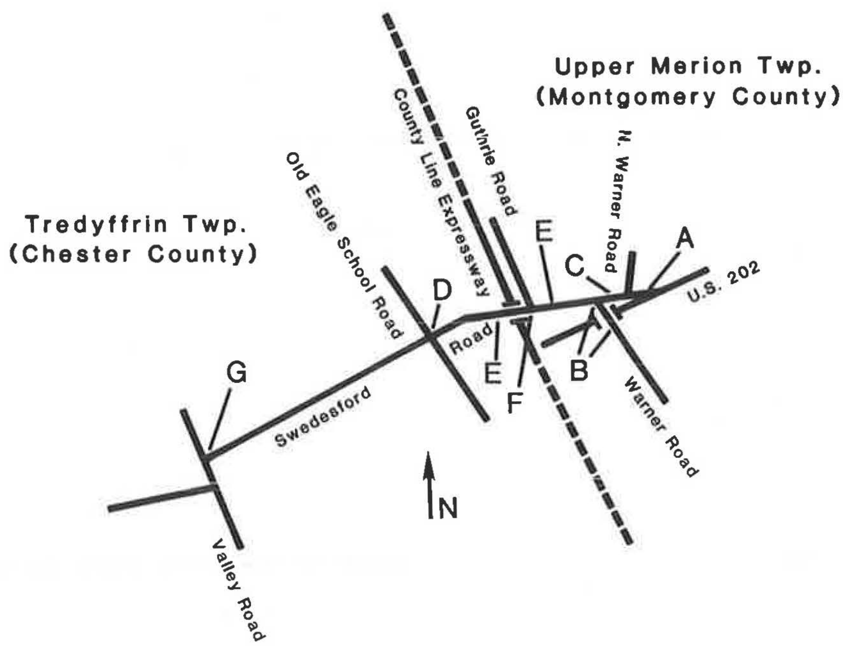
Implementation of the study recommendations is the most important phase in the planning process because it results in the construction of new and improved facilities and better transportation service. Successful implementation, however, requires coordination and depends on many considerations and decisions by a number of individuals and groups.

Agencies' Responsibilities

To implement the recommended transportation improvements, agencies at the local, county, regional, and state levels were advised that they must do their part in the planning, capital programming, design, and construction process. It was important that all parties agree to the policy guidelines and work cooperatively.

Municipalities

The municipalities in the study corridor were asked to concur with the proposed improvements. After con-



RECOMMENDED IMPROVEMENTS (Approximate Total Cost = $250,000)

A Erect Overhead Sign, Construct Improved Traffic Island

B Paint Pavement Lines, Cutback Northbound Swedesford Road Curb, Remove Vegetation, Install Improved Stop Signs

C Remove Vegetation

D Remove Treadle Pad on Westbound Old Eagle School Road Approach, Widen Eastbound Approach to Provide 2 Lanes, Restripe Northbound Approach

E Provide Shoulders on West Side of Swedesford Road*

F Restrict Northbound Swedesford Road Left Turns During Peaks

G Install Directional Informational Signing

*Future Developers should provide shoulders on West Side of Road.

FIGURE 5 Problem area schematic: Swedesford Road between north Warner Road and Valley Road.

currence on the scope of the proposed improvements, each municipality, with the assistance of Montgomery or Chester counties, must follow through in the implementation of the traffic improvements for the problem areas. Assistance in implementation, which includes local financing, engineering, land acquisition, and construction should also be sought from appropriate developers and businesses.

Counties

The function of the Chester County Planning Commission and the Montgomery County Planning Commission is to develop projects and priorities for capital programming by the county and region and to coordinate with Minor Civil Divisions (MCDs) on traffic studies. In addition, the planning commissions coordinate with the municipalities, DVRPC, and the Pennsylvania Department of Transportation (PennDOT) in the process. Because of funding constraints, a high priority was assigned to improvements in the corridor so that they would advance in the implementation process.

Delaware Valley Regional Planning Commission

Toward the implementation of transportation improvements in the high technology corridor, DVRPC's primary responsibilities are to evaluate the technical merits of projects, establish priorities, and to program projects. Before programming, the commission staff must evaluate projects based on criteria established by PennDOT and the U.S. Department of Transportation. In addition, the recommended improvements may be potential candidates for special state programs.

Pennsylvania Department of Transportation

PennDOT's responsibility is to support local, county, and regional initiatives by programming transportation improvements at the state level. After programming, it is charged with the tasks of engineering, acquiring any needed land, obtaining federal and state funds, and constructing the improvements. Local acceptance and cooperation will assist PennDOT in implementing high technology corridor improvements.

Southeastern Pennsylvania Transportation Authority (SEPTA)

Public transportation recommendations are usually the responsibility of SEPTA, the primary transit operator in Southeastern Pennsylvania. Working cooperatively with governments and the residential and business communities in the corridor, SEPTA must seek to provide improved transit service. Several issues concerning new local, express, and shuttle bus services raised during the study are currently being addressed.

Other Agencies

Because this study had the indirect goal of assisting in the economic development of the region by improving transportation service, many other local and state agencies have a role. Organizations, such as those responsible for paratransit services, taxicabs and limousines, and airport planning, must be aware of the opportunities and the potential of the high technology corridor for development. The special needs of the technology-oriented firms must be addressed on a continuing basis.

The findings of the study were shared with the Chester County Consortium for Economic Development, the Montgomery County Commerce Department, and other agencies, to provide a basis for supporting the transportation recommendations and advancing their own planning efforts. Overall promotion of the corridor for industrial development will be the responsibility of these agencies.

Private-Public Partnership (Creative Financing)

The benefits from constructing transportation projects in the corridor will accrue to employers, developers, and others who use the improvements or who are better-off by increased economic development. It is in the interest of these firms and groups to participate in the planning and financing of the projects if the benefits to each exceed their share of the costs, particularly if governments or transportation operators would not implement the improvements without this private support. It is in the interest of governments and transportation operators to develop and support improvements that have identifiable benefits to businesses and developers, especially when public funds are scarce and the transportation improvements would benefit the region.

Private-public partnerships and creative financing arrangements should be developed and built on this economic principle. It is most effectively accomplished by including the public and private sectors from the early stages of planning to the final implementation stages of programmed projects. The formation of special transportation task forces for specific project locations were recommended to assure active participation of the interested parties.

Transportation task forces have been or are currently working in various locations in the corridor, including the US-29 area, Upper Merion Township, and the Dresher area. The task forces provide a forum to discuss issues, establish goals, undertake studies, define alternatives, make recommendations, and design implementation strategies.

CONTINUING PLANNING

Transportation service in the corridor is related to many technological and socioeconomic factors that are changing. For example, there are many possibilities for substituting telecommunication for personal travel. Special television systems may provide a means for business meetings, education, and the conveyance of papers. Also, the magnitude and type of future development or changes in travel behavior because of special situations such as fuel shortages are difficult to predict. Therefore, priorities may change in the context of new funding constraints and political forces.

Transportation policies and recommended improvements for the high technology corridor should be reviewed in several years to confirm or modify these guidelines for decisionmakers. During the interim period efforts should be made to resolve outstanding issues. Small traffic studies to support, revise, and augment recommendations should be advanced.

CONCLUSION

Though the transportation needs of high technology firms are not significantly different from those of other industries, high technology executives and employees are accustomed to working with state-of-the-art products and systems. Therefore, they have a limited tolerance for traffic congestion and poor public transportation. In determining location sites for their industries, technology-oriented executives value highly the quality of transportation service that includes adequate maintenance of existing streets and highways.

As shown in this study, technology-oriented industries are often small (fewer than 50 employees) and they often research and produce products that have national and international markets. Access to these markets requires air travel that is frequent and dependable with a range of destination options. In addition, products and key employees must be transported to the international airport with minimum delay and maximum convenience.

The search for excellence associated with high technology translates into a desire to improve quality of life. In terms of transportation, this means fast and comfortable access to residential neighborhoods, shopping and restaurants, other regional amenities, educational institutions, and international airport facilities. The amount of new high technology that may be anticipated may be directly related to the extent that the corridor can offer or has access to these opportunities.

Therefore, the preparation and local acceptance of a strategic plan (providing recommended improvements, policy, and implementation strategies) addressing transportation and other environmental concerns and infrastructure, is an appropriate step toward planning for high technology.

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The Downtown Hartford Transportation Project: Public-Private Collaboration on Transportation Improvements

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ABSTRACT

The implementation of innovative approaches to managing transportation resources in downtown areas has frequently proven difficult. In addition, traffic, transit, parking, pedestrian, goods delivery, urban design, and economic development concerns typically are addressed in isolation rather than as part of an integrated program. The Downtown Hartford Transportation Project (DHTP) was a collaborative effort by public and private sector organizations to plan and implement a broad range of actions in anticipation of unprecedented levels of building and employment growth in the downtown. The DHTP represents a unique model of a transportation planning process--it is multimodal in scope, involves both physical and management-oriented improvements, and features a process of consensus building about solutions that served to smooth the transition between planning and implementation. The key features that make the Downtown Hartford Transportation Project unique and contributed to its success are described. These features include the type and level of public and private sector participation, the definition of the project's scope, the process of achieving consensus on solutions, and the use of information and technical analysis to guide decisions. Based on the experience of the DHTP, a set of guidelines is presented for following the Hartford example. It is concluded that although unique conditions in Hartford precipitated the DHTP, many features of the DHTP could be successfully adapted in other locales that want to better manage their transportation resources.

Hartford, the capital of Connecticut, has a population of 135,000 and is located at the junction of two interstate highways (I-91 and I-84) in the central portion of the state. Hartford is the home of several large insurance companies, including Aetna (more than 13,000 employees) and Travelers (9,000 employees). Hartford's business community has long been active in downtown transportation issues--due both to a concern for employee benefits in a highly competitive environment, and to a recognition of the importance of good access and a pleasant downtown to maintaining retail vitality. Aetna's vanpool program, initiated in 1977, now operates 135 vans and is one of the largest employer vanpool programs in the country. In 1980 the Greater Hartford Ridesharing Corporation was formed. Supported by public and private sector funds, it has a membership of more than 40 companies in the Hartford area. The history of public-private cooperation in Hartford laid the groundwork for the Downtown Hartford Transportation Project.

PROJECT OVERVIEW

The Downtown Hartford Transportation Project (DHTP) was organized to examine the likely impacts of unprecedented downtown growth on traffic congestion, parking availability, and the street environment in an era of decreasing availability of transportation funding. Jointly sponsored by major employers and the city of Hartford, the project's purpose was to develop and trigger implementation of a comprehensive program of actions to address Hartford's anticipated downtown transportation problems and to better manage the overall transportation system throughout the 1980s.

The DHTP was unique in many respects. Unlike more conventional, single mode transportation planning efforts, it examined all components of downtown transportation as an interactive system: traffic, parking, transit, pedestrian flow, and goods delivery. The implementation program that has been developed is comprehensive as well, including physical projects, such as crosswalk striping and traffic signal synchronization; management actions, such as peak-hour parking restrictions and work schedule changes; ongoing policy tools, such as requirements for transportation access plans for new developments; and organizational changes, such as the establishment of a Transportation Management Organization to coordinate private sector transportation actions. Most important, the DHTP has been conducted with a special concern for producing a widely accepted and implementable plan of actions.

Impetus

With more than 4 million ft^2 of scheduled new downtown development, both the city and the corporate community were concerned that Hartford's existing transportation facilities were inadequate to comfortably serve this much additional activity. Without improvements to the transportation system, downtown growth was likely to result in increased traffic congestion and air pollution, a worsening of an already tight parking situation, and a hostile pedestrian environment--all of which could make Hartford a less desirable place to work and shop. In fact, a major downtown department store announced plans to relocate to the suburbs, citing inadequacy of the transportation system as a major reason.

It was clear that there were no simple solutions to this dilemma--the shrinking availability of federal funds for major investments in street and transit facility expansion precluded relying on "big fixes." Although a number of efforts were underway in both the public and private sectors to manage more efficiently the use of existing transportation capacity (for example, carpool and vanpool programs and traffic engineering techniques), these efforts were not sufficiently aggressive or coordinated to produce the kind of results needed to make a dent in traffic or parking problems. Further, there was a sense of frustration in both public and private sectors that past transportation planning efforts were not producing results in a reasonable time frame, due both to a lack of general consensus about what should be done, and to the cumbersome bureaucratic process necessary for getting projects off the shelf.

In the summer of 1981, members of the corporate community acted on these concerns and initiated discussions with the city about conducting a comprehensive downtown transportation project, under joint public-private direction. The project was to develop a coordinated set of downtown transportation policies, an action plan of downtown traffic, parking, transit, pedestrian, and goods movement improvements, and an improved system of transportation project management. By January 1982, the project was underway, supported by $150,000 in private sector funds, and in-kind contributions from the city and other public agencies.

Accomplishments

The Downtown Hartford Transportation Project produced a set of goals, policies, and actions that the city and the corporate community have endorsed and that currently are being implemented. Clear roles and responsibilities for implementing each recommended action have been set forth and are forming the basis for currently ongoing activities. Perhaps most important, the project has established working relationships between the public and private sectors that are proving to be crucial not only for implementation of the action plan, but for future coordinated transportation planning and decision making in Hartford.

Implementation of the agreed-on policies and actions (see Table 1) was projected to enable the planned growth in downtown employment to be accommodated without a corresponding amount of growth in vehicle trips to the downtown. Because there is relatively little potential to increase the street capacity in Hartford through either construction or operational changes, emphasis instead was placed on management of the existing downtown transportation system, including actions to limit the increase in single occupant commuter trips and to encourage a wide range of more efficient travel choices. The goals of these actions is to increase central business district (CBD) work trips by transit and ridesharing modes from the present 52 percent to 61 percent over a 3-year period (see Figure 1). If this is achieved, a traffic analysis indicates that there will be no increase in the number of intersections experiencing serious delays. In the absence of the recommended actions, traffic at virtually every downtown intersection is projected to move more slowly than today, with almost twice as many inter-

TABLE 1 The Downtown Hartford Transportation Action Plan

Recommended Actions to be Implemented within a Year

Public Sector
- Peak hour parking prohibitions
- Improved enforcement at bus stops
- Peak hour delivery prohibition
- Bus stop consolidation
- Uniform Signing
- Designate streets pedestrian, vehicular, both
- Restrict turns
- Transit fare-free zone
- Increase on-street meter rates
- Restructure city parking facility rates
- Zebra-stripe cross-walks at major intersections
- Designate City Responsibility Center

Private Sector
- Restructure private parking facility rates
- Strengthen Downtown Council

Joint Public/Private
- Develop off-street delivery/pickup areas
- Develop off-street carpool staging areas
- Flextime/Staggered hours
- Establish target modal shares
- Main/State/Asylum pedestrian/transit improvements
- Adopt streetscape design guidelines
- Develop Main Street between Pearl and Gold as a streetscape prototype
- Develop Transportation Management Organization

Recommended Actions to be Implemented by End of 1984

Public Sector
- Signal interconnection
- Time of day signal phasing
- Eliminate selected exclusive pedestrian phases
- Classify streets for parking uses
- Require site access plan for zoning approval
- Improve on-street parking enforcement (increased tickets)

Private Sector
- Begin phase-out of employee parking subsidy
- Begin phase-in of travel incentives

Joint Public/Private
- Strengthen multi-passenger alternatives
- Hartford Federal block pedestrian improvements
- Implement target modal share program

Recommended Actions to be Implemented in 2-5 Years

Public Sector
- Computerized signal system
- Priority bus lanes

Joint Public/Private
- Develop remote parking facility
- Main Street streetscape improvements
- Civic Center/Allyn St. connector
- Bushnell Park gateways

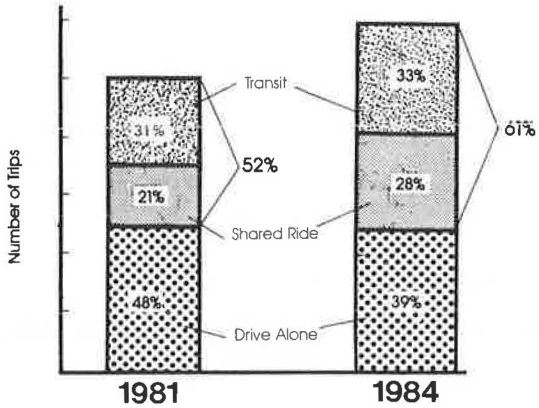

FIGURE 1 Target modal shares.

sections causing serious delays during the afternoon peak. Implementation of the action plan would provide 4,000 short-term parking spaces in the downtown, and at the same time continue to provide for adequate commuter parking (Figure 2). Currently, all but 2,000 of the 18,000 off-street parking spaces are full by 10 a.m. and only a handful are available at noon.

Implementation of the action plan will contribute to other important city, state, and federal objectives, in addition to economic growth. For example, although the project was not directly aimed at improving Hartford's air quality, the recommended actions were estimated to reduce downtown work-trip-related carbon monoxide and hydrocarbon emissions by 14 percent relative to what otherwise would occur in 1985, as well as contribute to decreased fuel consumption.

Of course, the individual recommendations that were adopted during the course of the DHTP were by no means new or unique. Many cities have instituted some form of access planning for new development--particularly in relation to granting reductions in minimum parking requirements in exchange for Transportation System Management (TSM) commitments (1). Groups of employers or nonprofit organizations representing the private sector have become increasingly involved in transportation issues during the past 5 years (2). Traffic and parking management techniques have long been applied in downtown areas. The notable aspect of the DHTP is not the individual projects that were recommended, but the nature of the planning process that occurred and that permitted a coordinated program of these individual actions to be adopted.

The DHTP provides an important model of a downtown transportation planning process that is collaborative and action-oriented. Key aspects of the DHTP--the type of public and private sector participation in the project, its scope of work, the process of "consensus-building" about actions that occurred, and the kinds of information and technical analysis used--are applicable to most downtown areas where significant new economic activity is occurring.

KEY FEATURES OF THE DOWNTOWN HARTFORD TRANSPORTATION PROJECT

Participation

There have been three types of "core" participants in the DHTP: representatives of Hartford businesses, public agency personnel, and consultants (Table 2).

Although the project was initiated and primarily funded by the private sector, funding was administered by the city, and responsibility for project management was assigned to the city Public Works Department. The city's project manager, however, worked out of a neutral territory--a special project office provided by one of the participating companies.

Because past transportation planning efforts had suffered from a lack of consensus about recommended actions and from a lack of emphasis on implementation, the project was set up from the beginning to involve those agencies and organizations whose cooperation, support (either technical or political), or resources might be needed for implementation of the recommended action plan. Within the private sector, the Chamber of Commerce, the Downtown Council (a chamber-sponsored group focusing specifically on the downtown), and the Greater Hartford Ridesharing Corporation were and are key participants. These organizations were responsible for coordinating the input from the many businesses and groups that actively participated in the project. Within the public sector, participants included the city manager, the city council, and key department heads within the city of Hartford, the Greater Hartford Transit District, the Connecticut Department of Transportation, and the Capital Region Council of Governments.

A team of five consulting firms was assembled to perform the technical work with collective expertise and experience in transportation planning, traffic

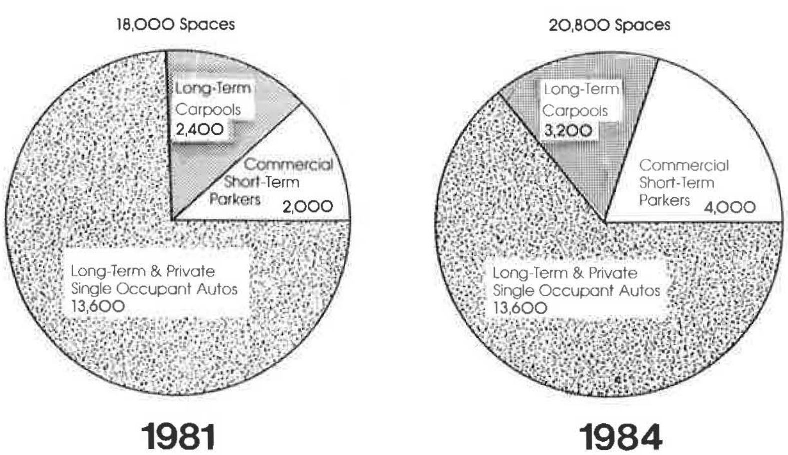

FIGURE 2 Target parking supply and use.

TABLE 2 Major Participants in Hartford Transportation Decisions

City

- Court of Common Council
- City Manager
- Public Works Director
  - City Engineer
  - Transportation Services
  - Engineering Services
  - Management Services
  - Operating Services
- Planning Director
  - Transportation Planner
- Finance Director
  - Purchases & Insurance
  - Accounting & Control
  - Pre-Audit
  - Financial Management
- Office of Management & Budget
- Police Department
  - Traffic Division
- Fire Department
  - Traffic Signal Maintenance
- Development Commission
- Parks and Recreation
- Human Relations Commission
- Redevelopment Agency
- Corporation Counsel
- Division on Aging
- Grants Administration

State

- Governor
- Office of Policy & Management
- Bond Commission
- Legislature
- Attorney General
- Department of Transportation
  - Commissioner
  - Bureau of Planning & Research
  - Bureau of Public Transportation
  - Bureau of Highways
    - Municipal Systems
  - Bureau of Administration
  - Consultant Negotiation Board
- State Traffic Commission
- Public Transit Authority

Regional

- Capitol Regional Council of Governments (CRCOG)
  - Policy Board
  - Transportation Committee
  - Staff
- Greater Hartford Transit District
  - Board
  - Staff

Federal

- Federal Highway Administration
  - Division Office
  - Regional Office
- Urban Mass Transportation Administration (UMTA)
  - Regional Office
- Environmental Protection Agency

Public/Private Partnership

- The Greater Hartford Ridesharing Corporation

Downtown Council

- Board of Directors
  - Staff

Chamber of Commerce

- Board of Directors
- Executive Committee
- President–Staff
- Transportation Committee
  - Highway Subcommittee
  - Employer Initiatives Subcommittee
  - Transit Subcommittee

Downtown Mobility Task Force

Retailers

Employers

engineering, transit planning, goods movement, parking management and enforcement, and urban design. Two of the consultants were former transportation officials from other cities; all of the firms had prior experience with transportation projects requiring public-private cooperation.

Scope

The scope of the DHTP was determined by the nature of the project sponsors' concerns, which were: (a) what can be done to maintain access to and circulation within the downtown given planned new developments; and (b) how to make sure that necessary transportation improvements are implemented given funding constraints and the slowness of project approval processes. These concerns dictated a very focused scope in terms of the geographic area, the time frame of concern, and the specificity of the solutions to be recommended, yet a rather open and comprehensive approach both to identifying potential problems affecting all components of the downtown transportation system and to devising types of solutions for addressing these problems.

Geographically, the DHTP is focused on the Hartford CBD, a 50-block area with a workforce of 42,000. (See Figure 3 for study area map.) The compactness of the study area allowed the kind of fine-grained data collection and detailed problem focus necessary to produce a well-defined plan of action. Moreover, it allowed for substantive input from the area merchants and employers, which was important to the development of a consensus about the action plan. In contrast to more commonplace corridor-level and regionwide transportation studies, which often include the downtown only as one component, the DHTP has been able to involve both important constituents for actions and key implementors of these actions. The result has been a transportation project equipped to develop realistic transportation policies and to put into practice management-oriented as opposed to capacity-expansion strategies for coping with downtown growth.

The DHTP is multimodal in scope because the expected increase in downtown activity will have impacts on all components of the downtown transportation system--parking, traffic, transit use, pedestrian activity, and goods delivery needs will all increase. Because these subsystems are so closely interrelated in a compact downtown area, addressing the expansion needs of one will have impacts on the others. For example, long-standing recommendations to improve pedestrian conditions on two major retail streets--Main and Asylum--would reduce traffic flow and transit capacity, while the potentially most effective signal rephasing improvement would have negative impacts on pedestrian movement. Development of an integrated plan of improvements and management strategies for all transportation system components allows potential conflicts among different users of street and sidewalk space to be addressed explicitly and provides an opportunity to develop coordinated and mutually reinforcing improvement strategies. The DHTP recommended an integrated street classification system that accommodates both traffic and pedestrian goals, allowing measures to increase capacity on certain streets, while restricting traffic and parking during peak hours on streets with heavy pedestrian activity (Figure 4).

Another important aspect of the DHTP's multimodal approach is that it includes policies for managing future growth in trips by encouraging use of the most efficient transportation modes, rather than merely planning around projections of unconstrained demand for each individual mode. For example, setting target modal shares (the relative split of trips by automobile and transit), reducing the amount of subsidized employee parking downtown, and expanding employer ridesharing and transit incentive programs are DHTP recommendations aimed at keeping traffic congestion in check by encouraging use of multioccupant travel modes.

The types of actions considered and recommended range from conventional, "tried and true" traffic engineering techniques to zoning code changes and employer-based transportation management practices. In contrast to more conventional transportation planning efforts that often focus on what one particular agency should do, the Hartford Action Plan was developed by and depends on the participation of many implementers, both public and private sectors, either working together or in sequence. For example, the integrated urban design component of the project provided a context for transportation planning, requiring that actions designed to improve transportation in the downtown contribute as well to the development of a more coherent city plan and a livelier streetscape.

In general, the action plan (3) features measures aimed at managing the use of existing transportation facilities through techniques such as:

- Improving facilities so they operate more efficiently,

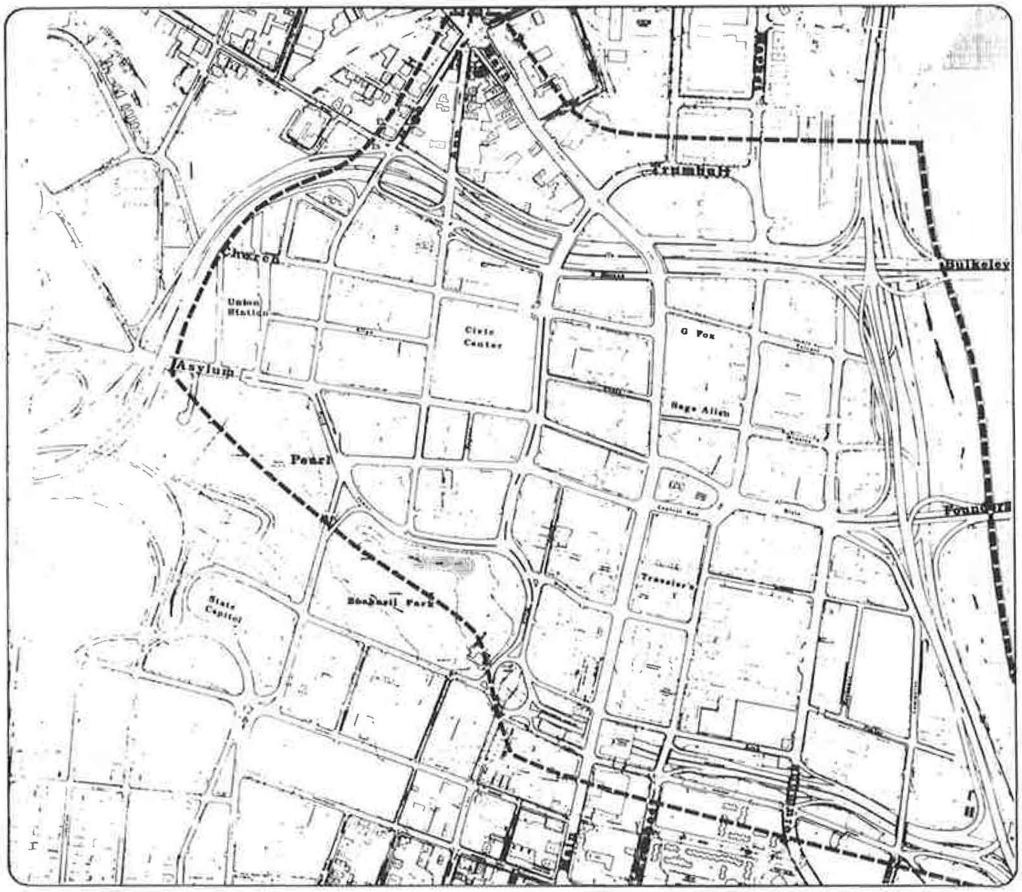

FIGURE 3 Geographic scope.

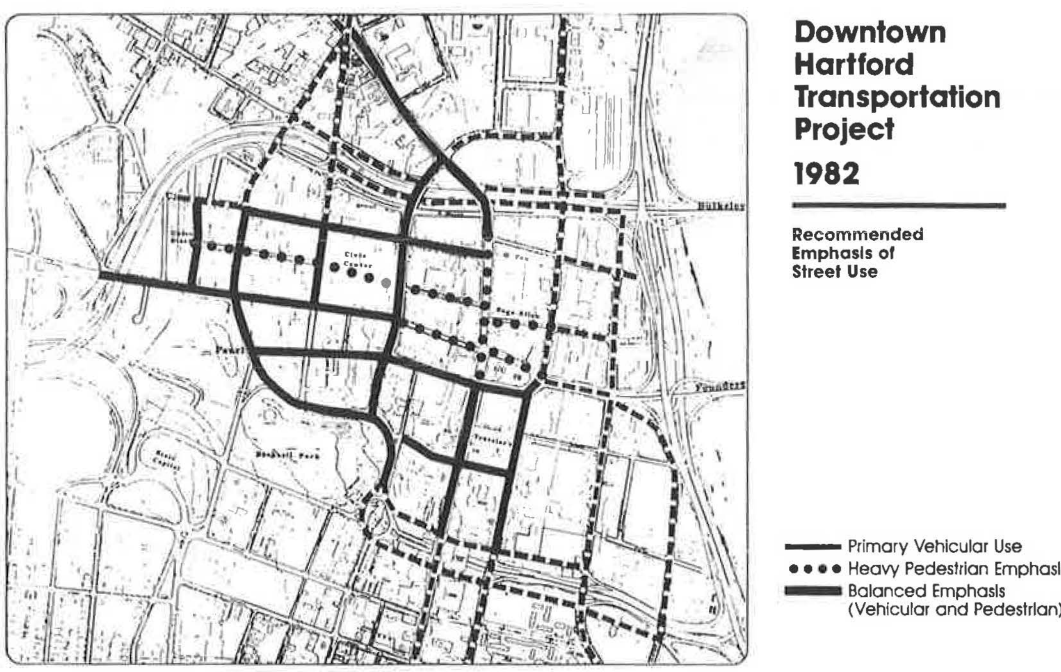

FIGURE 4 Recommended emphasis of street use.

• Improving the downtown streetscape and ease of circulation for pedestrians, and
• Providing Hartford with ongoing policy tools for managing future growth.

Assembling varied types of measures into an integrated package allows each measure to be viewed as part of an overall policy framework, thereby strengthening the implementation prospects for individual components of the plan. Another important aspect of packaging measures together was that inclusion of revenue generating actions (such as stepped-up enforcement of on-street parking regulations and institution of employer parking charges) tended to make the package as a whole more palatable from a financial perspective.

The final aspect of the DHTP's scope that is unique was the inclusion of an organizational analysis of the existing transportation project implementation process (4). This involved tracing the process by which city transportation improvement projects move from conception and initial design through the various stages of approvals, and finally to procurement of necessary materials and services for their implementation. Because the recommended plan of action was sufficiently ambitious that it would severely strain the existing project management and implementation process in the city, it was essential to identify the major sources of delay and take steps to create streamlined procedures. It was also necessary to establish an ongoing institutional mechanism for the public and private sectors to continue working together to successfully implement the developed transportation improvements. Thus, a system of two parallel responsibility centers was recommended, designating the city's Department of Public Works and the Greater Hartford Ridesharing Corporation as lead project management agencies in the public and private sectors, respectively (Figure 5).

Process

The DHTP can be characterized as a process of consensus-building which involved

1. Identification of, and agreement on, the most pressing downtown problems and needs to be addressed,
2. Agreement on a general approach to solving the identified problems, and
3. An iterative process of developing and screening successively more detailed policies and actions to be taken.

The problem identification phase of the project was organized around five subelements of the transportation system: traffic, parking, transit, pedestrian movement and urban design, and goods movement. The problems as perceived by the participants formed the initial nucleus. Site observation, interviews, field data collection, and projection of the impacts of new development were conducted for each of the five subelements, and existing and potential future deficiencies were summarized and presented to the DHTP participants. In some instances, the technical analysis confirmed the perceived problems (e.g., most off-street parking really was full at midday); in other instances, project participants learned that perceived problems, when measured objectively, were not as intense as initially thought (e.g., traffic congestion really was not very bad yet). In all cases, the technical work was presented in enough detail to assure its credibility. For example, questions about the number of additional employee trips that would be generated by new construction were answered at some length, with background information provided on the actual experiences with recent development in Hartford and other cities.

As a result of this explicit process of problem identification, general agreement was reached among project participants that future development could push Hartford's parking and traffic problems to levels they considered intolerable, and that something had to be done. Both public and private sector participants recognized that it would be both cost-prohibitive and damaging to the downtown environment to address these problems only by widening streets and building more parking facilities. From the beginning, there was a desire to determine what could be done to supplement construction improvements by managing the transportation system's use and growth, and participants made it clear that they were open to considering a wide variety of management strategies.

Four goals for the action plan evolved out of the assessment of problems and constituted the agreed-on general approach for solving the identified problems:

• Reducing the inconvenience of congestion,
• Managing the parking supply,
• Improving the street environment, and
• Improving public and private sector capability to manage the transportation system.

As the next step, an initial list of more than 30 policy options was drawn up that served as the basis for a more detailed, iterative design process. As

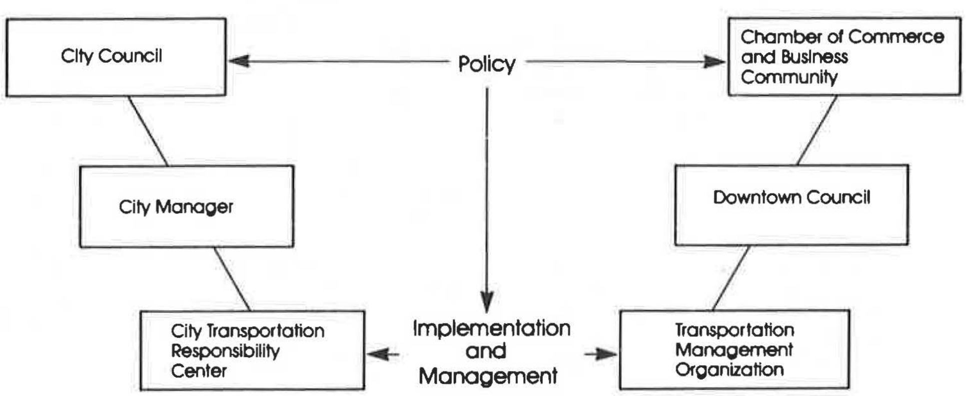

FIGURE 5 Recommended decision-making structure.

with the problem identification phase, special care was taken to include both new ideas and pending proposals developed by the participants. This original list of policy options was exclusive as well as inclusive, reflecting a deep skepticism about the feasibility of both transit expansion and "big build" solutions. The design process also involved a large number of off-the-record briefings and discussions to explain the rationale behind particular strategies and to discover and resolve disagreements about what should be done before formal presentation at a public meeting. In many cases, recommendations were modified to reflect concerns presented. It was during this period, for example, that a remote parking facility recommendation was clarified and an employee parking charge recommendation was strengthened and complemented with a range of other employee benefit options. Other concepts, such as identification of target modal shares and a target number of short-term parking spaces for the downtown, were developed into specific numerical recommendations during this period.

Some participants had concerns not about the intent of proposed actions, but rather about their associated costs; how they would be implemented, and how effective they would be. As a result of these kinds of concerns, further detail could be developed to put certain of the proposed actions on a firmer footing. Thus, the design process addressed both technical issues and potential implementation problems. Because low priority, high controversy actions were screened out, project resources were not unduly spent on analyzing measures that did not have a good chance of being implemented. These resources could be focused instead on working out necessary details for high-potential measures, which in turn helped project participants become comfortable with the evolving project recommendations.

There were five formal meetings of the project participants during the 11 months that the action plan was being developed. At each of these meetings (with the exception of the first, which was an introductory session) an endorsement or "yes" vote was given by the project participants for some major project milestone: agreement on the major problems, commitment to a set of general goals for addressing these problems, selection of policies to be analyzed for each goal, and finally, commitment to pursuing a specific set of actions. This process of obtaining periodic endorsements was facilitated by anticipating and responding to specific criticisms before recommendations were presented. The more informal, continuing discussions were a critical component of this overall process and constituted an extremely effective strategy for building a consensus. Most important, a central group of visible, respected individuals who had helped to initiate the project stayed deeply involved, taking the time to fully understand the technical work during each phase and then leading and focusing public discussion toward consensus on the most important issues.

Information and Technical Analysis

Information about existing downtown Hartford transportation conditions, and technical analysis to predict future conditions and the potential impacts of improvement measures played a key role in the DHTP. A solid, objective picture of transportation problems was essential for communicating a sense of priority to project participants and for laying the groundwork for developing policies. It was very important that the information collected be timely and credible--any suspicion about the quality or accuracy of the data could discredit the project from the start. Data collected for the project included traffic counts at all downtown intersections, morning and midday occupancy checks at all public off-street parking facilities, and turnover studies for a sample of on-street spaces. In addition, up-to-date information on transit ridership was analyzed, and subjective assessments of problems related to pedestrian movement, urban design, goods movement, as well as parking, traffic, and transit were made on the basis of site observation. Projections of trips to be generated by new development in 3 and 10 years were made and allocated to travel modes according to current shares. From the trip projections, estimates of future parking deficits and intersection level of service were derived.

It was also important to translate the technical analysis into nontechnical language and to use examples that participants could understand and easily relate to. For example, current and projected level-of-service rankings for intersections were displayed on maps and were discussed in terms of the length of delays a driver would experience. Parking conditions were described in terms of both the percent and actual number of spaces available at different times of day, and compared to conditions in other cities (5).

Because the action plan was to be comprised of very specific targeted measures, the data collected not only had to provide a good picture of what the problems were, but it also had to provide insights into both the causes of the identified problems and the policy initiatives that might effectively address them. For example, localized congestion problems were analyzed on a block-by-block basis to pinpoint causes, which included illegal parking, peak-hour deliveries, and passenger pick-ups. The shortage of midday parking in the downtown was traced, in part, to the fact that many Hartford employers subsidize parking for their employees, thereby encouraging them to drive alone into the downtown.

Experience at the Hartford Steam Boiler Inspection and Insurance Company indicates the impacts of decreasing employee parking subsidies and increasing transit subsidies (Hartford Steam Boiler, unpublished report). In 1982 the company provided a 40 percent transit subsidy and charged employees an average of $24 a month for parking (a 46 percent subsidy). In 1983 the transit subsidy was increased to 50 percent, and the average parking charge was increased to $44 a month (a 35 percent subsidy for solo drivers and a 50 percent subsidy for car pools). The result was an increase in bus use from 35 to 39 percent and a decrease in employee parking from 61 to 46 percent.

Putting the observed conditions into perspective by comparing them to other cities was useful throughout the project for distinguishing between real and perceived problems. For example, although congestion was perceived as being severe by many project participants, field observation showed that congestion was quite mild compared to other cities. Similar kinds of comparisons, such as the relative split between transit commuters and drivers in different cities, provided participants a basis for setting reasonable future goals for keeping congestion down by encouraging non-drive-alone modes.

Analysis of specific improvement measures focused on an assessment of what each action could accomplish toward achieving the agreed-on goals (Table 3). In addition, considerable emphasis was given to developing realistic cost and revenue projections, reflecting the implementation focus of the project. Estimates of implementation costs were developed, revenue sources were identified, and implementation responsibilities were assigned. Estimates of impacts were used to guide the technical design process and to illustrate how a comprehensive package of small-

TABLE 3 Estimated Traffic Volume Impacts of Recommended Program

Action	Effect on Peak Hour Traffic Volume	
1981 Base	11,000 vehicles	
1984 Increase	+2,500	(+23%)
Eliminate Employer Parking Subsidy	-750	(-7%)
Employer Program to Increase Transit/Rideshare Use to 62% of Work Trips	-500	(-4.5%)
Flextime to 1 Hour	-380	(-3.5%)
Convert 2,000 Additional Spaces to Short-Term Use (-750 and +500)	-250	(-2%)
Restrict Peak Hour On-Street Parking	-112	(-1%)
1984 With Recommended Action Plan	11,508	(+5%)

scale improvements could have a noticeable impact on congestion. While some parts of this analysis were modeled in detail, an appropriate mix of "back-of-the-envelope" techniques and experience with similar measures in other cities also were used in order to provide the participants an understanding of the likely impacts of a policy.

Implementation Focus

The developed action plan was designed to focus on those actions having a high probability of effective implementation and to provide project participants a clear understanding of their specific responsibilities for implementing the agreed-on recommendations. This includes an estimated budget for each action and a 1-, 2-, and 3- to 5-year timetable. The assignment of responsibility was an effort, at the request of both the public and private sector participants, to put project participants on the spot.

Overall, this approach is proving to be successful. At this time, the private sector is well underway with implementation of the initiatives for which they have either exclusive responsibility or share implementation responsibility with the public sector. This includes a major funding commitment to the Downtown Council and a substantial effort, coordinated by the Greater Hartford Ridesharing Corporation in its expanded capacity as the downtown Transportation Management Organization, to develop policy consensus among major employers. The public sector, assigned prime responsibility for 12 actions as well as shared responsibility with the private sector for other actions, has also taken important implementation initiatives, though at a slower pace than the private sector.

The city council directed the city manager to centralize transportation responsibilities in the city, as recommended, and has recently approved the closing of one block of State Street to facilitate development of an improved pedestrian space in the vicinity of the Old State House. Funding for other measures has been secured and the city has initiated detailed engineering design for the designated street improvements related to pedestrian and transit movement.

FOLLOWING THE HARTFORD EXAMPLE

Transferability

In Hartford, there were unique conditions that precipitated the DHTP. The business community had long been involved in transportation issues and was willing and able to commit resources toward transportation improvements. The Downtown Council in association with the Greater Hartford Chamber of Commerce had sponsored several studies, which provided many ideas for consideration by the DHTP, and both groups had been involved in raising funds for and setting up the Greater Hartford Ridesharing Corporation 1 year before the DHTP began. These activities, combined with the substantial commitment on the part of a number of Hartford employers to vanpool programs, paved the way for the type of public-private cooperation that characterized the DHTP.

Although every city has its own unique characteristics, history, politics, and problems, subsequent experience in San Antonio (6) and elsewhere indicates that certain features of the DHTP can be successfully adapted in other locales that want to better manage their transportation resources.

The sources of impetus for the DHTP--major downtown development plans, a shortage of parking, growing traffic congestion, tight transportation funding, major downtown employers seriously considering an exodus to the suburbs--can provide the necessary basis for a DHTP-like project, even in downtowns where public-private collaboration on transportation problems has been limited or nonexistent.

The following general guidelines can be used by cities that want to pursue a similar approach to that taken by Hartford in developing and implementing transportation improvements.

Organizing a Public-Private Collaborative Effort

The following steps should be taken to organize a public-private collaborative effort:

1. Find the right people to direct the project. The involvement of effective leadership from both the private and public sectors is central to a project of this nature, which involves considerable lobbying, support-building, and opening of new communication channels. Having the right people from the start can be critical to assembling the critical mass necessary for a successful project. People with leadership experience and contacts in both sectors can be especially valuable.
2. Share sponsorship and direction of the project between public and private sectors. Public-private collaboration can be initiated by either the public or private sector, as long as both public and private sectors invest in the project and have shared responsibility to direct it and ensure that it is responsive to the concerns of both. This will increase the likelihood that the project will produce a unified plan of action to which both public and private sectors are strongly committed.
3. Involve all parties having potential resources or responsibilities for project implementation. To ensure that the project will produce actions that are practical and implementable, it is important to obtain the involvement of all potential implementers of the proposed actions. Although it may not be productive to have everyone involved in a formal and substantive way, an effort should be made to periodically touch base with all relevant parties to eliminate unanticipated barriers.
4. Take advantage of "neutral experts." People with expertise in design and implementation of transportation management measures can play a critical role in the project not only by contributing technical expertise and knowledge about how similar measures have worked in other cities, but by serving as neutral mediators among involved parties.

Defining the Scope of Work

To define the scope of work:

1. Address the pressing concerns of downtown employers and of public agencies responsible for downtown transportation system planning and operation. Framing the project in terms of the "hot issues" on everybody's agenda (in Hartford, the parking shortage was an issue) will attract the interest and involvement necessary to make the project more than just a "paper study."

2. Be comprehensive enough to account explicitly for the interrelationship among transportation system components. The key to successful downtown transportation system management is recognizing and addressing conflicts among different users (pedestrians, cars, buses, parkers) and maximizing the people-moving capacity of the system. Failure to address the problems and capabilities of any of the system components may close key opportunities to solve problems of another related component.

3. Pay attention not only to "one-shot" actions, but also to continuing policies and institutional mechanisms required for effective ongoing management of the transportation system. It is important that the project result in a set of commitments to implement a specific set of actions in order to demonstrate that the public-private partnership is indeed an effective mechanism for getting things done. Management of a downtown transportation system, however, is an ongoing process that must continually be adjusted to respond to changing downtown conditions, particularly as downtown development occurs. Therefore, it is important to establish a policy framework for future transportation decision making along with corresponding institutional mechanisms in both the public and private sectors to carry out the agreed-on polices.

Assembling the Necessary Information

In order to assemble the information needed

1. Use high-quality, up-to-date data. Good quality information on transportation conditions is essential for both developing appropriate management strategies and for developing the necessary support for implementing strategies. Thus, using out-of-date information, data collected in previous studies that have been challenged on technical grounds, or collecting only limited information when the whole picture is needed (e.g., counting the cars in only a small sample of parking facilities) may cut costs but can seriously impair the project's credibility and ability to achieve a consensus about actions to be taken. Although existing data may be available and useful, selective and carefully designed new data collection will almost always be necessary.

2. Assemble information that is relevant to policies and management strategies that may be considered. While data collection is traditionally conducted before policies and other potential solutions start to be developed, anticipating the kinds of policies and transportation management measures that may be appropriate allows a data collection effort to be structured to provide policy-sensitive information. For example, if traffic signal synchronization appears to be needed, an effort might be made during data collection to quantify the range of delay that could be avoided through institution of this type of measure. If on-street parking enforcement is perceived as a problem, violation rates could be observed and the potential benefits of stepped-up enforcement (greater turnover, increased parking availability for shoppers) could be quantified.

3. Make relevant information from other cities available. Information about how other cities are coping with similar transportation problems is invaluable for fueling the project with ideas, and for reducing the uncertainty and natural hesitancy about implementing new kinds of strategies.

Building a Consensus

In building a consensus, it is necessary to

1. Employ a phased strategy of consensus building, starting with general agreement on what the problems are, and moving toward agreement on specific actions. The set of actions ultimately agreed on should evolve inexorably from agreement on the major problems to be addressed, the general approach to be taken to addressing them, and the policy framework to be adopted. This sequence involves project participants in an important learning process beginning with a clear understanding of the problems, an exploration of alternative solutions, elaboration of the strengths and weaknesses of each proposal, and the building of confidence that the final recommendations are the result of a careful and systematic assessment of opportunities.

2. Encourage extensive informal discussions among participants. Formal meetings of project participants serve an important function, but the real work of eliciting honest opinions and resolving concerns, for a variety of reasons, is best done "behind the scenes." Project participants can use informal, small group discussions to be more specific about interests and concerns, and project staff have the time in this setting to provide a detailed discussion of a particular point. Building an effective consensus involves marshaling a great deal of technical analysis to address problems that have many small components. Discussing each aspect in enough detail to satisfy the legitimate concerns of each individual participant in a large, formal meeting is likely to be extremely tedious for most participants during those portions of the meeting when their own personal interests are not being addressed. The result is an obscuring of the larger, more important issues. Smaller meetings are an ideal forum for this type of detailed discussion.

3. Use a screening process to eliminate low-priority or unpopular actions from consideration. Although it is important to start off with a wide range of alternatives for consideration, it is wasteful of project resources and damaging to the project's credibility and support to prolong consideration of alternatives that would be ineffective, infeasible, or the target of insurmountable opposition. This does not mean, however, that all alternatives that may be controversial should be eliminated. For example, in Hartford, the recommended phasing-in of employer parking charges has been extremely controversial but was nevertheless included as a recommendation not only because project participants agreed that it would be an extremely effective strategy, but also because major employers were ready to explore alternatives to continued employer-provided parking subsidies.

4. Include strategies with revenue generating potential to offset costs of other strategies in the recommended package. Parking fees are becoming an increasingly important transportation revenue source in cities and can be used both to adequately price the use of scarce downtown land resources and to support other strategies aimed at improving the pedestrian environment or encouraging use of alternative travel modes to the downtown. Inclusion of revenue-generating measures in a comprehensive downtown transportation action plan can significantly add to the implementation potential of the package as a whole.

Using these guidelines, the Hartford experience can serve as a useful model for approaching similar transportation problems in other cities.

ACKNOWLEDGMENTS

This paper is based on work performed during 1982 as part of the Downtown Hartford Transportation Project, a collaborative public-private effort performed by Cambridge Systematics under contract to the city of Hartford. Other firms participating in the Hartford project included TAMS, Moore-Heder Architects, The Urban Partnership, and Brophy and Associates. The findings and recommendations presented, thus, represent work of the entire consultant team as well as the many private and public sector participants.

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Urban Development Models for the San Francisco Region: From PLUM to POLIS

POULICOS PRASTACOS

ABSTRACT

Most of the operational urban development models were designed 15 years ago and do not reflect the planning concerns of the 1980s. PLUM (Projective Land Use Model), the land use system developed for the Bay Area in 1970, suffers from conceptual and operational limitations that hinder its use. A new model, which is structurally and behaviorally different from the traditional Lowry models, was designed at the Association of Bay Area Governments. The new model, referred to as POLIS (Projective Optimization Land Use Information System), is based on microeconomic behavioral principles; it is formulated as a mathematical programming problem and considers job location, housing selection, and trip making in an integrated fashion.

Urban modeling is the science that attempts to represent in mathematical terms the location and interactions of activities within a metropolitan urban environment. The origins of the field can be traced back to the early 1960s when the growing problems of cities and the widespread use of automobiles in every aspect of everyday life necessitated the development of analytical tools that could assist planners in evaluating policy alternatives and predict and prescribe the future.

A transportation planning process that focused on comprehensive planning and long-range capital investments for transportation facilities, coupled with a massive increase in federal assistance to state and local governments, led to the design of urban development models for several metropolitan areas during the period 1960-1975. The vast majority of these models were developed in planning agencies rather than academic environments and had ambitious goals. It was widely believed that models could be used for comparing the effects of alternative transportation networks; for controlling and directing urban growth; and for analyzing urban redevelopment plans, the existence of racial ghettos, and problems of poverty and housing deterioration (1,2).

The failure of the models to meet the initial grandiose goals resulted in a backlash for urban modeling. As planners gained experience, they realized that models could not solve the urban problems and became critical of the use of models in planning. Lee (3) proclaimed that large-scale models are dead, whereas the empirical work of Boyce (4) and Pack (1), who studied the actual experience of planning agencies, showed that urban models had minimal impact on policy and decision making.

Critics of urban modeling were correct in pinpointing the limitations of the early models, but failed to notice that most of these arose from either the overambitious expectations about the role of models in planning or the general lack of knowledge about the state of the art and the capability to implement successfully complex mathematical equations. They did not provide an alternative methodology that could address some of the more modest goals and potential applications of large-scale models (consistent set of forecasts, evaluation of alternative transportation improvements).

As a result of the reversal of attitude toward models, few, if any, models have been developed for metropolitan areas in the last decade. Urban modeling research has been carried on at the universities, often at a theoretical level, or abroad, mainly in England, while planning agencies continued using the models of the 1960s without any improvement or modification. However, local governments and planning agencies are still faced with the issues that led to the massive application of models before 1975. There is still a need to disaggregate regional population and employment totals among smaller spatial units; there is still a need for a consistent set of forecasts that could permit a local government to plan for capital improvements and a regional agency to carry out evaluation of new projects (A-95 review). Finally, because of the limited availability of capital, there is a greater need now to analyze thoroughly the impact of alternative transportation improvements.

Today, planning agencies are attempting to answer these questions with models that are 20 years old. Most of the operational models are descendents of the work of Lowry (5) in 1964 and the 1965 early version of EMPIRIC (6). These models represent the planning concerns of their time, concerns that were different in scale and scope from today's problems. They describe an urban environment with a population composition, economic structure, and geographic distribution significantly different from the one that exists today. Accordingly, they cannot be used to answer the problems of today. The mere recalibration of these models with recent data is not enough because they are based on socioeconomic assumptions that are no longer valid. Planning needs of the 1980s must be addressed by procedures that recognize the key behavioral and economic issues that influence the location of households and firms.

Reported in this study is the experience of the Association of Bay Area Governments (ABAG), the planning agency of the San Francisco region, with the implementation of POLIS (Projective Optimization Land Use Information System), a land use and transportation model that is behaviorally and structurally different from the models used in the past. PLUM (Projective Land Use Model), the ABAG land use modeling system in the 1970s, is reviewed along with its limitations. The rationale behind the new model and its mathematical structure are discussed and the potential applications of the model for planning are outlined.

THE ABAG MODELING SYSTEM IN THE 1970s

The history of land use models in ABAG goes back to the early 1970s when the Series 1 projections for the Bay Area were developed based on the PLUM model. The PLUM model, one of the most widely known variants of the Lowry model, was first developed in 1968 at the Institute of Transportation and Traffic Engineering of the University of California by a research team led by William Goldner (1). It was adopted by ABAG and through time became synonymous with the ABAG modeling system. During the period 1970-1978 it was calibrated for several metropolitan areas and underwent a series of changes at ABAG and the San Diego Comprehensive Planning Organization. Most of the changes altered the outputs of the model but not its internal structure.

The PLUM modeling system consists of two major models that operate in sequence, BEMOD (Base Employment Model) and PLUM. The former provides an allocation of basic employment to place-of-work zones. The employment allocations from BEMOD are then used to "drive" PLUM, which locates population, housing, and local serving employment and accounts for the land absorbed and the land use constraints. In addition to these two models the system contains a myriad of utility models that prepare the inputs and disaggregate the outputs of PLUM by income, housing structure, type, and so forth.

The most recent implementation of BEMOD in the Bay Area recognizes 14 industrial groups. Through a modified shift-share process, regional totals for these sectors are partitioned among the four Standard Metropolitan Statistical Areas (SMSAs). Within SMSA, zonal employment allocations are made on the basis of regression equations developed from a cross-sectional analysis of 1964 data. The independent variables include the size of vacant industrial area, the amount of developed basic land, the zonal share of county employment in the base year, and physical characteristics such as mean elevation, presence of water frontage, and so forth. When applying the model to project future employment levels the coefficients of the regressions are held constant.

The spatial allocation of households and local serving employment in PLUM involves a three-step process. First, the changes in basic employment derived from BEMOD are allocated to residential locations by a probability function describing the willingness to commute. Then, based on these residential allocations and the location of basic employment, demand for population serving employment is estimated. Home-to-shop and work-to-shop probability functions are used for that purpose. The third stage of PLUM checks for violation of any land use constraints. Any zonal residential demand exceeding land supply is reallocated to the nearest zone with available land.

The PLUM modeling system has several shortcomings that limit its usefulness for the planning needs faced today in the San Francisco Bay Area. There are serious conceptual limitations that arise from the assumptions embedded in the system. The most significant of these are described next.

1. The model disregards to a great extent the interaction between jobs and housing. It assumes that changes in housing location patterns do not

affect the location of industries. This might be true for the traditional heavy manufacturing sectors but does not apply to "footloose" industries. Intraurban locational decisions of these firms are influenced by the availability of a qualified labor force and the presence of agglomeration economies rather than the amount of capital invested in the past, the magnitude of transport costs, and environmental concerns. The electronics, research and development, finance, insurance, and real estate (FIRE), and business services sectors, which constitute the most prominent, and fastest growing segment of the Bay Area economy, are typical examples of footloose industries.

2. The model overemphasizes the importance of the traditional basic sectors (agriculture, mining, manufacturing transportation) in the economy. Employment in these sectors is allocated first and assumed to be the dynamic element in the economy. However, with the rapid transformation of the economy from one centered in heavy manufacturing to one driven by industries with high technology and financial products, the basic/nonbasic partitioning does not fully describe the dynamics of the different sectors. In the Bay Area, high-technology-related jobs are expected to double in the next 20 years, FIRE employment is expected to increase by almost 50 percent, while traditional manufacturing (SIC 20-34, 37) will experience a growth of only 20 percent in the same period.

3. The PLUM system as formulated lacks a behavioral interpretation. It describes the urban system as it exists in the base year without attempting to explain the decision making at the micro level. Residential choice is simulated by a function that replicates aggregate trends, but does not address the decisions of the individual household searching for a house. The allocation algorithm for the industries is based on established patterns and not on some economic concept such as profit maximization. This approach disregards the behavioral aspects of every locational and trip-making decision and can be of limited use in environments undergoing changes in the sectoral composition of employment, household size, labor force participation rates, and the amount of land available for development.

4. The model represents the transportation system in simplistic terms. There is only one mode, and generalized travel costs are defined to be equal to travel time. None of the behavioral techniques for modeling the travel to work or the travel to shop behavior is utilized.

5. The model cannot easily handle planning and zoning constraints. The allocation algorithm for housing and local serving jobs operates sequentially through the zones in zone-number order. Land constraints are addressed at the end of each iteration, at which point overflows are reallocated in the next iteration. This procedure often distorts the results of the model because overflows are allocated to distant zones because all the nearby zones are filled (7).

In addition to the conceptual limitations, the San Francisco version of PLUM suffers from several operational problems that hinder its use. The zonal system (440 zones) is not homogeneous and zones vary substantially in size, population, and housing characteristics. The 440 zone system, which was initially specified to facilitate detailed traffic analysis, is very disaggregate for 20 years' projections. At this level of detail the model's output is so large that the planner cannot properly evaluate it, and the modeling process is a number-crunching nightmare.

The other major operational problem with PLUM is the sheer size of the computer code. PLUM was originally written in 1968-1970 and has never undergone a complete revision. Over the years different users have made changes and modifications on an ad hoc basis, most of which are not documented. The original code has more than tripled and is now unmanageable. The procedure for running the different programs is so cumbersome that it can take 2 to 3 weeks to complete a full run of the model.

FRAMEWORK FOR A NEW MODEL

The PLUM system was used during the 1970-1980 period to generate three sets of projections (Projections 1, Series II, and Projections '79). When preparing for the next round of projections in 1982, it became obvious that the shortcomings of PLUM were too serious and could not be corrected. PLUM had grown to be a dinosaur and contained assumptions that were outdated. The experience with the latest set of projections in 1979 had also indicated that some of the zonal forecasts of PLUM were often inaccurate. It was then decided to abandon the complete PLUM system and construct a new model that could be useful in conducting strategic planning for the 1980s.

As a first step in developing a new system, a thorough analysis of the objectives and constraints of the modeling process was carried out. In order to avoid the disillusionments of the early land use models, it should be clear from the beginning what the model is expected to perform and the constraints that are imposed by limited resources and our knowledge of the state of art. To accomplish the former, the Bay Area economy was studied to pinpoint the planning concerns of the next 20 years and to define the important variables and interactions that the model must consider. This analysis led to the following conclusions that guided the overall modeling process.

1. The model should simulate the interaction between jobs, housing, and regional transportation systems and should provide a consistent description of the future patterns of development.

2. The primary use of the model will be for prescriptive purposes; that is, to produce projections, reconcile forecasts with local jurisdiction's constraints, and to balance jobs and housing.

3. Because the model could at some time in the future be used for policy impact analysis, it should be sensitive to the variables that are affected by changes in policy, namely, provision of housing, location of large development projects, and construction of new transportation facilities.

4. The model must have a behavioral interpretation and must be based on economic concepts (utility maximization, profits).

5. Local planning and zoning constraints are very significant in the development process and should be explicitly considered by the model.

Because our efforts were not supported by a research grant, two resource constraints were imposed: (a) the new modeling system must be developed in-house and should be operational in less than 12 months, (b) the data required for calibration should be readily available from the 1980 Census, or from ABAG's data base. These two constraints played a crucial role in the design of the new model, and the final form and structure of the model is an attempt to meet the guidelines and objectives under the resource constraints.

The outcome of the modeling effort was the design and calibration of POLIS for the Bay Area. POLIS is a land use-transportation model that allocates employment and housing at the subregional level and estimates commuting flows and shopping trips. It is different from the traditional, Lowry-type land use models in three key respects: (a) it is based on microeconomic behavioral principles; (b) it is formulated as a mathematical programming problem; and (c) it considers job location, basic and nonbasic employment, residence selection, and trip making in an integrated fashion.

STRUCTURE OF THE MODEL

The allocation process in POLIS is based on several criteria, some reflecting the behavior of the locators and some describing the physical and planning constraints imposed on a growing urban region. Residential choice is determined by the travel-to-work and shopping behavior, the availability and inherent attractiveness of housing, and the existence of nearby employment opportunities. Retail activity is located in proximity to population centers to maximize sales revenue. The profit maximization and cost minimization objective of the different industries is translated into locational patterns influenced by the accessibility to labor supply, the existence of agglomeration economies, and the interindustry relationships.

In a drastic departure from the long history of operational land use models, which are formulated as a system of equations whose solution can be carried out only through an iterative procedure, POLIS is cast within the framework of mathematical programming. In this framework, decision variables are optimized with respect to prespecified goals while satisfying the planning constraints. The use of mathematical programming to describe the urban system has advantages and disadvantages. The major disadvantage is that it results in a complex mathematical notation and solution procedure; the major advantage is that residences, employment, and trip flow patterns are estimated in a single iteration and are consistent with each other and the land use constraints. There are no overflows of activity to be reallocated, and the final solution is not sensitive to the sequence in which zones have been numbered.

The main difficulty in designing an optimization land use model is the specification of the objective function. Because the results of the model must describe the most probable land use configuration at some future time, the objective function must reflect goals that are widely accepted to govern the formation of cities. In a free economy system the plurality of decision making makes it difficult to define a unique objective. Earlier attempts to build normative models failed because they used objective functions which, at best, could be considered as partial representations of reality. For example, the objectives of cost minimization and overall efficiency in the works of Schlager (8) and Mills (9) are not realistic because they presuppose the existence of some authority regulating all growth activity.

In the proposed model the objective function is defined by invoking the framework provided by random utility theory (10,11). The fundamental premise of random utility theory is that an individual faced with a set of alternatives will choose the one that maximizes his or her utility or surplus. Accordingly, the appropriate objective for an urban growth model is the maximization of the total locational surplus. The surplus can be interpreted as the total net benefits arising from a specific plan or policy, and its maximization reproduces the individual behavior at an aggregate level.

The functional form of the locational surplus can be obtained by analyzing the choice mechanisms the model is expected to simulate. In POLIS, activity patterns are affected by locational decisions of two decision makers: individual selecting a job and a nearby house to live in, and firms choosing the site to locate new employment opportunities. The job-housing choice is reduced to a simple residential choice because intraregional wage differential for the same type of job is often insignificant. Residential choice is assumed to be influenced by (a) the location of workplace, or more correctly, the duration of the travel to work trip; (b) the mode of travel to work; and (c) the shopping behavior of the individual. Invoking the formalism of random utility theory (12), it can be shown (13) that in this case total locational surplus or benefits are given by

$$Z(T_{ijm}, S_{ij}) = \left\{-(1/\beta^{w}) \sum_{ijm} T_{ijm} \left[\ln \sum_{m} T_{ijm}/W_i \; -1\right]\right\} + \left\{-(1/\lambda) \sum_{ijm} T_{ijm} [\ln T_{ijm} - 1] - \sum_{ijm} T_{ijm} c^{w}_{ijm}\right\} + \left\{-(1/\beta^{s}) \sum_{ij} S_{ij} [(\ln S_{ij}/W^{s}_{j}) - 1] - \sum_{ij} S_{ij} c^{s}_{ij}\right\} \quad (1)$$

where

T_{ijm} = number of work trips from i to j by mode m,
c^{w}_{ijm} = travel cost of the work trips from i to j by mode m,
S_{ij} = number of shopping trips from i to j,
c^{s}_{ij} = travel cost from i to shopping activities at j,
W_i = nonlinear transformation of the utilities interpreted as an indicator of the attractiveness of zone i for residential choice,
W^{s}_{j} = nonlinear transformation of the utilities interpreted as an indicator of the attractiveness of zone j for shopping, and
β^{w}, β^{s}, λ = parameters converting the utility associated with trip making into monetary units compatible with the transportation costs incurred.

The first two components of Z define the locational surplus attached to residential choice when considering only work trips; the multiple dimension of the decision process associated with work trips results in two surplus functions: one for destination and one for modal choice. The last component depicts the contribution of the shopping behavior in the total surplus.

The maximization of the locational surplus Z, in addition to describing individual trip making and house-seeking behavior, results in location patterns for retail activities that are consistent with the profit maximization principle. By maximizing the accessibility of consumers to shopping establishments, the accessibility of shops to potential customers and therefore the expected revenues are also maximized.

The location of nonretail industries is integrated in the mathematical framework by adding to the objective function the factors influencing their locational decisions. For the sectors dominating the Bay Area economy (electronics, research and development, finance, and services), it is assumed that the two most important factors are access to qualified labor and existence of agglomeration economies. The first factor is already part of Z; the surplus function represents the locational benefits of the employees with respect to their travel-to-work behavior; hence, it maximizes the accessibility and interaction between labor supply and labor demand.

Agglomeration economies arise from the propensity of firms to locate adjacent to each other in order to take advantage of some common resources. When several firms locate in the same area, they cumulatively create an environment that induces growth and facilitates business. Access to sources of capital, labor market economies, proximity to suppliers and competitors, access to specialized business services, and superior training facilities are some of the components that are referred to as agglomeration economies.

Because these economies cannot be easily quantified or estimated, the proposed model uses surrogate variables to simulate their impact. Two types of agglomeration economies can be discerned: those occurring at the zonal level and those exhibited at the macro (county) level. The former stem from the inherent attractiveness of small areal units and are directly related to zonal characteristics such as relative cost of land and accessibility to other employment centers. The latter consist of the causal relationships that link activities to each other and represent comparative advantages and profitabilities arising from the existing structure of production. The intersectoral relationships shown by the input-output table and the tendency of certain industries to locate in specific counties are the most significant ones.

Zonal economies are incorporated in the objective functions by adding the component

$$\sum_{i,k} f_i^k(\cdot)E_i^k \tag{2}$$

in Z, where $f_i^k(\cdot)$ is a function of some zonal characteristics and represents the agglomeration potential of zone i for sector k and E_i^k is employment of the same zone and sector. Macro economies are integrated in the model by adding equations in the constraint set, which show the spatial sectoral relationships for each county and sector. These equations take the form

$$E_{co}^k = a + b\,E_{co,t-1}^k + \sum_{q \in Q} c_q\,E_*^q \tag{3}$$

where subscripts co and t-1 denote, respectively, county and lagged variables E_*^q is total regional employment in sector q to be allocated among the different counties, and Q is the set of sectors with which industry i has strong economic relationships.

The objective function represents the joint surplus of the individuals seeking homes and firms locating new employment. It does not include any component related to the limited availability of land because land restrictions are not part of an individual's behavior. In an environment that has unlimited development potential, locators locate so that their surplus is maximized. If, however, land constraints do exist, then locators might be forced to select second best choices. In the POLIS framework, the issue of limited availability of vacant land is handled easily by specifying constraints that limit the development in certain zones.

POLIS simulates the changes between two states. At each time period only the new increase in employment opportunities and households is allocated, and relocation of base-year jobs is handled by appropriately increasing the number of jobs to be distributed. The total number of jobs and housing to be allocated is given exogenously and is derived from regional economic models.

The complete mathematical representation for POLIS is as follows:

$$\begin{aligned} \max Z(T_{ijm}, S_{ij}^k, \Delta E_j^n, \Delta H_j) = {} & (-1/\beta^w) \sum_{ij} T_{ijm} \left[\ln\left(\sum_m T_{ijm}/W_i \right) - 1 \right] - (1/\lambda) \sum_{ijm} T_{ijm} \left[\ln T_{ijm} - 1 \right] \\ & - \sum_{ijm} T_{ijm}\,c_{ijm} - \sum_{k \in K} (1/\beta_k^S) \\ & \sum_{ij} S_{ij}^k \left[\ln(S_{ij}^k/W_j^k) - 1 \right] - \sum_{ijk} S_{ij}^k\,c_{ij} \\ & + \sum_{i,n \in K} (f_i^n)^{an}\,\Delta E_i^n \end{aligned} \tag{4}$$

subject to

1. Origin-destination constraints for work trips T_{ijm}. Work trips out of a zone are related to the number of households through a trip generation rate a_i

$$\sum_{jm} T_{ijm} - a_i(H_i^o + \Delta H_i) = 0 \tag{5}$$

Work trips in a zone are related to employment through a trip attraction rate b_j^n

$$\sum_{im} T_{ijm} - \sum_n b_j^n (E_j^{no} + \Delta E_j^n) = 0 \tag{6}$$

2. Origin-destination constraints for shopping trips S_{ij}^k. Shopping trips out of a zone are related to the number of households through a trip generation rate e_i^k

$$\sum_j S_{ij}^k - e_i^k(H_i^o + \Delta H_i) = 0 \tag{7}$$

Shopping trips in a zone are related to retail employment through a trip attraction rate h_j^k

$$\sum_i S_{ij}^k - h_j^k(E_j^{ko} + \Delta E_j^k) = 0 \tag{8}$$

3. Land use density constraints for employment and housing. Available land limits the number of jobs and households to be allocated in a zone

$$\sum_n d^n\,\Delta E_j^n \leqslant \bar{L}_j \tag{9}$$

$$\overline{\Delta H}_{i,lb} \leqslant \Delta H_i \leqslant \bar{V}_i \tag{10}$$

4. Allocation of all employment and housing. All regional employment and housing units must be allocated

$$\sum_j \Delta E_j^n - \bar{E}_*^n = 0 \tag{11}$$

$$\sum_i \Delta H_i - \bar{H}_* = 0 \tag{12}$$

5. Spatial-sectoral constraints for county employment. Employment in one sector is related to employment in other sectors

$$\sum_{j \in P_c} \Delta E_j^n - \sum_{q \in Q} \sum_{j \in P_c} c^q\,\Delta E_j^q - y_c^n = 0 \tag{13}$$

6. Exogenous location of employment and housing (policy constraints). A priori allocate a certain number of jobs and housing units in some zones

$$\Delta H_{i,lb} \leqslant \Delta H_i \tag{14}$$

$$\Delta \bar{E}^n_{j,lb} \leqslant \Delta E^n_j \leqslant \Delta \bar{E}^n_{j,ub} \quad (15)$$

$$T_{ijm}, S^k_{ij}, \Delta H_i, \Delta E^n_j \geqslant 0 \quad (16)$$

where

S^k_{ij} = number of shopping trips from zone i to service activities of sector k in zone j,

ΔE^n_i = number of new jobs for sector n in zone i,

ΔH_i = number of new housing units (households) in zone i,

$\bar{L}_j$ = area of land available for employment growth in zone j, and

$\bar{V}_i$ = vacant residential land in zone i.

Most of the constraints are self-explanatory. With the coefficients e^k_i denoting mean expenditures per per household, the flow variables S^k_{ij} can be interpreted as volume of sales. The two land use constraints (9,10) can be combined if there are no restrictions on the type of development that can occur in an area. Finally, the constraints (Equations 14-15) have been added to handle the exogenous location of large development projects. By appropriately specifying the lower bounds, the model can be used to evaluate the systemwide effects of these projects.

The number of trips can be obtained by considering the Lagrangian function. It can be shown (Equation 13) that at optimality trip flows are equal to

$$T_{ijm} = A^W_i H_i B^W_j E_j \exp(-\tilde{\beta}' c_{ij}) [\exp(-\lambda c_{ijm})/\sum_m \exp(-\lambda c_{ijm})] \quad (17)$$

$$S_{ij} = A^s_i H_i B^s_j E^s_j \exp(-\beta^s c^s_{ij}) \quad (18)$$

where A^W_i, B^W_j, A^S_i, and B^S_j are the balancing factors, β' is a transformation of β, and λ and $\tilde{c}_{ij}$ is the composite travel cost between i and j given by

$$\tilde{c}_{ij} = (1/\lambda) \ln \sum_m \exp(-\lambda c_{ijm}) \quad (19)$$

The expression for the trip flows is the well-known nested logit model similar to the one derived from a behavioral analysis at the micro level. This is another indication that, although POLIS is formulated at the aggregate (macro) level, results in spatial interaction patterns are consistent with individual behavior.

POLIS can be estimated in two different ways. The first approach is to use a standard nonlinear programming algorithm to estimate the dual problem of Equations 4-16. It is easier to solve the dual instead of the primal because the former has a significantly smaller number of variables and constraints. The second approach is to exploit the structure of the primal and solve the model by applying the Bender's Partitioning Algorithm. Although the direct solution is preferable, the current version of POLIS employs the partitioning solution method because the author did not have access to a nonlinear programming algorithm at the time the model was first designed.

ESTIMATION AND CALIBRATION OF POLIS

The complete land use transportation model was calibrated for the San Francisco Bay Region using data from two different time periods, 1975 and 1980. The empirical estimation relied only on already available data; no major data collection effort, such as a household survey or a special tabulation of census data, was undertaken. Different sources of information were used, and as a result, the data were often inconsistent. The major sets of data used were:

1. 1975 distribution of jobs and housing and complete land inventory (available at ABAG);
2. 1980 distribution of jobs and housing (available from the 1980 Census);
3. 1975 detailed (440 zones) travel-to-work trip tables by mode and level of service characteristics--travel time, distance, value of time (available from the Metropolitan Transportation Commission);
4. 1980 aggregate (30 zones) shopping trips table;
5. 1975-1980 development activity and 1980 development potential for every zone;
6. 1980 household soicoeconomic characteristics (available from the census).

For the purpose of the model the 9 counties of the Bay Area were divided into 107 zones, each representing an aggregation of census tracts. Two modes, automobile and transit, and four employment sectors were recognized. The four sectors were:

1. Manufacturing;
2. Transportation, Finance-Insurance-Real Estate;
3. Retail Trade; and
4. Services

The implementation of the model in the Bay area consisted of three major tasks: estimation of the attractiveness weights and agglomeration economies function, specification of the spatial sectoral equations (Equation 13) and complete calibration of the model to determine the values of β^W, β^S, λ, and α^n. Because POLIS has a complex structure and because there was no information on 1980 travel-to-work trip flows, the seven parameters could not be calibrated simultaneously. An alternative procedure was devised and the model was calibrated in three stages. A complete discussion of the calibration process can be found in The Land Use Information and Transportation System for the San Francisco Bay Region (13).

To evaluate the ability of the model to forecast accurately, the calibrated model was used to forecast the 1980 location of housing and jobs; 1975 was the base year. The goodness-of-fit statistics of these forecasts with the actual 1980 data are tabulated in Table 1. The goodness-of-fit of both the total values and the incremental 1975-1980 changes are reported.

Overall the statistics depict a fairly good fit. The R^2 for total housing and for each of the employment sectors are all between .85 and .91. The figures for total employment and housing, .89 and .90, respectively, indicate an almost perfect fit. These high values might arise from the fact that the model allocates only the total regional change, which, for the 1975-1980 period, does not exceed 35 percent of the employment and 20 percent of the in-place housing.

The fit of the model when comparing the forecasts with the actual 1975-1980 change was also acceptable. The R^2 for housing and employment drops to .74 and .78. There is a wide variation in the fit of the different sectors. Retail Trade is the sector with the best fit (.82), whereas transportation and FIRE exhibits the worst fit (.64). The fit of the basic sectors is on the average less successful than that of the retail and service sectors. This may be attributed to several factors; for example, it is

TABLE 1 Results of the Calibration Goodness-of-Fit of Predictions With Actual 1980 Data

	R^2
Housing units	
Total	.90
1975-1980 change	.74
Total employment	
All sectors	.89
Manufacturing	.90
Transportation, FIRE	.84
Retail trade	.91
Services	.85
1975-1980 employment change	
All sectors	.78
Manufacturing	.75
Transportation, FIRE	.64
Retail trade	.82
Services	.74
Trips to work (1975)	
Total	.79
Automobile	.81
Transit	.69

possible that the zonal agglomeration functions were not defined or calibrated correctly, or that some of the factors influencing locational decisions of basic industries were ignored. Additionally, some errors are introduced by the way some sectors are defined; the sector of transportation and FIRE includes employment groups that do not have the same locational characteristics. The fit of total employment is superior to that of most of the individual sectors, a sign that the model captures the aggregate locational patterns.

An interesting aspect revealed by the goodness of fit statistics is that the model is more successful in predicting total employment than housing. Housing that was not disaggregated by ownership type or quality characteristics--price range, age, number of units in structure--has a fit that is not as good as the one for total employment. These results indicate that extensions in the model should be in the area of disaggregating housing by type and introducing supply equations linking supply and demand.

Only the fit of the travel-to-work trips is reported because there was not a detailed trip table for shopping trips. The fit of the work trips is not as good as expected. In aggregate transport studies, R^2 in the range of .85 to .95 are not uncommon. However, it should be kept in mind that the model was calibrated to reproduce the 1980 distribution of housing and employment and not necessarily the trip table for 1975. The R^2 obtained after the first stage of the calibration process, when the parameters were calibrated to reproduce the 1975 trip tables, were close to .90. Finally, the generalized costs and values of time were taken from another study and might not be the appropriate ones for the proposed model.

POTENTIAL PLANNING APPLICATIONS OF THE MODEL

A major reason for building a new land use information system for the San Francisco area was the need to provide a tool that could be useful in strategic planning. The Bay Area economy is undergoing a series of structural changes that will have significant repercussions on the utilization of the transportation network, the differential growth of various communities, and the adoption of zoning policies. Some of the issues that can be addressed by POLIS include:

- The impact of changes in local policies regarding land development;
- The impact of accelerated shifts in regional employment from manufacturing to research and development, finance, and services industries; and
- The impact of investments in the transit system, such as the proposed extension of BART, on the location of housing and employment.

The first issue is related to the development policies of the different cities and counties of the Bay Area. A community's development policies include general and specific plans and other programs to either encourage or discourage development activity in an area. Local zoning regulations for the type and density of new developments, capital improvement schedules, and building permit allocation are some of the methods used to manage the rate of growth.

The different land use policies of local government can be used to define the supply of land available for accommodating future households and employment activities. Their impact can be easily simulated by POLIS because land constraints are explicitly considered in the model. Policies imposing lower densities for new residential units can be directly translated into number of acres available for development or potential housing units, and their citywide and regionwide impacts on housing location can be tested. More important, because the model addresses the issues of housing supply and employment location in a systematic fashion, the impact of the policies restricting housing growth or the number of jobs attracted in the affected areas can also be simulated.

The second issue, change in the sectoral composition of employment, can have profound effects on the character of the Bay Area. The new industries have locational patterns and labor force requirements that are in several aspects different from those of traditional manufacturing. They are characterized by an increasing emphasis on decentralization and product specialization, reliance on the availability of a well-educated labor force, and diminishing requirements for large initial capital outlays. All of these might result in considerable shifts in population and employment. Employment in areas that traditionally have been considered to be "dormitory towns" are suddenly swelling because of the rapid increase in the number of self-employed individuals and the formation of many small companies with specialized products, computer software, for example.

The emerging tendency in some industries to locate the office close to the homes of the employees might lead to a substantial divergence in the growth rates of the current central business districts (CBDs) and the peripheral areas; eventually, this will have important repercussions on the transport network utilization. Traffic volume on the CBD-bound highways and transit systems might remain steady or even decline. In the peripheral areas--Central Contra Costa, Solano, and Sonoma counties--where the automobile is often the only available mode of transportation, the congestion on the highways might lead to chaotic situations.

POLIS has the capability to simulate the impact that changes in the composition of regional employment will have at the local level and can assist in the evaluation of the various policy alternatives. Employment is disaggregated in four sectors and can be further disaggregated should the need for a more detailed analysis arise. Transportation is integrated in the framework, and trip-flow matrices for different growth scenarios can be computed and policy implications can be derived.

Finally the last issue, evaluation of investments in transportation infrastructure, is the issue for which the majority of the land use models have traditionally been designed. Investments in the transportation infrastructure alter the accessibility of certain areas, which, in turn, induce locational shifts. Additionally, as noted earlier, the change in the locational patterns might lead to an increased demand for transport in areas where the infrastructure is inadequate. It must be acknowledged that because of the relatively high level of aggregation of the transport network, the model does not lend itself to the simulation of minor transportation investments, for example, highway interchanges, rather it lends itself only to major additions to the system. The proposed extensions of the BART system and the provision of improved transit services in the high growth areas are examples of investments whose impacts could be tested by POLIS.

CONCLUSION

In the last 10 years the field of operational urban models has been in a stagnant state. Disillusionment with the early applications of the Lowry model has led most public agencies to abandon efforts to build urban development models. To this author's knowledge, POLIS is the only comprehensive land use-transportation model implemented for a metropolitan area of the United States in the last 10 years. The calibration of the model for the Bay Area points out that meaningful models can be calibrated despite data availability and limited resources constraints. Finally, the successful use of POLIS for producing long-range subregional forecasts for the Bay Area is an indication that large models can be useful for planning purposes if cast in the appropriate framework.

ACKNOWLEDGMENTS

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Development of a Simulation Model to Study the Impacts of Rapid Urban Growth on the Transportation Sector—The Case of Charlotte, North Carolina

G. BUDHU and D. GRISSOM

ABSTRACT

To successfully plan for the development of a region, it is necessary to understand the possible causal relationships, feedbacks, and interactions between the different sectors of the region, including the transportation sector. In this paper a conceptual framework is presented along with a mathematical model for studying the problems of urbanized regions using system dynamics and simulation techniques developed by J.W. Forrester. The conceptual view of the approach is presented by causal submodels of the eight main sectors of the economy: population, housing, business, heavy manufacturing, light manufacturing, government, agriculture, and transportation. The mathematical model, which is represented by 96 differential difference equations, was used to evaluate the impacts of three urban policies on the transportation sector: (a) heavy manufacturing, (b) light manufacturing, and (c) downtown development. Policy c provided the least negative impacts on the transportation sector; that is, with a level of service of 0.6 for freeways and 0.4 for primary arterials, and even more significant, only 0.3 of the urban land fraction occupied by 1990. The strength of the proposed modeling technique presented here is not so much in the absolute values of the output of the three investment strategies, but, rather, in the use of the model as a planning tool to understand and study the direction in which the economy is likely to go and especially the impacts of a given urbanization policy on the transportation sector.

Urban growth or decline involves a complex interaction and feedback phenomenon among the various socioeconomic sectors and main growth shapers in a region, such as transportation, utilities, open space and major activity centers. As such it should be analyzed with its main socioeconomic and growth shapers explicitly incorporated in the planning model. Past planning models based on the analysis of a single sector or component of an urban system have not been able to deal with some of the significant long-term induced problems, such as traffic jams, in-and-out migration, and urban sprawl. This may be because (a) the nature of the problem has not been fully understood, and (b) the current methodologies cannot explicitly incorporate and trace the key variables that create and sustain the problem of the urban system over time.

PURPOSE AND OBJECTIVES

Essentially transportation in terms of economic development is a derived demand and is dependent on the development plans of the other sectors of the economy. The correct task of transportation planning, therefore, consists of the accomplishments of all necessary movements of people and goods at a minimum overall cost to the economy (1). The overall purpose of the paper, then, is to analyze and evaluate the causal forces and feedback phenomena that underlie growth or changes in an urbanized region and the effect of such growth on the transportation sector. The specific objectives of the paper are to

1. Collect data in order to define urban variables and their relationships.
2. Develop both the causal model and calibrate the mathematical model that explains urban growth or change.
3. Apply the developed model as a tool to determine the strategic or long-term transportation needs for different urban investment plans; that is, manufacturing, and business.

Concept of the Model Development

The model development is based on the fact of the interdependence of the main sectors of the economy. A simple block diagram can portray the interrelatedness or interdependence of the urban economy. Figure 1 shows that any financial allocation in any of the key sectors affects the other sectors and feeds back eventually on itself. Figure 1 also shows that if nothing else, urban land availability will eventually constrain urban growth or that continued growth in one sector will be at the expense of the other sectors in terms of land occupancy.

Several variables must of necessity be required to explain these complex interaction and feedback phenomena of the different sectors. Figure 2 shows a conceptual framework of the socioeconomic sector as an example for the causal and mathematical models. Consider a policy that favors downtown business expansion. Such a policy can be represented by the following variables and their associated impacts. Business Construction increases Business Structure (as indicated by the plus sign at the end of the

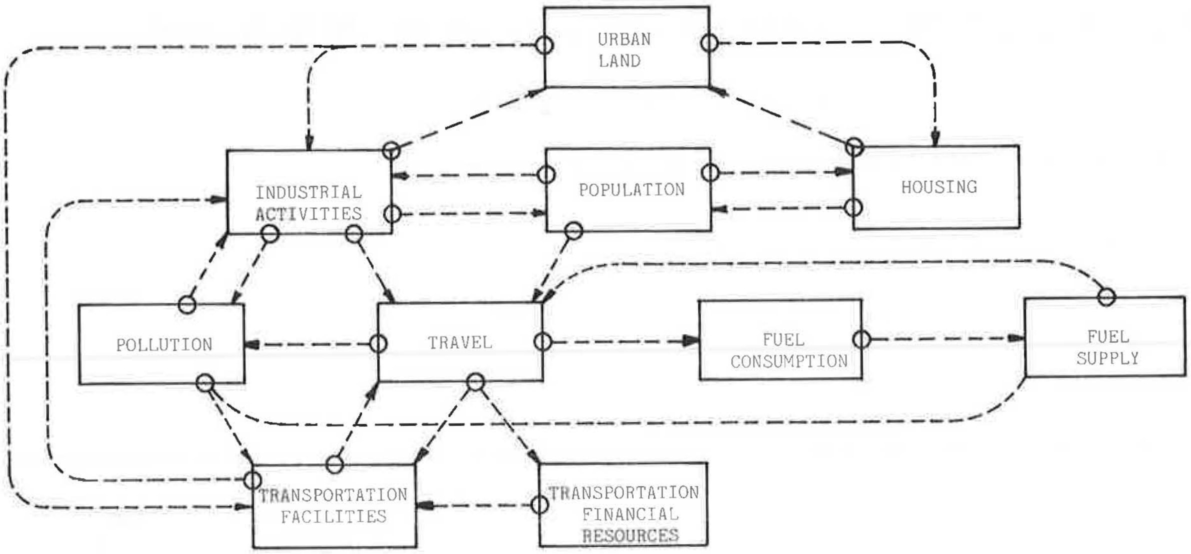

FIGURE 1 Transportation within the urban system *(2)*.

arrow in Figure 2), Business Structure, in turn, increases the number of Employment Opportunities, which positively affects Population; an increase in Population stimulates Land Development, and an increase in Land Development in turn increases Land Availability, which feeds back to Business Construction, thus encouraging further growth. However, a reduction in free land or Land Availability suppresses or negatively affects further business expansion. From this loop, the effect on the transportation sector can be felt through the Population and Employment Opportunities variables; that is, population and jobs are the key variables in most transportation trip generation models.

The causal model depicted in Figure 2, even though it is a powerful tool in understanding the complex interrelationships involved, is of little use in addressing the quantitative needs and resulting impacts in an urban region for any given policy. These relationships must be converted to mathematical forms if meaningful planning is to be done. Both the causal models and the mathematical relationships are developed after Forrester's (2) System Dynamics Methodology. Differential difference equations are developed for each variable in the model; as an example of a formulation, the mathematical equation for highway construction is presented.

$$RCR_{t+1} = \text{Min}\ [DFR_t (RCB_t/CCPM) URLAM_t]/RCT$$

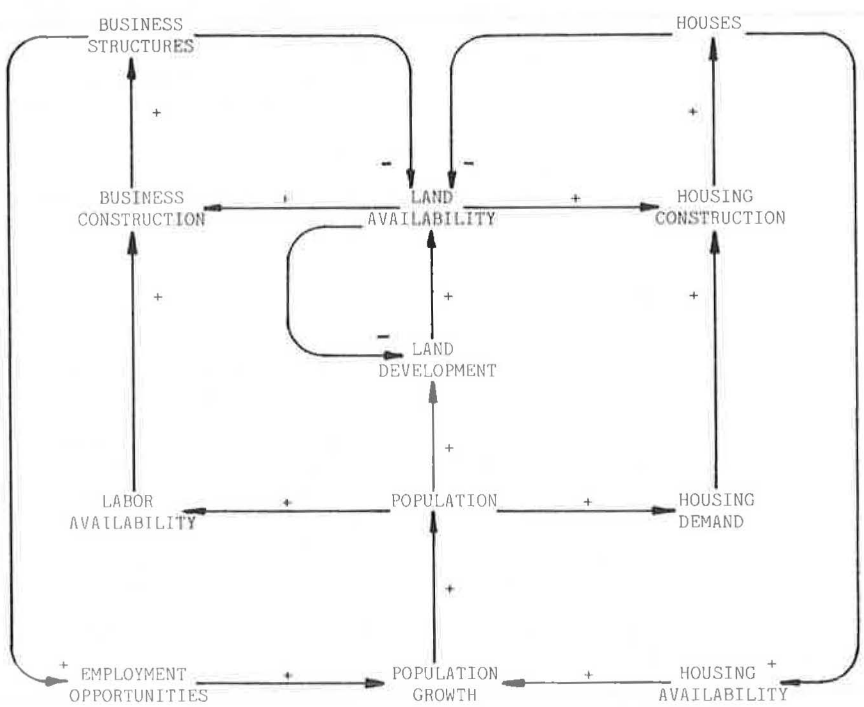

FIGURE 2 Socioeconomic sector.

where

RCR_{t+1} = road construction rate (mile/year) at time t+1;
Min = minimum of the function;
DFR_t = demand for road at time t;
RCB_t = road construction budget at time t;
CCPM = construction cost per representative mile of road in the network;
$URLAM_t$ = urban road land availability multiplier, which represents the availability of urban land for road construction; and
RCT = road construction delay time; that is, the time required for road construction from planning to operation.

Procedure

Each sector of the urban economy presented in Figure 1 was examined and modeled independently to determine the intrasectoral variables, causality, and feedbacks. The key points (variables) of linkages were then identified and the individual sectoral submodels were linked at these key points (variables) to form a single mathematical model for the urban region. Solution of the single mathematical model then provided directions in which the economy is going and the demand for usable highway miles in the simulation period for a given urban development strategy, manufacturing, business, and so forth. The developed model was calibrated with real-world data; in this study, the data base of Charlotte, North Carolina, was used.

CASE STUDY OF CHARLOTTE, NORTH CAROLINA

The city of Charlotte is approximately midway between Atlanta, Georgia, and Washington, D.C., at the intersection of I-77 and I-85. It is the hub of a 12-county region known as metrolina. Its favorable climate; that is, mild winters and summers, and its sparsely populated counties, together with fairly good transportation and proximity to the Atlantic Ocean and the mountains has moved Charlotte into one of the high growth southern Sun Belt cities. The accelerated economic growth has begun to show its impacts on the city road network. Level of service on the main arterials are E to F in the peak. Moreover, the current growth is likely to continue in the foreseeable future. The authors believe that the city presents a good example for an integrated system approach to determine strategic transportation needs under various manufacturing and business investment policies. The basic socioeconomic data for the city is given in Table 1.

Model Calibration

With a model this large [i.e., eight sectors: (a) population; (b) housing; (c) business; (d) heavy manufacturing; (e) light manufacturing; (f) government; (g) agriculture; and (h) transportation] whose formulation is based on observed data, assumptions, and concepts drawn from demography, economics, agriculture, transportation, and technology, it is particularly important to test its predictive ability over a period of time.

Calibration was attempted as follows: a set of variables (over a 10-year period) whose characteristics more or less determine the regional behavior was compared with the model (or simulation) output for the same period. Table 2 gives the comparison between the model values and the observed values (data) for population, housing, heavy manufacturing, business, and highway miles. A difference of less than 10 percent between the predicted model and the observed data was acceptable as an adequate calibration.

TABLE 1 Basic Socioeconomic Data of Charlotte

Basic Data	1970	1980
Population	354,656	404,270
Housing units	114,974	156,134
Business	1,645	2,270
Heavy Manufacturing	652	827
Light manufacturing	1,335	1,987
Agriculture establishment	46	111
Transportation network (miles)	912	1,012
Government establishment	1,000	1,600
Land area (square miles)		138

Note: Data collected from various reports on the socieconomic data base for Charlotte, North Carolina.

TABLE 2 Predicted and Observed Values

	Time (year)	
Variables	1970	1980
Population		
Model	354,656	400,710
Observed	354,656	404,270
Percent difference	0.00[a]	0.88
Heavy manufacturing		
Model	652	886
Observed	652	827
Percent difference	0.00[a]	6.66
Transportation		
Model	912	1,033
Observed	912	1,012
Percent difference	0.00[a]	2.03

[a] Beginning of simulation.

Development Policies

Most cities' growth can be ascribed to a combination of planned growth through zoning, ad hoc decision making, or piecemeal acquisition and conversion of land to different use. Irrespective of the developmental process, today's city transportation engineer is expected to provide, or at least recommend, a plan that would provide viable mobility in the city. As such, the engineer may react to growth or, as suggested in this paper in the case of Charlotte, assume a certain direction of growth for a given planning period and thus identify the probable transportation needs for a given investment direction. The model will be used to simulate the following policies for the city:

1. Emphasis on heavy manufacturing,
2. Emphasis on light manufacturing, and
3. Emphasis on downtown business development.

The impact of each one of these policies on the highway network will be analyzed in terms of lane-miles of road needs and peak-hour level of service provided for (a) freeways, (b) primary arterials, (c) minor arterials, and (d) local roads, under the assumption that the rate of highway construction continues as it is currently being planned and as it is at present.

Policies in the system dynamics methodology are incorporated in the model through the rate variables. Recall from Figure 2 (the causal model of the socioeconomic sector) that Business Structure has a positive impact on both Population and Employment Opportunities and that the population and jobs variables

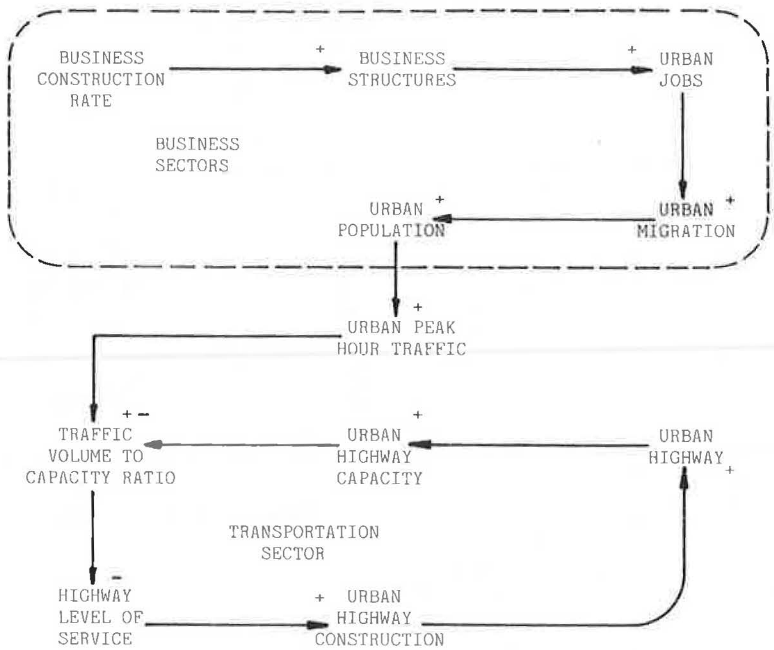

FIGURE 3 Linkage between the business sector and the transportation sector.

are generally the key variables in transportation trip production modeling. A simplified causal model showing the linkage between the socioeconimic sector and the transportation sector is shown in Figure 3.

Figure 3 also shows how the impacts of Policy 3, emphasis on downtown business development, determines Urban Peak Traffic and Traffic Volume-to-Capacity Ratio for the urban highway network. The rate variable Business Construction Rate is used to incorporate various policy decisions on downtown development.

Analyses and Impacts of Different Urban Policies

Table 3 gives a summary of the information on the main socioeconomic indicators for the city at different points in time. A close examination of Table 3 reveals the following impacts:

1. Population: Within 10 years Policies 1 and 2 show an increase in population from 404,270 to 510,520 and from 404,270 to 605,040, respectively, whereas Policy 3 shows a change of 16.5 percent in 10 years.
2. Roads: The demand for new roads; that is, lane miles is most crucial for Policy 2, a change from 1,033 to 2,010.
3. Level of service: Policy 3 will reduce the highway system to a level of service C in 20 years.
4. Land fraction occupied: Policy 2 is the most demanding on land development rate: 60 percent occupied within 10 years.

Figure 4 shows a typical time series plot for total highway needs for the city.

CONCLUSIONS AND RECOMMENDATIONS

In dealing with a complex system, the structure of the solution process sometimes appears more important than the solutions themselves because the lack of definition of the right problem is much more crucial than finding a sound answer to the wrong problem. System Dynamics, through the use of feedbacks and simulation allows constant evaluation of the approach to the problem because a trace of the behavior of a given policy is provided instead of a projection to a given point in time.

TABLE 3 State of the Economy Under Different Urban Policies

Indicators	Policies No. 1	No. 2	No. 3
Time (years)	1990 or in 20 years[a]	1990 or in 20 years[a]	1990 or in 20 years[a]
Population	510,520	605,040	470,860
Roads			
Freeway (miles)	118	130	128
Primary arterials	426.7	460	430
Level of service			
Freeways	C	C	C
Volume-to-capacity ratio	0.6	0.7	0.6
Primary arterials	C	B	B
Volume-to-capacity ratio	0.7	0.5	0.4
Land fraction occupied	0.4	0.6	0.3

[a]Beginning of simulation, 1970.

The Effect of Future Trends on Trip Patterns, Urban Commercial Structure, and Land Use

J. H. SHORTREED, P. MAY, and E. DUST

ABSTRACT

The "Third Wave" or the information society is changing our society. The major effects are: (a) reductions in traditional labor activities such as manufacturing and data gathering; (b) growth in jobs that deal mainly with information; such jobs can be located almost anywhere, including the home; and (c) growth in available leisure time, and an increase in the potential for achieving living style objectives. One possible outcome of these major effects is a dramatic restructuring of urban areas including the decentralization of urban nodes over a whole region. This is in direct contrast to the industrial society in which the urban structure has a highly centralized, hierarchical form focusing on the regional or metropolitan city as aptly described by central place theory. This growth pattern reversal dramatically changes the requirements for transportation facilities from those contained in existing transport facility plans. The effect of the third wave may result in the placement of many existing plans at risk in that the projected transport demands may not materialize. In this paper an approach to evaluating the risks to transport investment in southern Ontario is described. A series of exploratory models is being developed to implement the concepts presented in the paper. By incorporating other dimensions of the locational behavior of individuals, these models are extensions of economic base theory and the Lowry model.

The "Third Wave," or the information society, is predicted to sweep across our society in the next few years (1). Many changes are expected to take place in its wake. The objective of this paper is to assess the impact of these changes on urban structure and transportation. In particular, an approach is proposed to estimate the changes in the southern Ontario region, which is centered on Toronto.

The term "wave" implies a washing effect of all-encompassing change, which will characterize the Third Wave. It is based on the widespread application of computers in all aspects of life and an order of magnitude advance in communication systems. So many changes are expected to occur in so many sectors so quickly that modeling them with certainty would be an impossible task, yet it is believed that the impacts of these changes are too important to ignore. By identifying the major trends, it may be possible to estimate the direction and the likely magnitude of changes in both population and employment and their impact on the requirements for new capital investment in transport.

The changes become clearer if the current urban structure is examined. With the industrial revolution and the development and maturation of the industrial society, there was a continual growth in cities within a region. This growth was focused in a hierarchical way on the central city in the region; for example, reference is made to the New York region, the Chicago region, and the Toronto region. Around the central city were a number of subregional cities and a number of local cities as described in the classical central place theory. The driving forces were the economies of scale from mass production and the advantages of locating firms near the market and near a large skilled labor pool. These forces continued unabated until about the 1950s when a few of the world's largest cities began to decline. People from rural areas were attracted to the growing hierarchical cities by better jobs and a higher standard of living.

The driving forces behind the industrial society are accurately represented by the Lowry model. The Lowry model uses basic employment as the driving force behind the location of land use. Around this basic employment the population and labor force is located within commuting distance, then the service employment and its associated population and labor force is added. Today, however, basic employment is declining because of increased mechanization, replacement of office functions by computers, and so forth. Therefore the use of the Lowry model to predict future land use will no longer be valid because the driving forces of the industrial society are changing.

The information society has been appropriately conceptualized by Toffler (1) and its progress has been monitored by Naisbitt (2). It is estimated that as much as 75 percent of the current labor force deals only with data and information. There is no longer the necessity to be at a particular physical location because data and information can now be communicated and processed anywhere. Moreover, the large mass production, industrial, and manufacturing plants that were the root cause of the location and growth of regions of cities were the first to be computerized and automated. They had many repetitive, low skilled, high-wage jobs that had the best return on computerization.

Figure 1 shows the impact of the decline in manufacturing on population and transport volumes in London, England. (Personal communication with D. Bayliss, London Regional Transport.) The data are for Greater London and illustrate the decline in manufacturing and employment and the growth in the service sector. The growth in employment in finance, business, and public service is also subject to reduction through computerization, and the first

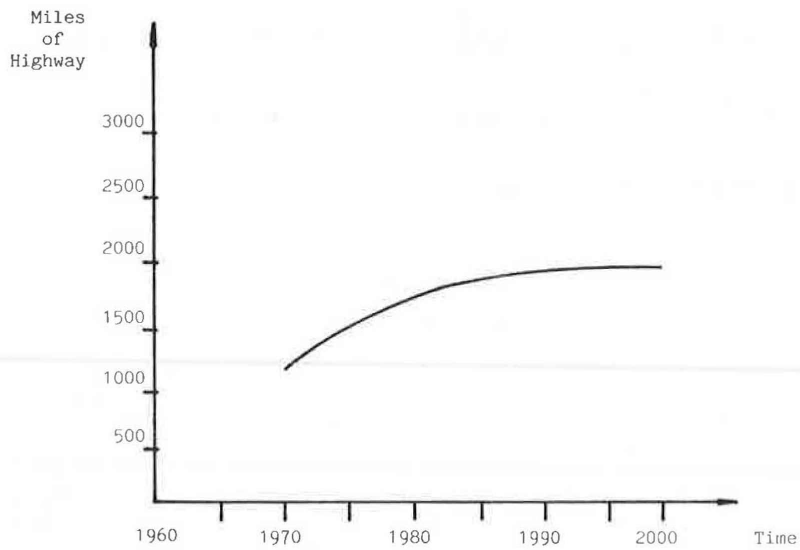

FIGURE 4 Time series plot for highway miles: policy no. 2.

Further, the methodology or modeling technique can be used to communicate and incorporate the views and opinions of groups not involved in the building of the model. By experimenting with changes in policies and model parameters and observing the effects of these changes on behavior, these groups can help or be helped to better understand the dynamic forces at work in the real world.

At first glance, the size (eight sectors) and "seeming complexity" of the model (feedbacks and differential difference equations) might be questioned for its usefulness for transportation planning. However, the allocation of large sums of money in transportation and related economic infrastructure that affect the lives of present and future generations must of necessity be carefully analyzed if negative impacts are to be minimized.

A planning model that affects growth should provide insights into where the economy is likely to go for a given urban investment policy. The output from the model for a given policy is not significant in terms of its absolute value but rather should be used as information indicating the direction in which the city is likely to evolve in the forseeable future for a given urban policy.

Further, because the output from the model is a trace of the performance of the economy through time, the model can be used to study post-project (decision) performances. If forecasted values are not realized, timely adjustments could be made to key resources (inputs) in the city to correct unwanted impacts.

Policy 3 for a simplified macroscopic approach to the Charlotte scenario provides the best (i.e., positive) impacts on highway miles and level of surface and should be further investigated, that is, more adeptly calibrated and simulated for a given horizon or planning period.

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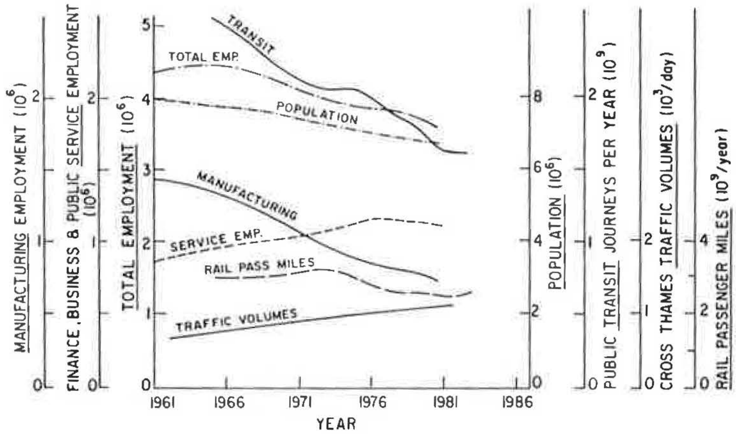

FIGURE 1 Trends in Greater London at the onset of the information society.

sign of this was seen in the late 1970s. The decline in employment and population in Greater London has an associated growth in population in the rest of the London region as the population has decentralized to other urban areas in the region.

As shown in Figure 1, there is a significant decline in the use of the total transit system while the traffic volumes continued to grow and now appear to be stabilizing. Rail passenger miles that mainly serve the central area have maintained their level primarily because of increasing journey length from an average of 4.45 mi in 1965 to 4.80 mi in 1983.

The impacts in terms of investment requirements in transport facilities show an interesting shift from expansion of capacity to a focus on quality of service and efficiency.

> [In] the 1960s it was anticipated that investment (in London's public transportation system) would be needed to increase capacity by the expansion of signalling sections on key sections of the railways, increase train lengths and building new underground lines to provide relief to the worst overcrowding. Most of these capacity expansion schemes have been abandoned with the exception of resignalling the busier main line termini approaches. Even this is designed to improve quality of service as much as capacity. The emphasis currently is to invest to improve productivity in order to sustain the network, to improve interchange to increase its appeal and to expand coverage to complement and assist new development. (Bayliss, personal communication, 1985.)

It is expected that as the information society gains momentum it will increasingly affect the regional distribution of population and employment and thus the resulting requirements for transport investment. It is the authors' view that these requirements may represent a complete about face in the characteristics of transport investment. For these reasons a study was undertaken of the Toronto-centered region in order to understand the potential impact of the Third Wave and to evaluate the associated risk for transport capital investments.

The approach taken has been to

1. Review the trends of the information society;
2. Conceptualize the variables and the process that will adequately describe the impacts on transportation;
3. Create exploratory models of (a) interurban location of population and employment, and (b) the location of service employment; and
4. Test a number of future scenarios to define the elements of a more definitive study to evaluate the risk.

The first three approaches are described here. The study area is shown in Figure 2. It consists of the whole of southern Ontario, bounded by the Great Lakes and focusing on Toronto, the regional city. Toronto is a classical industrial society city. It was located at a break in the transportation system for the preindustrial fur trade and has developed as a center of finance, government, industry, population, and service within a hierarchical region of supporting cities.

INFORMATION SOCIETY TRENDS

A number of observable trends, representative of the Third Wave, will increasingly have an important effect on society.

Computers

The information society is mainly driven by developments in computing. The trends toward faster, cheaper, higher capacity, more available computing power is so well known that it need not be discussed. This trend is expected to continue, and within the next decade the average dwelling and its occupants will have as many computers as those today have electric motors. This trend will be pervasive and will forever change the way things are done and, thus, will change our lives.

The Declining Workweek

The average workweek decreased from about 67 hr in 1860 to about 42 hr in 1952 (3). In the 30 years following the average workweek has remained approximately constant as shown in Figure 3, which is partly the reason for the current high unemployment situation. Technological changes have increased worker productivity but there has not been a corresponding decrease in the length of the workweek.

1 - Brant
2 - Bruce
3 - Dufferin
4 - Dundas
5 - Durham
6 - Elgin
7 - Essex
8 - Frontenac
9 - Glengarry
10 - Grenville
11 - Grey
12 - Haldimand-Norfolk
13 - Haliburton
14 - Halton
15 - Hastings
16 - Huron
17 - Kent
18 - Lambton
19 - Lanark
20 - Leeds
21 - Lennox
22 - Middlesex
23 - Muskoka
24 - Niagara
25 - Nipissing
26 - Northumberland
27 - Ottawa
28 - Oxford
29 - Parry Sound
30 - Peel
31 - Perth
32 - Peterborough
33 - Prescott
34 - Prince Edward
35 - Renfrew
36 - Russell
37 - Simcoe
38 - Stormont
39 - Sudbury
40 - Toronto
41 - Victoria
42 - Waterloo
43 - Wellington
44 - Wentworth
45 - York

FIGURE 2 The southern Ontario/Toronto study area.

In order to keep pace with the technological advances the average workweek will have to decline. Across the entire labor force, this may take various forms; for example, the average day or the average week may decrease or the worker may take longer vacations or retire earlier. These changes may be accompanied by increases in job-sharing, parttime work, or high levels of unemployment. In any event the available leisure time or "nonwork" time will steadily increase.

Flexibility in the Workplace

With the arrival of the information society, many jobs have become increasingly location-free. People

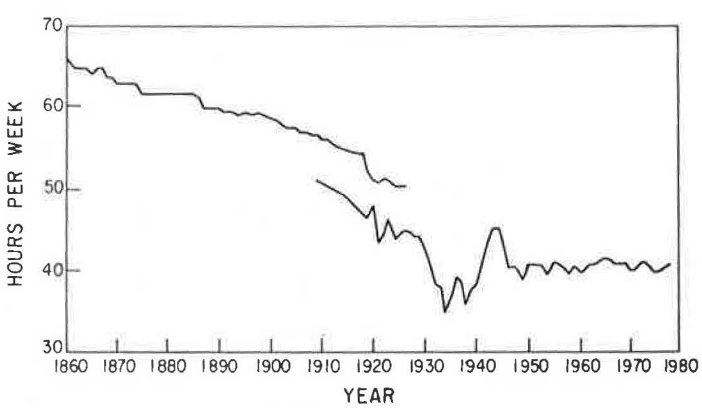

FIGURE 3 Average workweek in manufacturing industries in the United States.

can, or will be able to work wherever they choose and merely send or receive products along information channels. The cost of sending information is distance insensitive, meaning that it costs no more to send the same information across the country than it does to send it across the city. Many workers will be able to work wherever they choose, which will often be at home or at a local office, rather than at the firm's main location.

The office as it is currently known may never be the same. Some of the large, centrally located offices will become obsolete. They may be replaced by small, local offices that workers can easily get to from their residences. Therefore, there may be an increase in "rent-an-office," which a company will be able to rent and use for a few days or for several years. It is necessary to distinguish between workplace, where a person actually works, and work base, which is the location of the work control function. Traditionally, these have been at the same physical location but this is no longer necessary.

It is noted that not all workplaces will become location-free, but the number will continually increase over the next 20 years and will become a significant proportion of the employment sector. A large number of workplaces will exist in part at home and in part at the office. The personal meeting between two people cannot easily be replaced by communications between two spatially separated points. Therefore, many workers may still travel to a central office, but only for 1 or 2 days a week.

Manufacturing

One of the most important changes will be the continuing decrease in employment in the manufacturing sector. Employment in manufacturing currently accounts for about 28 percent of total employment in Ontario. It has been predicted that this figure will decrease to as low as 6 percent by the year 2000 because of the increase of automation in manufacturing. Robots are increasingly being used in manufacturing processes, especially in countries such as Japan.

Within the manufacturing sector itself, factories will become smaller and more efficient, and as a result, more easily relocatable from their traditional big city locations. More efficient use will be made of available factory space as robots will be able to work 24 hr a day, 365 days a year. Large companies will decline and smaller companies will increase as information, design capability, manufacturing technology, and marketing services become available on a wider basis and not just to companies with large personnel and financial resources. Mass production will decline as factories become smaller in size. Small production runs of a few hundred units will become commercially viable because of computer-aided manufacturing systems.

Office

The structure of the office will also continue to change. A completely computerized office is now a reality. As more office workers begin to work at home, and job sharing increases, the need for office space will decline. Computer-aided design, drafting, accounting, inventory control and ordering, filing, and word processing will all aid in the decline of the large centrally located office. In the extreme case in which an office only processes information, it may disappear completely. This, for example, has happened to many individual middle management positions whereby the availability of computerized data has completely replaced the need for middle managers while also improving the quality of the information available for decision making.

Information Employment

The decrease in the manufacturing sector must be met by an increase in another sector of employment. The development of the information society is triggering an increase in the sectors of employment related to information. The sale, distribution, and availability of information is increasing and becoming a major sector of the economy. The longer term future of this sector of the economy is very uncertain because by definition it will ultimately make itself obsolete. In the recent past this has been observed with the decline in computer analysts as computers were made more user friendly.

Corresponding to this increase in the information sector is a dramatic change in the workplace, both in its location and its size. During the industrial society, factories had to be made large in order to take advantage of economies of scale, and they also had to be located in large cities to be close to their labor pool. Now, however, any person employed in an information-related job can work anywhere where there is a computer terminal and a telephone. Factories now need fewer employees and the factory is no longer tied to the large city. The expected decentralization of employment on a regional scale may also lead to a significant change in the structure of employment.

Demographic Changes

The composition of the family is also changing. Birth rates have declined; the incidence of divorce and family splits is on the increase. People are leaving home earlier but deciding to marry later. These changes have led to an increase in the number of people living on their own or in smaller family units.

The composition of the work force is also changing. As the baby boom generation gets older the average working age will increase. An increasing number of women are entering the work force. However, the work force is no longer growing as fast as it previously did. In the 1970s the work force increased by an average of 2.7 percent, whereas in the 1980s it will probably only increase by about 1.5 percent (4). As the workers of the baby boom generation begin to retire, the work force may actually start to decline.

In Canada for the years 1981-2001, the most significant population increases are in the over 45 age groups whereas the 0 to 45 age groups will actually decline. The median age will increase from 26.3 in 1961 to 35.7 in the year 2001.

An important demographic change is the increasing education and level of knowledge of the population and the increase in employment positions. For example, in Ontario from 1971 to 1981 employment grew 110 percent in management positions, 65 percent in professional and middle management positions, and only 33 percent in semiskilled and unskilled positions (5).

Communications

The large-scale development of the computer has led to an increase in the availability of information that will increasingly influence our lives. The development of communication networks such as TELIDON will dramatically increase the ease of access to information. For example, Northern Telecom predicts that in 1985 products will be available that allow a 300-page book to be transmitted in 5 sec over twisted wire telephone lines.

The option of shopping at home may soon become a reality as people will be able to examine and purchase goods through their television screens. Information on almost any topic will become easily available. For example, choosing from recreation and entertainment possibilities will be easier with information available at the touch of a button. Planning a holiday can occur without the travel agent from the comfort of one's home by accessing files on prices and flight times.

Improvements in communications are expected to lead to many other changes. Separation of workplace and work base will become cheaper. There will be an incentive to develop extensive on-line data bases as the feasibility of marketing them increases. Distance education may become the norm in the next century. The impacts of communication may eventually be more significant than the computer.

Diversity and Prosuming

At the start of the industrial revolution almost all occupations could be listed in a nursery rhyme, "the butcher, the baker and the candlestick maker..." Moreover, knowing a person's occupation revealed how they spent most of their time, where they lived, their income, their religion, their pastimes, and so forth. However, today there are at least 200 different types of engineers and perhaps 1,000 common occupations. Knowing a person's occupation today indicates a little about their life style but not much.

This increase in diversity is expected to continue as work requirements decrease and nonwork time increases. One way to describe the Third Wave is: "Production is independent of labor." That is, the production of many goods and services within the traditional production units will no longer have a significant input of labor. The information, technology, energy, capital, and land inputs will predominate. This is, of course, the reason for the expectation of both increasing affluence and increasing nonwork or leisure time. It also explains the current discussion on the implications of the decline of the work ethic, which was the cornerstone of industrial society.

It is a truism that computers cannot be eaten, and except for games and entertainment, they are pretty well useless as direct consumer products. Thus, it becomes clear that computers will not be an activity that uses the increased nonwork time. Moreover, it appears that people have an inherent need to do something productive with at least part of their nonwork time. This leads to the suggestion by Toffler (1) that prosuming will continue to grow. Prosuming is the integration within the household unit of both the production and consumption of goods and services. The increase in crafts, cottage building, gardening, and so forth, all attest to this trend. There is, for example, currently a rapid increase in specialized publications on all aspects of living and prosuming. These publications are characterized by small circulations over wide geographical areas. Prosuming may become an important element in determining the locations selected by people as they are able to separate the workplace from the work base.

It appears that there will be a continuing increase in the diversity of the occupations and living styles of the population as a result of the information society, and, in turn, this may become the hallmark trend of the Third Wave society.

Uncertainty

One of the unanswered questions of the information society is what jobs will replace those lost in manufacturing and offices. The growing sectors of information, health, recreation, education, entertainment, and so forth, are not adequate to provide jobs for everyone as attested to by the present and future unemployment prospects.

In the industrial revolution when more than one-half of the labor force lost their jobs, it was clear that the new jobs would be created first in the manufacturing and then in the service sector. In the Third Wave the character of the new jobs is unclear. The expectation for increased diversity along with the implications of regional decentralization of employment suggests that it may not be possible to make accurate manpower forecasts. If future employment characteristics are unable to be predicted, then the prediction of future locations of population and employment also become increasingly difficult and uncertain.

Finally, it must be noted that the whole future of society is also uncertain. The social structure of the industrial society is vastly different from that of the agricultural society. The transition to the industrial society spanned 10 generations. The transition to the information society is expected to span only one or two generations. The rate of change may be too rapid and this, in itself, introduces tremendous uncertainty in predicting the future.

EVALUATING TRANSPORT IMPACTS OF THE INFORMATION SOCIETY

The Lowry and other urban land use models were developed in the 1960s in order to try to predict future urban land uses. They were developed in a time of extensive economic growth. The manufacturing sector was rapidly increasing as well as most other sectors of employment. These models were successful in sketching the development of cities. Their main variables were the given location of basic employment and the estimates of population and service employment to complement the basic employment. They also used daily commuting accessibility over a congested transport system as the main determinant of spatial structure.

As indicated the "basic" employment of the Lowry model is now rapidly declining as is the need for daily commuting, and even a decline in transport congestion may not be far behind. Moreover, existing land use models focused on the urban rather than the regional level. For these reasons they are no longer useful.

In the transition to the information society there are a number of additional variables besides employment and travel time that must be included to forecast the structure of regions. The following variables have been identified: living style, environment, cultural heritage, and quality.

Living Style

It was necessary to eliminate the artificial separation of population and employment. Living style is a classification that includes both a person's residential activities and his nonwork activities. The living style variable ranges between an industrial society living style and an information society living style. The main determinant is the degree of locational freedom of residence and workplace and the extent to which the locational choice recognizes both nonwork objectives and also personal satisfaction in the work activity. At one extreme there is an individual who travels during peak hours, 5 days a week, to work at a large industrial plant and has residential choices limited by the large size of the city. At the other extreme is an individual whose workplace has been moved to a smaller city in the region to take advantage of the local beach and skiing opportunities, who travels only 10 min to work and whose work base is in the region's central city.

In the absence of any appropriate and available data to classify the study area population by living style, the standard census occupation and industrial classifications were examined and a subjective classification made at five levels of living style. The classifications of both the occupation data and the industrial data were coordinated so that there was the same number of people in each class. Comparison of the data over the period 1961 to 1981 indicated that there was good agreement between the two distributions. Figure 4 shows the historical and forecast living styles for all of Canada based on the Standard Industrial Classification. The growth of the information society and the decline of the industrial society can be clearly seen.

Environment

This variable is a measure of the attractiveness of an urban area in terms of natural landscape; housing quality, cost, and availability; education, health, and cultural activities; population density; and other quality of community life variables. This variable represents the attractiveness of a community for living. It is being measured by assembling all of the available data and then using a factor analysis to reduce the variables to a manageable number. In the preliminary analysis the important factors include education and income of the resident population, population density, climate, local tax base, and retail sales.

Cultural Heritage

This variable is a special quality-of-life variable that identifies the historical and cultural ties of a particular urban area or region. For example, in Canada, for many years the population of the Maritime provinces had to leave in order to find employment. In recent years, with the possibility of local employment, many people have returned home to work or to start new businesses. This variable is currently measured by the population of the area in 1950. Although conceptually it is believed to be important, there is not yet any evidence to suggest that it requires separate treatment.

Quality

This variable relates entirely to the transport system. It is believed that the Third Wave will place an increasing emphasis on the quality of life, and thus within the transport sector, the operative variable should be the quality of transport, which will include reliability, comfort, and convenience, as well as the traditional travel time variables. It is expected that as the frequency of journeys decreases and the lengths increase (especially to the work base), the quality of transport will become very important.

In the authors' opinion these types of variables that are not represented in existing land use models are critical to forecasting the changes that will occur in urban regions. In the remainder of this paper two models that are being used in the study area to explore the possible future impacts of the information society on urban regions are described. The first model forecasts the expected migrations of population from one area to another in the region. Preliminary results have explained 60 percent of the population changes that occurred between 1971 and 1981 in the 45 zones of the study region. The second model is concerned with the location of the consumer service sector.

Figure 5 shows the expected changes in locational forces that will occur during the transition from a second wave to a third wave society. The industrial society is characterized by a strong tie between the home and both the place of work and services. There are also fairly strong ties between the work base and the labor pool, market, geography, and so forth. This resulted in a concentration of basic employment in the region's central city core area with the rest of the central city and surrounding region focused on and supporting this concentration.

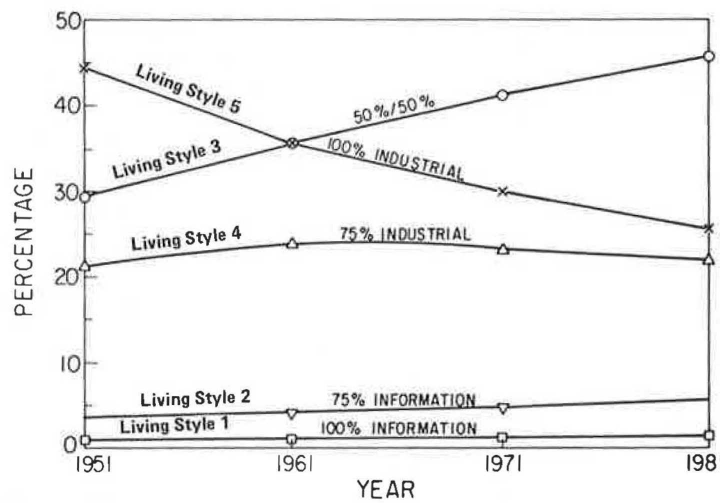

FIGURE 4 Living style trends in Canada for five classes based on a subjective allocation of available data by the standard industrial code.

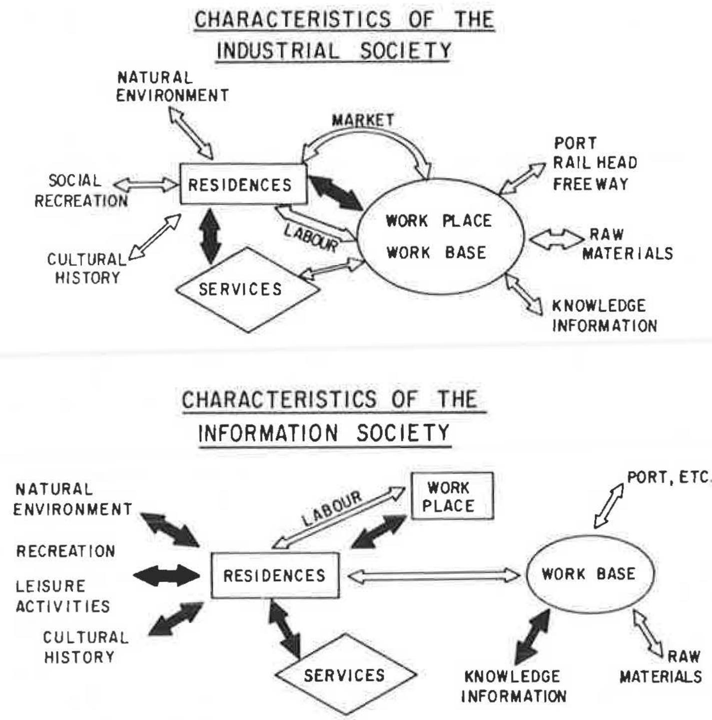

FIGURE 5 Changes in the location forces from the second wave to the Third Wave in a regional setting.

The purely Third Wave or information society as shown in Figure 5(b) will be characterized by much weaker links between the work base, market, labor pool, geography, and the home and/or workplace. The home will have much stronger ties with the environment, services, cultural heritage, and so forth. As people and employers become more location-free, other reasons such as the environment and quality of life will become more important in determining the living style and thus the choice of location. The information society will tend to break up the existing regional structure, as small packets of basic and service employment break off from the central city and locate elsewhere in order to satisfy living style objectives. There will no longer be the large concentrations of employment in the central business district (CBD) and other areas of the central regional city.

The weaker links between the residence and the work base are created in two ways. As the workweek continues to decline and an increasing number of people can, for at least some of the time, work away from the work base, the importance of the travel linkages between home and work will decline. People will make fewer journeys to work, and in some cases work will become location-free. Therefore, people will not be constrained to live close to their place of employment. Even if people have to make one or two journeys to work per week, they will be willing to make a longer trip if it means that they can live in a preferred location. For example, instead of working 5 days a week and traveling to the cottage on weekends, people may live at their cottage and journey to work only when necessary. This may result in large cities becoming increasingly decentralized. However, many people will prefer a highly urban environment that will lead to a counterbalancing centralizing force (6).

Firms are becoming location-free as they become smaller and more information oriented. Although employees of these firms may still have to travel to work every day, the firm and its employees will move together to a preferred location and this also will lead to a decentralization of population.

Modeling Intraregional Population Shifts

The proposed model allocates population and employment together as the living style variable. The basic model hypothesis is that as society moves from the industrial to the information society, people will have increased freedom of location. The locational choice will be based on such factors as the environment or amenity of the zone, accessibility to employment, and the distance from the zone of origin. These factors will have varying importance depending on the living style classification being considered.

The model is similar to a singly constrained gravity model. Five-year time increments are used in the model with the allocation process performed at the end of each time period. At the end of each 5-year time period, the population of each zone is increased by the predicted average population increase for the entire study area. The increases and decreases in each of the living style categories are determined for each zone, based on those predicted for the total study area from trend projections such as those shown in Figure 4. Living styles 4 and 5 are closest to the industrial society and are in decline. The associated population is then allocated to the predicted increases in the information society living styles 1, 2, and 3. The basic allocation equation is:

$$M_{i,j} = O_i * A_i * D_j * I_{ij} * ff_{ij}$$

where

M_{ij} = the movers from zone i to zone j;
O_i = decreases in zone i in living styles 4 or 5;

D_j = increases in zone j in living styles 1, 2, or 3;
A_j = balancing factor for the origin zone,
= $1/(D_j\ I_{ij}\ ff_{ij})$;
I_{ij} = interactions between zone i and zone j,
= $a * (ENV_i/ENV_j) + b * (ENV_i/ENV_j) + c * . . .$ where a, b, c are calibrated weights; and
ff_{ij} = friction factor between zone i and zone j,
= $1/Dist_{ij}^{n}$ with n = calibration constant.

The interaction term includes the environment, cultural heritage variables, as well as a measure of accessibility to other population in the region. The interaction term is in a comparative ratio form to reflect the comparison of conditions in one zone with those in another. The model will be calibrated using maximum likelihood for both the coefficients of the interaction term and the distance exponent.

After the 5-year allocation process each zone is checked to determine if it has grown more than the zone capacity allows. If any zone has a population greater than this maximum, that particular zonal population is set to the maximum and the excess population is allocated to the adjacent zones. The excess is allocated in the same proportions as the predicted increase for the adjacent zones in the last 5-year time increment. A check is made to restrict any increase or decrease in population to a maximum 5-year rate of change determined from observed maximum historical changes. This is to represent the inertia of the city.

The model outputs will be analyzed to determine if they are reasonable estimates of what might happen in the future. A sensitivity analysis can also be performed to determine how much the model is affected by its inputs. This will result in a range of possible outputs and provide information for more realistic specification of the allocation model. It should be noted that data are very scarce, especially for some of the environmental and living style variables.

Location of the Consumer Service Sector

It is expected that the Third Wave trends will reshape the urban structure of Ontario including the service sector. In fact, the service sector will become increasingly important as manufacturing declines. Moreover, as the population of the region decentralizes, there are expected to be significant impacts on the location of the consumer service sector.

Consumer-service firms abound in the modern city--almost on every corner there is a restaurant, gasoline station, or corner store. Most of these firms will not be visibly shaken by the Third Wave. Some, however, will have a sizable portion of their "reason d'être" (their market) removed. Some of this market deterioration will be due to a shift in the "drop-in" or link-trip trade, which has been previously ignored in traditional consumer-service location models, such as the Lowry model.

Link trips involve the subordination of certain secondary trip purposes to other primary purposes in an attempt by trip makers to conserve time, effort, and, hence, energy. By making a less important stop on the way to a more important destination, the trip maker fulfills his need for a certain good or service without having to make a special trip at another time. Both the existence of trip linking by consumers and link-trip orientation by consumer-service firms has been documented in recent research, but little effort has been applied to the connection between consumer and firm behavior over urban space. On the consumer, or demand side of the relationship, Hanson (7) found in Uppsala, Sweden, that many urban trip linkages involve either home or work as primary activities. In the Third Wave, the home-work-home pattern will be dramatically altered, and with it the link-trip patterns that have shaped the existing urban consumer-service land use pattern. Research on the supply side clearly shows that firms are oriented to different combinations of the surrounding residential and passing traffic markets, reflecting underlying operating strategies (8-11). Through quantifying these operating strategies by type of consumer-service firm, we hope to be able to predict the firm's orientation to the "linear hinterland."

Figure 6 shows the basic approach to the consumer service location model. The demand for services is separated from the supply of services. Link trips for consumer services are secondary to primary trips, such as work trips, and distinct from other primary trips for consumer services that go directly from home to the service and return. The model considers demands from linked or secondary trips separate from primary demands for consumer services. Also, the relative demands are expected to vary over time as living styles change. For example, the Ontario data on secondary trips indicated that executive/manager employees made 41 percent secondary trips whereas clerical/sales employees made only 25 percent secondary trips. There was a direct relationship between socioeconomic status and the percentage of secondary trips. Thus the expectation is that the percentage of linked trips will increase in the future.

As shown in Figure 6 the supply side will be

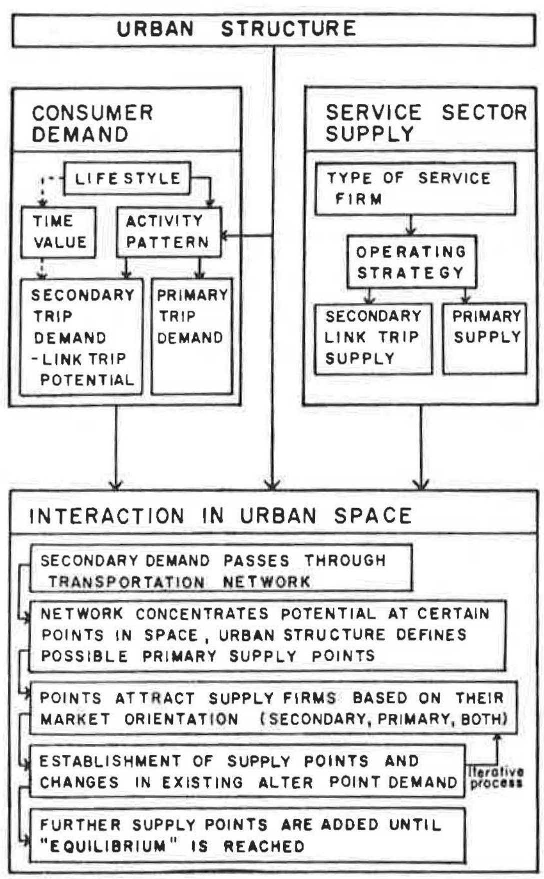

FIGURE 6 Flowchart of proposed consumer service location model.

considered to respond to both secondary and primary consumer trips. The supply of link trips is the provision of locations at which consumers may stop while traveling from one primary activity to another. It is the decision by an operator of a firm in the consumer-service sector to capture this link trip potential flowing through the urban transportation network. The network is represented in the model simply by the major nodes in the transport network, as these points already have maximum accessibility to link trips.

The secondary trips are assigned to the nodes according to the minimum path of the primary trips on which they depend. The potential market available to each node is the summation of these secondary trips for the primary trips passing through the node, plus the potential primary service trips distributed to that node in the preceding step.

The supply of consumer service centers will be determined in an iterative fashion by 5-year time periods. At the beginning of a time period, all nodes in the network receive a service center. The node with the lowest potential is tested stochastically for removal. The stochastic element simulates business risk and the required threshold potential. After a center has been removed, the potential is reallocated to other nodes. Equilibrium would be reached when there are no further reductions in supply points.

It is expected that the results of the consumer service location model will be able to reproduce the observed trends toward ever larger commercial complexes at more decentralized network nodes. It is also expected that when applied at a regional level, the model will be able to predict the observed trends for intercity locations for some fairly large and specialized commercial activity centers.

SUMMARY

The objective of this paper was to present some ideas on the impacts of the Third Wave or information society on transport. Research to date revealed that (a) there are no data, (b) there are no theories, and (c) there is no experience. The intent was to develop a fairly comprehensive model that would keep track of individuals, estimate the transitions between living styles, and so forth. It became clear that the transition to the Third Wave would be over before this research was finished.

The impacts of the Third Wave are believed to be revolutionary. The regional centralizing forces of the past 200 years are expected to reverse, and regions will experience a series of very strong decentralizing forces as the importance of manufacturing and daily commuting decline. The Toronto-centered region is currently being studied in an attempt, even in a preliminary way, to assess the risk associated with proposed investments in transport facilities.

The approach taken is one of conceptualizing the operative variables, mainly (a) living style, (b) environment, (c) cultural heritage, and (d) quality of transport, and obtaining crude measures of these variables from available data for the study area. The model is proposed to allocate population by living style, between urban areas, at a regional level of analysis. The model is driven by trend forecasts of the population in each living style class. The objective of this initial modeling activity is to use it to explore the ways in which the Third Wave will affect our cities and through this process define more specific future research objectives.

The main conclusion is that the impacts of the Third Wave demand a complete reexamination of transportation requirements as embodied in existing plans.

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Abridgment

A Methodology for Forecasting Beltroute Corridor Land Use Impacts

JASON C. YU and JAMES L. ALLISON

ABSTRACT

Forecasting land uses represents the first step toward ensuring compliance with land use plans and preventing inadequate transportation routes. This study was intended to develop a methodology for forecasting land use impacts within the corridor through which a beltroute is aligned. The methodology consists of assigning land uses to portions of the corridor, based on the potential those portions have for accommodating the requirements of the land uses. A planned requirements approach is used to assign land uses to tracts of land within the corridor. This approach of aggregating land uses at potential sites is advantageous in revealing the pressures that will bear on the goals and objectives of land use and transportation agencies. A computer aid based on the developed methodology has been implemented on a microcomputer and used in a real-world case. The methodology shows promise for assisting land use and transportation agencies in forecasting land uses in a beltroute corridor.

Beltroutes are limited access highways that completely or partly encircle an urban area. Such routes are particularly capable of altering, on a large scale, the attitude potential land users have for land within the region through which the route will be located, as well as for land within a reasonable distance of the beltroute. A tract of land that is considered undesirable because of a lack of accessibility may become very desirable for a number of different types of potential land users with the proposal to build a beltroute in the vicinity.

The land use-transportation relationship can be more concisely stated when considered in the context of beltroutes than if considered in the broader terms of transportation in urban areas. Three aspects of beltroutes contribute to the unique set of characteristics that affect adjacent land use developments. First, beltroutes tend to serve large amounts of local traffic. The type of traffic that a route serves consequently contributes to the land uses that locate within the corridor. Second, within the urban setting, uncongested beltroutes represent the ultimate in linking large sectors of the urban environment. Third, because a beltroute partly or completely encircles an urban area, a single beltroute could pass through as many types of land use as are existent in any one community. The implication this has for the land use-transportation relationship will depend on the particular urban area with its specific terrain, antecedent land uses, and goals.

Because a beltroute can facilitate and even precipitate new land uses within the urban area, it becomes incumbent on those responsible to anticipate and plan for the effects of the beltroute (1,2). Efforts can be made to capitalize on the changes wrought as a result of a beltroute. Further, problems of an inadequate or inappropriate design of the beltroute can result as a consequence of plans made without anticipation for future land uses. Because some types of land use projects will locate in anticipation of a beltroute, planning for the land use demands must be ongoing and must begin with conception of the particular project (3,4).

To date, a number of beltroutes have been completed or are being planned across the nation. Owing to the large impact such routes have, numerous studies have been undertaken to address the impacts these routes have had on land use. However, no universally applicable methodology has been developed to forecast likely land use within a beltroute corridor.

The objective of this study was to develop a methodology for forecasting land uses within a beltroute corridor. In order to demonstrate its usefulness and applicability, the developed methodology was then applied to the real-world case of I-215 located in the Salt Lake Metropolitan Area in Utah. However, the case study will not be presented in this paper due to space limitations. It is expected that the methodology will not only assist planners and decision makers in anticipating beltroute land use impacts, but it will also aid public and private sectors in capitalizing on the opportunities beltroutes offer.

DEVELOPMENT OF THE METHODOLOGY

The developed methodology has as its basis the planned requirements approach (5), which relies on locating sites within the corridor suitable to land uses projected to develop in the metropolitan area under study. There are 13 interrelated tasks involved in the methodology. Figure 1 shows the interrelationships of these tasks.

Task 1: Development of the Corridor Land Use Requirements Table

The history of land uses along representative beltroutes in the United States are examined to reveal the change or lack of change in land use under "before and after" conditions. A land use requirements table (LURT) for the beltroute corridor can be developed to show definite correlations between potential land uses and certain sets of original conditions.

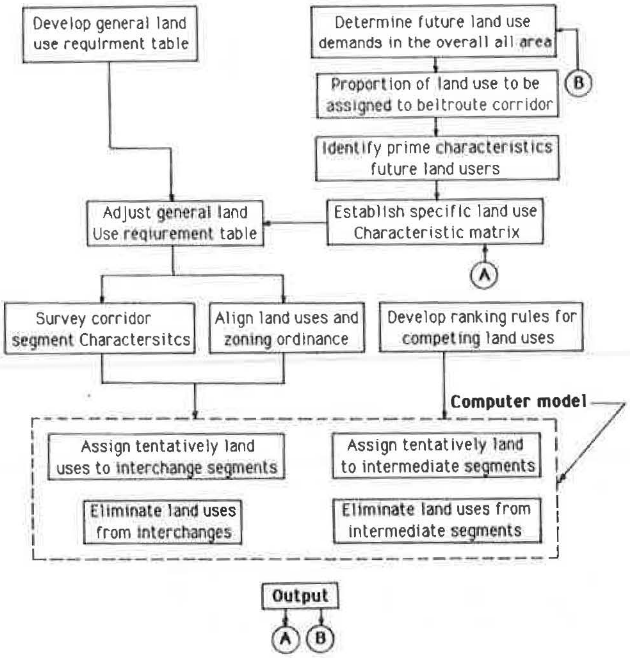

FIGURE 1 Methodological procedures for forecasting land use impacts in beltroute corridor.

Task 2: Identification of Future Regional Land Uses

The likely future land uses that will seek sites within the entire urban area where a beltroute is located are identified. It cannot blindly be assumed that the demands for types of land uses in one urban area will be the same as in another. This is obvious by noting the differences in industries and, hence, land uses when considering two grossly different regions.

Task 3: Forecasts of Future Land Use Demands within the Corridor

This task is to estimate the future growth of the urban area and the proportion of that growth that will be located within the corridor. Typically, a future point in time must be chosen for which projections are calculated. Supporting data such as population projections, housing demand, industrial growth, income level, and land costs and availability can be used to forecast the growth of various land uses within the urban area or the beltroute corridor. One way to allocate growth to the corridor would be by examining those land uses for which there is a projected growth. Attendant with each land use would be the prime characteristics required of a potential site. A survey of the corridor would then reveal how much land is available within the corridor that would be acceptable to the individual land uses.

Task 4: Identification of Prime Considerations Sought by Land Users

Characteristics that the industries or other land users will seek when selecting a site for development are identified by this task. Each land use identified will have one or more characteristics that are considered vital for a potential site. That a particular land use will contribute one characteristic, whereas another may contribute five or six is of no consequence.

Task 5: Formulation of Characteristics Versus Land Use Matrix

This task is to form an m by n matrix, where n is the number of characteristics from Task 4 and m is the number of land uses identified in Task 2. If a desired characteristic holds for a particular land use, assign the digit one to the intersection of that row and column, otherwise assign a zero. This matrix is called the characteristics matrix (CM) for a particular beltroute corridor.

Task 6: Adjustment of the Land Use Requirements Table

It is possible that the LURT and the CM may have a different set of land use characteristics listed vertically and each may have a different set of land uses listed horizontally. This task will adjust the LURT based on the CM so that the resulting LURT reflects the characteristics future locators of land use activities will consider as being of prime importance when considering sites within the particular beltroute corridor.

Task 7: Survey of Beltroute Corridor Characteristics by Segment

Homogeneous portions within a beltroute corridor are called segments. Each segment of the beltroute corridor is surveyed for the characteristics listed in the original LURT. If the LURT has been adjusted, then the revised version is used.

Task 8: Alignment of Land Uses and Zoning Ordinances

The set of zones from the local zoning ordinances should be aligned, as nearly as possible, into a group having the same description as the list of land uses from the LURT. The purpose of this task is to condense a number of different zones into the broad land uses of the LURT based on

1. What currently is in existence within the zone; that is, is it already developed to some extent or zoned?
2. The latitude that is allowed in development by what has already been constructed and what the zone is currently.

Task 9: Rankings for Assigning Competing Land Uses

This task will establish one or more ranks by which individual land uses are considered for final assignment to segments within the corridor. The ranking system is established on the basis of special considerations of the study beltroute corridor. There are basic components of the ranking that will be fairly constant. Other considerations being equal, if two activities seek to locate at a given site, the one with the higher ranking will be allowed to locate at the site and others may be forced to locate elsewhere. Also included in this task is the formulation of a land use compatibility table (LUCT). Such a table would indicate which combinations of land uses are not to share a segment or are to occupy adjacent segments.

Task 10: Assignment of Potential Land Uses to Interchanges

Within this task and Task 11, a planned requirements approach becomes apparent. The assignment is accomplished by examining each segment in turn, and on a tentative basis assigning as many land uses to the interchange segment as will have their prime consideration factors satisfied there. The prime consideration factors for a particular land use are recorded in the LURT. Whether or not a land use qualifies for a segment is determined by referring to the column below that land use in the LURT. Each interchange will have a list of characteristics. These characteristics are previously gathered in Task 7.

Task 11: Elimination of Land Uses from Interchanges

Each interchange segment is individually considered in combination with adjacent interchanges that are not separated by an intermediate zone. As many land uses as possible should be eliminated from each interchange segment based on land use compatibility, zoning considerations, and region versus local serving priority. The elimination process is conducted by considering the rankings established in Task 9. The recommended order for applying the rankings is application of the LUCT followed by those aspects of the zoning ordinances with which a unanimity of opinion exists.

Task 12: Assignment of Potential Land Uses to Noninterchange Segments

One method is to begin by attempting to assign all qualifying land uses to unfilled segments closest to the interchanges. Each interchange is taken in turn. This is continued until the supply of assignable land uses is exhausted. The second possibility is to assign all segments between an adjacent interchange pair before moving to the next noninterchange segment. Which method is used will depend on the policies in a particular reach of the beltroute. Where a policy of filling in of vacant land before allowing development elsewhere exists, the second method should be used. If the policy is not to constrain development with an infill policy, then the first method should be used.

Task 13: Elimination of Land Uses from Noninterchange Segments

After each segment between the interchanges is assigned a set of tentative land uses, attempts are made to eliminate land uses from the assigned sets based on compatible zones, ranking criteria, and land use compatibility.

COMPUTER AID

The developed methodology is partly computerized for facilitating its use. The dashed rectangle around Tasks 10 through 13 in Figure 1 encloses the computerized portion of the methodology. It is the computer model that maintains accounting information on land use characteristics resulting from changes in policy, prompts the analyst for input data, and displays warning information about land use conflicts and overly restrictive policy.

Aside from the relative interactions shown in Figure 1, other important aspects are the feedback loops from the computer model. These loops are designated A and B. The loops imply input or a decision from the decision makers who are questioned as to the desire to alter land use policy. Policy is defined as those actions a governing body can take to direct land use.

The developed methodology requires a considerable amount of manipulation of the small amount of data that it uses. For a beltroute corridor that has a large number of segments, as well as many characteristics and land uses, the methodology is prohibitively tedious. To assist users of the methodology, an interactive computer program has been developed. Through the interactive framework, the analyst is confronted with options to alter the data sets used by the program.

DATA PREPARATION

The data preparation process for the methodology can begin only after the land uses that will likely locate within the corridor have been determined. Once the land uses are known, they subsequently define one dimension of the LURT. The list of characteristics that describe the land uses dictate the second dimension of the LURT and the data that are to be collected from the corridor.

The first stage in data preparation, after all possible land uses have been determined, is that of characterizing the land use. If the LURT can be accepted as it appears, no further preparations are needed before starting stage two. Altering the LURT is possible by adding a row for each new characteristic and a column for each new land use. Next, a one is placed in the columns considered to be of prime importance to the added land use. By similar reasoning a land use could be removed. As a final step in the first stage, a zero is placed in boxes of the LURT not having a one. The LURT is now ready to enter into the computerized process.

The second stage of data preparation involves describing the beltroute corridor in the same terms as those used to characterize the various land uses. More specifically, the beltroute corridor segments should be described in the same terms as the list of characteristics in the original LURT.

CONCLUSIONS

Beltroutes encircling urban areas have definite effects on adjacent land use and urban development patterns. Both transportation and land use planners should realize these consequences of the beltroute and plan accordingly. Through coordinated transportation and land use planning, the beltroute can become a positive form-giving element in the metropolitan area.

A methodology for forecasting land use impacts within the beltroute corridor has been presented in this paper. Strengths of this methodology are the speed with which alternative land use policies can be examined and the minimal amount of data required. In the application of the methodology and computer aid to a real-world case (I-215 in Utah), it is apparent that the methodology is very useful for forecasting and monitoring land use development within a beltroute corridor. Of equal significance is the potential this methodology has for being useful in the design phases of a beltroute by affording an integrated design involving both the physical aspects of the route and the policies that affect land uses within the beltroute corridor.

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Effects of Freeway Stage Construction on Nearby Land Uses and Vehicle User Costs

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ABSTRACT

Because of the huge costs involved, most freeways are commonly constructed in lateral or longitudinal stages. In the case of lateral stage construction, service roads are constructed and opened to traffic before the main lanes. In the case of longitudinal stage construction, the service roads or main lanes are constructed on a freeway section-by-section. Impacts of stage construction include adjacent area land use development, user travel time costs, vehicle running and speed change costs, and accident costs. This paper contains the findings of a study of stage construction impacts on two freeways located in Houston, Texas: (a) one completely stage constructed and (b) the other partly stage constructed. Although authorization was given to purchase right-of-way for both freeways within 2 years of each other, the second freeway to receive authorization was completed at least 6 years before the first. During the "before" construction period, the socioeconomic characteristics of the areas adjacent to the two freeways are shown to be generally similar. During the construction and "after" periods these characteristics are shown to be dissimilar, partly because of differences in the construction schedules of the two freeways. A regression analysis of historical land use changes reveals that certain land uses are sensitive to nonstaged freeway construction. Other variables such as abutting and nonabutting, freeway location differences, capacity changes, and average daily traffic volumes are included in the analysis. A user analysis reveals that staging a freeway costs more in vehicle user costs than benefits gained from delaying construction expenditures.

It is recognized that a major thoroughfare, such as a freeway, attracts not only traffic but also affects nearby land uses. The presence of a major thoroughfare can obviously set off a chain reaction among land uses with one land use affecting other land uses. Accessibility resulting from the existence of the thoroughfare is a major contributing factor. People are more willing to live farther from the city or farther from other currently well-developed areas if they can count on a quicker way to get to and from work. Industries are less reluctant to rule out the possibility of locating their firms in rural areas if they are certain of good accessibility for their workers and for their goods and supplies.

Besides the mere presence of a freeway, it is believed that the method of constructing a freeway can influence how land is used. Because of the huge costs involved, most freeways are commonly built in longitudinal or lateral stages. In longitudinal staging, one segment of the freeway is built and opened before the next segment is started. In lateral staging, the service roads, if any, or part of the main lanes are built first. Later, all of the remaining main lanes are constructed.

It is also believed that staging of freeways affects user costs. A freeway does not reach maximum efficiency in carrying traffic until all the main lanes and service roads are constructed and opened for use. Until this is accomplished, part of the traffic that would normally use the freeway will have to choose an alternate route in the corridor that may require more travel time, incur higher vehicle operating costs, and be more hazardous from an accident standpoint.

The land use and user effects of freeway stage construction are not documented in the literature. A study just completed by Chui, Memmott, and Buffington reveals some of the economic effects of staging two freeways in Houston, Texas (1). The results of that study are summarized in this paper. Ideally, one of the freeways should have been staged and the other nonstaged with the latter considered as a control for the purpose of studying the staging effects of a freeway. However, a survey of the construction histories of freeways over the state revealed the absence of an ideal pair of freeways for study. Efforts were then diverted to searching for two staged freeways that had different amounts of lateral stage construction. For example, one of the freeways had to have at least one section nonstaged laterally and the other sections staged over a longer period of time than the other freeway.

Using the preceding guidelines, the Northwest (NW) freeway or US-290 was selected to be the study facility and the Southwest (SW) freeway or US-59 was selected to be the control facility. All of the study sections of the NW freeway were constructed in lateral and longitudinal stages. All but Section 1 of the SW freeway were constructed in lateral stages. Figure 1 shows the location of the two freeways and the study sections. The first section of the SW freeway (SW1) had both its service roads and its main lanes opened at the same time, and the other three sections were staged over a much shorter period of time than those of the NW freeway. Even the longitudinal staging of the SW freeway was different from that of the NW freeway. The service roads were not staged longitudinally on the SW freeway, whereas both the service roads and the main lanes were staged longitudinally on the NW freeway.

This paper contains a comparison of staging as opposed to nonstaging of freeway construction by studying various sections of the NW and SW freeways. The various historical characteristics of the two freeways and the surrounding areas are compared to determine major before and after construction differences. Among the characteristics analyzed are the following: (a) construction schedule, travel volume, and cost characteristics of the study freeways; and (b) socioeconomic characteristics of the study areas.

The impact of stage construction of the study freeways is determined by measuring changes in abutting or nearby land use and vehicle user costs. The land use impact of stage construction is determined by evaluating historical land use data with two simultaneous equation estimation techniques, and the vehicle user cost impact is determined by inputting historical traffic data into the Texas Highway Economic Evaluation Model (HEEM) (2).

Finally, this paper contains conclusions and recommendations that are based on the findings of the user cost and land use analyses.

CHARACTERISTICS OF THE STUDY FREEWAYS AND AREAS

Based on definitions given earlier on staging and nonstaging freeway construction, Section 1 of the SW freeway (Figure 1) is nonstaged because both the service road and the main lanes were built simultaneously and opened for use in 1962, whereas the other sections of the SW freeway and all sections of the NW freeway are staged.

In this section of the paper, various characteristics of these two freeways and the areas along them are discussed separately.

Construction, Traffic Volume, and Cost Characteristics of Study Freeways

Table 1 gives the section lengths, opening dates, and time lapse from the date of authorization to purchase of right-of-way (ROW) until the date of opening the service roads and main lanes, for each section of the freeways under study. Figure 1 shows the location of the two study freeways in relation to the Houston metropolitan area. All sections of the two freeways are of adequate length for study. The total lengths of the study portions of the two

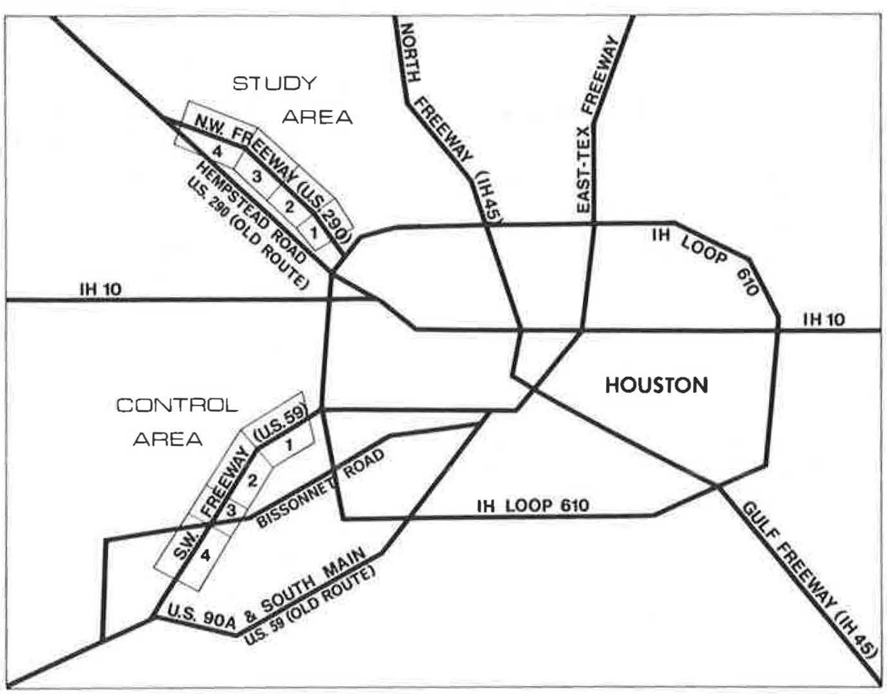

FIGURE 1 Location of the NW and SW freeways and study sections in Houston, Texas.

TABLE 1 Section Lengths, Opening Dates, and Time Lapse from Date of Authorization to Purchase of Right-of-Way Until Date of Opening Service Roads and Main Lanes of Study Freeways

Freeway	Section	Section Length (miles)[a]	Opening Dates: Service Roads	Opening Dates: Main Lanes	Time Lapse Since ROW Authorization[b]: Opening of Service Roads	Time Lapse Since ROW Authorization[b]: Opening of Main Lanes
SW	1	2.1	1962	1962	4	4
SW	2	2.5	1962	1965	4	7
SW	3	1.4	1962	1969	4	11
SW	4	2.5	1962	1974	4	16
NW	1	0.8	1970	1975	10	15
NW	2	1.4	1970	1979	10	19
NW	3	1.4	1975	1981	15	21
NW	4	2.5	1975	Not open	15	Not open

[a]The combined length of the four study sections is 8.5 mi for the SW freeway and 6.1 mi for the NW freeway.
[b]Time lapse since year when authorization was given to purchase the right-of-way for each freeway. The authorization date is 1958 for the SW freeway and 1960 for the NW freeway.

freeways are comparable, with 8.5 mi of the SW freeway and 6.1 mi of the NW freeway.

The authorization date to purchase the right-of-way is 1958 for the SW freeway and 1960 for the NW freeway. As indicated in Table 1, there are considerable lateral stage construction time lapses from the right-of-way authorization until the opening of the service roads and main lanes. Only in the case of Section 1 of the SW freeway is there no time lapse between opening the service roads and the main lanes. For Section 1 of the NW freeway, the time between opening the service roads and the main lanes is 5 years.

Also, there are considerable longitudinal construction time lapses between opening one section of service roads or main lanes until opening another section of service roads or main lanes on both freeways. Such time lapses are smaller for the SW freeway than for the NW freeway. Again, there is no time lapse between opening each section of service roads on the SW freeway. In the case of the NW freeway, there is a 5-year time lapse between the 1970 opening of Sections 1 and 2, and the 1975 opening of Sections 3 and 4.

Design and Traffic Volumes of the Study Freeways and Alternate Routes

The designs of the study freeways and the alternate routes that they replace are similar. Both freeways have six to eight main lanes and four- to six-lane service roads serving each section. The alternate routes for each of the study freeways have four undivided lanes. As shown in Figure 1, Hempstead Road is the alternate route for the NW freeway and South Main is the alternate route for the SW freeway.

Table 2 gives the average daily traffic (ADT) volumes on the study freeways and alternate routes according to freeway right-of-way purchase and construction stage. The ADT on alternate routes is near the same level at the time of authorization to purchase the right-of-way for the two freeways. With such a small difference in ADT on the alternate routes at that time, and with other things being equal, it would be expected that both freeways would be built on about the same time schedule. As indicated in Table 1, the completion date for all four sections of the SW freeway is 6 years before the completion date for three sections of the NW freeway.

Table 2 gives the effects of delayed construction of the NW freeway on its ADT as well as the ADT of

TABLE 2 Average Daily Traffic Volumes on Study Freeways and Alternate Routes, by Freeway Right-of-Way Purchase and Construction Stage

Freeway Right-of-Way Purchase and Construction Stage	Study Freeways: SW	Study Freeways: NW	Alternate Routes: South Main	Alternate Routes: Hempstead Road
Right-of-way purchase authorized[a]	–	–	13,705	12,205
Service roads open[b]				
Section 1	9,700	12,400	14,330	22,280
Section 2	9,700	12,400	14,330	22,280
Section 3	9,700	27,915	14,330	17,526
Section 4	9,700	27,915	14,330	17,526
Main lanes open[b]				
Section 1	9,700	27,915	14,330	17,526
Section 2	12,060	48,000	13,880	17,526
Section 3	66,450	Not obtained	16,420	20,714
Section 4	111,495	Not open	21,060	Not obtained

Note: Dash = not applicable.
[a]Year that authorization was given to purchase right-of-way for freeways, which is 1958 for the SW freeway and 1960 for the NW freeway.
[b]Year after opening service roads or main lanes.

its alternate route at the same construction stage of the SW freeway. As can be seen, the ADT on the NW freeway and its alternate route is higher than the ADT on the SW freeway and its alternate route at any comparable stage of construction.

Right-of-Way and Construction Costs

Table 3 gives the right-of-way costs for the two freeways, as measured in 1962 dollars, using the U.S. Consumer Price Index (CPI). A comparison of the cost per mile reveals that the right-of-way cost for the SW freeway is about 28 percent lower than that for the NW freeway. Part of this difference can be explained by the fact that some of the right-of-way for the SW freeway was donated by one or more landowners. Stage construction allowed more time for purchasing the right-of-way, but this time delay resulted in higher right-of-way costs, in real terms, for the NW freeway.

Table 3 also gives the construction costs, measured in 1962 dollars, of the study portions of the two freeways. These costs include traffic signal and lighting costs. The construction cost per mile for the NW freeway is 2.2 times that for the SW freeway. Most of the extra construction cost incurred on the NW freeway is a result of the delay in construction

TABLE 3 Right-of-Way and Construction Costs of the Study Portions of NW and SW Freeways in Constant 1962 Dollars

Freeway and Freeway Element	Cost per Mile[a] ($)	Total Cost[a] ($)
NW freeway		
Right-of-way	110,469	673,860
Construction[b]	3,694,590	22,537,000
Total	3,805,059	23,210,860
SW freeway		
Right-of-way	79,983	679,854
Construction[b]	1,716,118	14,587,000
Total	1,796,101	15,266,854

Source: Texas State Department of Highways and Public Transportation.
[a]Cost of the four study sections of each freeway, covering a total distance of 6.1 mi for the NW freeway and 8.5 mi for the SW freeway. The U.S. Consumer Price Index is used to deflate these costs.
[b]Includes traffic signal and lighting costs.

of the main lanes and the rise in construction costs in excess of prices in general.

Socioeconomic Characteristics of Study Areas

The study areas defined in this study include a one-half mile strip of land on each side of the study freeways. It is believed that an investigation of the changes in population, housing units, housing costs, and family income in the study area should reveal some of the social and economic characteristics of the general areas where the freeway facilities are located. Census tract data collected by the U.S. Bureau of Census are used to analyze these characteristics in each study area.

Table 4 gives the socioeconomic characteristics of the study areas in the before period (1950-1960) and in the during and after period (1960-1970). In 1950 and 1960, the socioeconomic characteristics of the two areas were generally similar. By 1970 the socioeconomic characteristics of the two areas became dissimilar. By that time the construction schedules of the two freeways were quite different, thus encouraging faster settlement and development along the SW freeway than along the NW freeway.

IMPACT OF STAGE CONSTRUCTION OF STUDY FREEWAYS

Even though lateral and longitudinal stage construction occurred on both of the study freeways, the primary emphasis of the analysis presented here is on determining the economic impact of lateral stage construction. The SW freeway, which has one section (Section 1) that was not constructed in lateral stages, is regarded as the control freeway in the land use analysis presented in the next section. Because construction of the service roads and main lanes of the NW freeway occurred over a much longer period of time than in the case of the SW freeway, the effects of long-term staging can be determined. The extent of land use and vehicle user impacts of freeway stage construction are presented under separate headings.

Land Use Impact

The land use impact evaluation of freeway stage construction is based on the historical land use data obtained from the records of the Houston City Planning Department and from aerial photographs of the U.S. Department of Agriculture.

The land use data represent one-half mile strips on each side of the SW and the NW freeways for the following 6 years: 1953, 1957, 1962, 1970, 1975, and 1980. The year closest to the opening date of a certain facility is used to represent the opening date of that facility because most of the actual opening dates do not fall exactly on any of these 6 years but rather fall in between.

The one-half mile study strip on either side of each freeway is divided into two parts: the abutting portion, which is 100 ft wide next to the freeway and the nonabutting portion, which encompasses the remainder of the study strip. Therefore, the 4 sections of each of the 2 study freeways are multiplied into 8 subsections, yielding a total of 16 subsections for both freeways. With 6 years of land use data on each of these subsections, a total of 96 observations or data points can be used in the regression analysis presented next.

A regression model is formulated in order to relate each land use to the lateral staging effects of freeway construction by use of a set of binary variables. The staging effect is divided into two phases, the first phase denoting completed service roads, with no main lanes, and the second phase denoting the completed freeway main lanes, along with the service roads. Besides the staging effects, other effects such as abutting versus nonabutting, freeway location differences, capacity changes, and average daily traffic volumes are also investigated. Out of the many types of land use, five of the more dominant ones are chosen for the study. They include single residential, multiple residential, commercial, industrial, and undeveloped lane uses. The dependent variables (DV) in the model are represented by these five lane uses and are defined as follows:

1. SHP = percentage of single residential acreage to total acreage in each study subsection.
2. MHP = percentage of multiple residential acreage to total acreage in each study subsection.
3. COMP = percentage of commercial acreage to total acreage in each study subsection.
4. INDP = percentage of industrial acreage to total acreage in each study subsection.
5. UDEVP = percentage of undeveloped acreage to total acreage in each study subsection.

The effects tested are the explanatory variables (EV), which include six sets of binary (qualitative) variables and one continuous variable defined as follows.

1. Binary variable for abutting effect: DA = 1 if land is abutting study freeway section, DA = 0 otherwise;

TABLE 4 Socioeconomic Characteristics of the Study Areas in the Before Period (1950-1960) and the During and After Periods (1960-1970)

Year	Area	Population	Family Income ($)	No. Dwelling Unit	No. Single Dwelling Unit	Medium House Price ($)	Medium Gross Rent ($)
1950	NW	11,097	3,308	3,438	2,954	6,432	29.00
	SW	5,463	3,054	1,830	1,736	8,971	29.20
1960	NW	27,938	6,377	8,787	7,403	12,200	59.00
	SW	21,665	7,822	6,213	6,191	15,333	79.00
1970	NW	41,203	10,585	13,249	10,953	17,000	110.00
	SW	58,783	13,100	20,493	12,409	23,640	167.00
Change in the before period (1950-1960), %	NW	16,841	3,069	5,349	4,449	5,768	30.00
		151.8	92.8	155.6	150.6	89.7	103.4
	SW	16,202	4,756	4,383	4,455	6,362	50.00
		296.6	156.1	239.5	256.6	70.9	171.2
Change in the during and after period (1960-1970), %	NW	13,265	4,208	4,462	3,550	4,800	51.00
		47.5	66.0	50.8	48.0	39.4	86.4
	SW	37,118	5,278	14,280	6,218	8,307	88.00
		171.3	67.5	229.8	100.4	54.2	111.3

2. Binary variable for freeway location differences: LC = 1 if land is along the Southwest Freeway, LC = 0 otherwise;

3. Binary variable for the first phase of freeway construction staging where only service roads have been built: SR = 1 if freeway section is staged with just the first phase completed, SR = 0 otherwise;

4. Binary variable for the second phase of freeway construction staging where both the service roads and main lanes have been built: SFS = 1 if freeway section is staged, with the second phase completed, SFS = 0 otherwise;

5. Binary variable for freeway construction type where freeway section has not been staged, main lanes and service roads were built together: SFN = 1 if freeway section is nonstaged, SFN = 0 otherwise;

6. Binary variable for capacity change: CP = 1 if number of freeway main lanes changes, CP = 0 otherwise; and

7. Continuous variable for average daily traffic volume, ADT.

Because it is believed that interaction among land uses is highly probable, the model is, therefore, expressed in a set of simultaneous equations. Each of the dependent variables is expressed as a function of other dependent variable(s) and some combination of explanatory variables (3). In functional form it is shown as follows:

$$DV_i = \alpha_i + \sum_j \beta_{ij} + DV_j + \sum_k \gamma_{ik} EV_k \qquad \text{for } i \neq j$$

where

i = type of land use, where $i = 1, \ldots, 5$;
j = type of land use, which is different from i;
k = number of explanatory variables, where $k = 1, \ldots, 7$; and
α, β, γ = estimated coefficients.

Because the staging effect is the most relevant effect investigated in this study, the three sets of binary variables, SR, SFS, and SFN, attempting to capture this effect, are included in all the equations.

The simultaneous equation model is estimated first by two stage least squares (2SLS) to give consistent and unbiased estimated of the coefficients. Because it is likely that there are interactions among disturbances across equations, third stage least squares (3SLS) is also used to reestimate the model in order to improve the efficiency of the estimated coefficients.

Tables 5 and 6 give the estimated results of the regression model using 2SLS and 3SLS, respectively. Among the large number of explanatory variables, some are found to have little significant influence on one type of land use but a significant influence on another type, and some are found to have no significant influence on any type of land use. The capacity change is found to be in the latter category and, therefore, is eliminated completely in the final model formulated. The resulting model consists of a set of simultaneous equations, with each equation relating one type of land use acreage, in percentage of the total acreage, to one or two influential endogenous variables together with various combinations of mostly significant binary variables.

An examination of the estimated coefficients in Tables 5 and 6 shows that the two statistical methods (2SLS and 3SLS) have similar impacts on all variables, except that two of the estimated coefficients differ in levels of significance and in magnitudes. The estimated coefficient of SR in the equation for commercial land use, COMP, is significant statistically at the 10 percent level when 2SLS is used but narrowly misses that level of significance when 3SLS is adopted. The reverse is found to be true for the estimated coefficient of SFS in the equation for undeveloped land use, UDEVP.

R^2 for the 2SLS set of estimated equations ranges from 0.2620 to 0.9343, whereas the set using 3SLS, R^2 is 0.6032. The effects of the three binary variables most closely related to freeway stage construction (SR, SFS, and SFN) on land use changes, using the results for 3SLS, are summarized in the following paragraphs.

Single Residential Acreage

Single residential acreage is significantly and positively influenced by all three types of freeway construction: (a) first phase of the staged freeway segment (SR), (b) second phase of the staged freeway segment (SFS), and (c) the nonstaged freeway segment (SFN). Among the three, the nonstaged freeway segment construction has the greatest influence on single residential acreage, which is estimated to be 16.4 percentage points higher than would have occurred with no freeway construction. As expected, a

TABLE 5 Estimated Coefficients Using Two Stage Least Squares

		Independent Variable										
		Exogenous Variable						Endogenous Variable				
Dependent Variable	Constant	DA	LC	SR	SFS	SFN	ADTX10^{-4}	SHP	MHP	COMP	R^2	F Ratio
SHP												
Coefficient	15.9431[a]	-5.3771[a]	-10.2050[a]	8.5989[a]	15.7813[a]	16.6607[a]			.2138		.2620	5.27
t-statistic	6.09	-2.03	-3.37	2.64	4.08	2.21			-.53			
MPH												
Coefficient	1.7440[a]	-4.0859[a]		1.5131	-3.7463[b]	4.0612[b]				.3963[a]	.3750	10.81
t-statistic	1.77	-3.22		1.10	-1.55	1.38				3.86		
COMP												
Coefficient	3.4274[a]			3.1015[a]	8.2992[a]	7.2605[a]	2.4648[a]	-.2006[b]	-1.0980[a]		.7100	36.32
t-statistic	1.89			1.40	2.67	1.85	6.44	-1.29	-2.83			
INDP												
Coefficient	1.6734[a]		-2.9449[a]	.6717	4.1950[a]	5.0917[a]			.3183		.4248	13.29
t-statistic	2.64		-3.34	.71	3.75	2.36			2.78			
UNDEVP												
Coefficient	102.4407[a]	.9463		1.8683	4.0655	2.5595		-1.3510[a]	-1.1675[a]	-1.2552[a]	.9343	178.80
t-statistic	50.02	.51		.94	1.20	.71		-9.33	-4.57	-8.12		

[a]Significant at 5 percent
[b]Significant at 10 percent.

TABLE 6 Estimated Coefficients Using Third Stage Least Squares

Dependent Variable	Constant	Independent Variable: Exogenous Variable: DA	LC	SR	SFS	SFN	ADTX10^{-4}	Endogenous Variable: SHP	MHP	COMP
SHP										
Coefficient	16.548[a]	−7.7758[a]	−8.3099[a]	8.7963[a]	15.3543[a]	16.4194[a]			−.2959	
t-statistic	6.34	−3.08	−2.79	2.70	3.98	2.18			−.73	
MHP										
Coefficient	1.3085[b]	−3.1690[a]		1.5232	−3.5111[b]	4.3018[b]				.3843[a]
t-statistic	1.34	−2.56		1.10	−1.45	1.47				3.75
COMP										
Coefficient	3.5886[a]			2.6473[a]	8.9043[a]	5.1946[b]	2.1622[a]	−.2283[b]	−.6279[a]	
t-statistic	2.04			1.21	3.01	1.33	6.20	−1.55	−1.77	
INDP										
Coefficient	1.7732[a]		−3.2234[a]	.6724	4.3229[a]	5.3207[a]			.3143	
t-statistic	2.80		−3.68	.71	3.87	2.47			2.74	
UDEVP										
Coefficient	103.8327[a]	−.9895		2.1558	3.2552[b]	.7807		−1.4109[a]	−1.0746[a]	−1.2002[a]
t-statistic	56.68	−.88		1.12	1.48	.23		−10.99	−5.77	−18.89

Note: R^2 = .6032.

[a]Significant at 5 percent.
[b]Significant at 10 percent.

freeway with main lanes and service roads constructed by either the staging or nonstaging method influences the percentage of single residential acreage more than by construction in the first phase of staging, with only service roads completed.

Multiple Residential Acreage

The first phase of staged freeway construction with only service roads opened has no significant influence on this land use category. A freeway with both main lanes and service roads built by the staging method has a negative and significant influence on MHP land use. The nonstaged freeway construction method is positively and significantly related to MHP. Therefore, among the three types of freeway construction, only the nonstaged type has a positive influence on this land use category and that effect is relatively small with only a 4.3 point increase in the percent of MHP land use compared to areas with no freeway construction.

Commercial Acreage

Freeway construction with only service roads opened is found to be positively related to COMP but barely below the 10 percent level of significance, whereas the other two freeway construction types are found to positively and significantly influence COMP. In comparing the second phase staged and nonstaged freeway construction, it is found that the former type exerts greater influence on COMP than the latter type. This finding is not consistent with what had been expected. However, commercial development is likely to be greatly stimulated along a freeway where the service roads have been built in anticipation of the main lane construction. Together the staged and nonstaged main lanes and service roads increase commercial acreage by about 14.1 percentage points compared to areas with no freeway construction.

Industrial Acreage

Among the three dummy variables for freeway construction types, the coefficient of SR is found to be statistically insignificant whereas those of both SFS and SFN are found to be positive and significant. The estimated coefficient of SFN is larger than that of SFS, implying that the nonstaged freeway construction is more influential on the mean INDP than the staged freeway construction. The two influences combined increase industrial land use by about 9.6 percentage points compared to areas with no freeway construction.

Undeveloped Acreage

The only type of freeway construction that is significant at the 10 percent level in relating to UDEVP is the second phase, staged construction type. The positive estimated coefficient of SFS is surprising because it is expected that any type of freeway construction should have a negative effect on UDEVP (a positive effect on development). In this case the coefficient is not significant at the 5 percent level and the sign appears to be dominated by the highly significant endogenous variables. These variables appear to be, in effect, overcompensating for the staging effect on overall development, thus, causing the surprising sign of the coefficient SFS in the equation. This could also be the result of losses of existing land use development when the right-of-way was purchased.

VEHICLE USER IMPACT

The decision to stage a new freeway construction rather than build the entire facility at once should include the additional user costs that would result if access to the facility is delayed for a period of time as the staging progresses.

Obviously, there are benefits to staging, mainly from the delay in expenditures for highway construction. However, those benefits should be compared to the costs to users of the delayed facility in order to determine the overall direct effects of staging a highway facility.

Calculation of User Costs

The additional user costs of staging for a particular highway section can be defined as the difference in user costs between the costs generated while the facility was not open and the costs if the facility had not been staged. In mathematical terms,

$$AUC = \sum_{i=1}^{n} UC_{Ai} - UC_{Ei}/(1+r)^i \quad (1)$$

where

AUC = present value of additional user costs resulting from staging,
UC_{Ai} = actual corridor user costs in year i,
UC_{Ei} = expected corridor user costs in year i if facility had been open,
n = number of years staging delayed opening of facility, and
r = discount rate (assumed 8 percent).

Vehicle user costs consist of four major components: time costs, vehicle running costs, speed-change cycling costs, and accident costs. An improved version of the Highway Economic Evaluation Model (HEEM), which uses a more realistic corridor traffic allocation procedure, provides equations and parameters to calculate each one of these user costs components in a simple and consistent manner (4). Therefore, these equations are used to calculate the user costs as a result of staging for the two Houston freeways examined in this paper, the NW freeway, US-290, and the SW freeway, US-59. Three sections of each freeway are included in the analysis. The first section (NW1) of the NW freeway is deleted from the analysis because of the lack of traffic count station data for the corresponding section on Hempstead Road. The first section (SW1) of the SW freeway was not staged.

There is evidence that improved capacity induces additional vehicles to use a particular facility (5). However, because induced traffic could not be handled with any degree of precision, it is not included in this analysis. Therefore, the additional user cost numbers reported here should be regarded as a minimum value because the true value would be higher if induced traffic were included.

Calculation of Construction Costs

Construction cost savings from staging are handled in a similar fashion as user costs. Only construction costs attributable to staging the service roads or main lanes are included in this analysis. The costs of right-of-way, utility adjustments, storm sewers, and preparation of right-of-way are not included. Because it would be difficult, if not impossible, to identify the projects that would have been deferred in Texas if these freeways had not been staged, direct motorist benefits cannot be calculated and are, therefore, calculated indirectly by using the cost of capital (or discount rate) as a proxy for those benefits.

$$BDC = \sum_{i=1}^{n} C_i[1-(1+r)^{-i}] \quad (2)$$

where

BDC = benefits of delayed construction for a given highway segment,
C_i = construction cost in year i,
n = number of years staging delayed opening of facility, and
r = discount rate (assumed 8 percent).

Effects of Staging on Costs

The changes in user costs and construction costs for each freeway as a result of staging are given in Table 7. The net cost of staging, which represents the difference between the additional user costs and the benefits of delayed construction, is also given.

For each of the highway segments, the net cost of staging is positive. This indicates that the costs to users of staging are greater than the benefits of delaying construction expenditures. There is also a significant difference in the effects of staging service roads compared to staging the main lanes. On both sections of the NW freeway, the net staging costs for the service roads are substantially less than the comparable net staging costs for the main lanes.

TABLE 7 Additional Costs as a Result of Staging of NW and SW Freeways

Freeway Section and Design Element	Years	Thousands of 1962 Dollars: Additional User Costs[a]	Benefits of Delayed Construction	Net Cost of Staging
Northwest Freeway				
Section 2				
Service road	1962-1969	1,085.9	457.5	628.4
Freeway	1962-1978	4,652.7	1,714.7	2,938.0
Sections 3 and 4				
Service road	1962-1974	3,307.8	2,216.1	1,092.6
Freeway	1962-1980	13,390.5	8,049.6	5,340.9
Southwest Freeway				
Section 2				
Freeway	1962-1965	1,060.6	79.0	981.6
Section 3				
Freeway	1962-1969	1,664.3	274.7	1,389.6
Section 4				
Freeway	1962-1974	4,303.6	2,420.8	1,882.8

[a]Assumes 8 percent trucks, value of time for cars of 9 cents per vehicle minute, and a value of time for trucks of 18 cents per vehicle minute.

The difference between the costs of service road staging and main lane staging is due, in part, to the longer delay in building the main lanes. The service roads were opened sooner and avoided the accumulation of user costs as corridor traffic volume increased in recent years. But there is a significant difference in user costs between the service roads and main lane freeway even in the earlier years. It is, therefore, reasonable to infer that the delay of main lane freeway construction has a greater impact on user costs than delay of service road construction. This implies that the current practice of first opening the service roads, then the main lanes, may not be the optimal strategy, especially in a rapidly growing area such as Houston.

Additional costs as a result of staging are higher for the NW freeway than for the SW freeway (Table 7). In the case of the NW freeway, all sections were staged and the construction of each stage has been spread out over a much longer period of time than was the case of the SW freeway. The results indicate staging decisions should be carefully evaluated, incorporating both user and nonuser impacts, and should not be made exclusively on the basis of budget constraints.

CONCLUSIONS

The economic effects of stage construction of a freeway on users and nonusers is investigated in this study. The effects on users are limited to time costs, vehicle operating costs, and accident costs, and the effects on nonusers include a comparison of land use changes on property adjacent to or near the freeways under study. The following conclusions can be drawn as a result of the study:

1. The designs of the two study freeways and the "before" construction characteristics of the alternate routes and the surrounding areas are very similar. However, the construction schedules of the two freeways are considerably different. Therefore, significant differences in land use changes and user costs for the two freeways can be partially attributed to differences in their service road and/or main lane construction schedules.

2. The analysis of actual land use changes reveals that single and multiple residential uses, as well as industrial uses, are sensitive to staging freeway construction. Residential land use is by far the most sensitive to freeway construction, with main lanes having a greater impact than service roads. Overall, residential development is 40.6 percentage points higher in areas that have freeway access compared to areas that have no freeway stages completed. The impacts are similar for both commercial and industrial development but with lower magnitudes, 16.7 and 10.3 percentage point increases, respectively. The impact of freeway construction on multiple residential land use is much smaller and less statistically significant with an overall increase of only 2.3 percentage points compared to areas with no freeway construction stage completed.

3. The results obtained indicate that stage constructing a freeway costs more in vehicle user costs than in benefits gained from delaying construction expenditures. Also, the delay of main lane freeway construction has a greater impact on user costs than delaying service road construction.

4. Freeway staging decisions should not be made exclusively on the basis of budget constraints. Other factors, such as land use impacts and vehicle user impacts, need to be considered. This type of information and trade-off should be explicitly incorporated into the decision-making process of project selection and construction timetable.

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The Work-Based Retail Activity Model: A Tool for Downtown Development Planning

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ABSTRACT

The major findings of research on the work-based shopping behavior of central business district (CBD) employees are described. Using survey data collected in Boston, Massachusetts, a system of econometric models was developed to test hypotheses about work-based shopping behavior and to provide a tool for evaluating the retail impacts of new downtown development. The research demonstrates the importance of employee shopping trips to the downtown economy; the average employee expenditure in 1982 dollars was $1,540, and the total employee contribution in downtown Boston was roughly $546 million per year. The model system provides a useful tool for forecasting the CBD retail sales that will be generated by employees in proposed new developments. Model estimation has also revealed that shopping behavior is sensitive to the number and location of shopping and lunch opportunities available and the models have been used to forecast the effect on retail sales of proposed new retail development. Characteristics of the employee, sex, income, and occupation can also explain differences in trip rates and expenditure amounts. This is of particular importance because of changes that are occurring in the composition of the CBD work force. The applicability of the model system for analysis of development impacts is demonstrated by example applications. The paper concludes with a discussion of the strengths, weaknesses, and general capabilities of the model system in the context of planning and policy analysis.

The decade of the 1960s saw an unprecedented deterioration of the retail economy in the nation's central business districts (CBDs). Urban highway development, suburbanization of metropolitan areas, and the development of regional shopping centers left the stores and restaurants in the CBD at a competitive disadvantage, resulting in a decline in sales (in constant dollars) in almost every major city.

A resurgence in the 1970s and 1980s of the CBD as a major center for new office development has brought new hope to downtown retailers. An annual growth rate of CBD office employment of 3 to 5 percent is not uncommon in the larger U.S. cities (1). Although this growth has generally been viewed favorably by retailers, the actual impact on sales has not been clearly understood.

In this paper a comprehensive profile of employee shopping activity in Boston, Massachusetts, is presented and a model system that was developed to predict the sales impact of future downtown development is described. The profile and the model system are based on more than 10,000 surveys of downtown workers conducted in 1978 and 1980 (2). The research was conducted for the Boston Redevelopment Authority and is documented in greater detail in the report "Downtown Crossing: An Economic Strategy Plan" (3).

The primary motivation for the development of the work-based retail activity model (WRAM) was the need to assess the potential retail sales volume that might be generated in downtown Boston, by new employees in proposed development projects in the CBD. The development and application of the WRAM system was only one part of a larger economic analysis of the impact of new developments and the potential for increasing retail sales in the Boston CBD conducted for the Boston Redevelopment Authority. The specific focus of this element was on the daytime shopping activities of employees who work sufficiently close to the CBD to either shop or eat a meal there on a work-based trip.

One of the main objectives of the analysis was to provide a clear and comprehensive profile of the daytime shopping activities of CBD employees. This profile was produced using a combination of simple tabulation of survey results and model simulation. The purpose of the model was to represent the decision making of downtown employees in a way that would allow the analyst to approximate the choice of downtown employees in the presence of retail opportunities different from those faced by the employees included in the survey or as defined by alternative policy scenarios.

A summary of the characteristics and capabilities of the WRAM system is presented in this paper. The model structure and specification are described and, through example applications, an indication of the model sensitivity is provided. Also provided is a profile of employee shopping behavior produced by the model system. The paper concludes with a discussion of model system capabilities and limitations.

THE WORK-BASED RETAIL ACTIVITY MODEL (WRAM)

Model Structure

The WRAM system represents decisions about four types of trips:

1. Midday trips for lunch,
2. Midday trips to shop,

3. Evening trips for dinner, and
4. Evening trips to shop.

Within each of the four trip types, four decisions are represented in the modeling system:

1. Whether to make a trip,
2. Where to make the trip,
3. Whether to purchase something, and
4. How much to spend.

An illustration of the structure of the modeling system is provided in Figure 1.

Models of the first type are referred to as trip generation models. In the case of the WRAM system, the models predict the probability that an employee will make a trip of the type designated. The aggregate number of trips in a forecast is found by summing the probabilities of individual employees.

The second type of decision determines the distribution of trips. The WRAM system does not distribute trips of individual employees to specific stores or restaurants, but sums the number of trips in each zone of a 40-zone system and then distributes the trips in the zone among the 40 zones.

The last two decisions are combined and are represented in WRAM by a single average purchase value per trip for each trip type. This average purchase value reflects the decision on the part of some trip makers not to make a purchase. Their trips are, in effect, averaged in with a purchase value of $0.00. The purchase values used in the model (in 1979 dollars) are:

Trip	Purchase Value ($)
Lunch	3.74
Midday shopping (when combined with a lunch trip)	10.48
Midday shopping (when no lunch trip is made)	15.72
Dinner	7.48
Evening shopping	15.72

All sales values or expenditure levels expressed in other parts of the paper is dollars other than 1979 dollars imply certain assumptions about the inflation in retail prices since 1979.

Model Formulation and Estimation

Each of the models in the package was estimated by using what is referred to as a "logit" formulation. The name is derived from the logistic curve; an S-shaped curve that represents the probability that an individual will make a particular choice over all other choices for different levels of relative utility of the choices.

The logit model is based on the assumption that a decision maker associates with each choice alternative a particular utility and will choose the alternative with the highest utility. Utilities cannot be measured directly, but if assumed to be linear functions of certain measurable attributes, the functions can be estimated by using maximum likelihood estimation.

The probability of a particular choice i is related to the utilities of each of the choices available according to the relationship:

$$p(i) = \exp(U_i) \sum_{\text{all } k} \exp(U_k)$$

where

$P(i)$ = the probability of choosing alternative i,

U_i = the utility associated with alternative i, and

U_k = the utility associated with alternative k.

Estimation of the model coefficients was performed by using a standard estimation package that selects the set of coefficients that have the maximum likelihood of producting the observed choices. For more information on maximum likelihood estimation, the reader is referred to a standard econometrics text (4) or a text on choice modeling (5).

In the case of the trip generation models, the choice is a binary one; between making a trip and not making a trip. In the case of a binary choice model, all exogeneous variables can enter into the utility formulation for one option. The coefficients or weights that are estimated by the estimation package may be either positive or negative reflecting either a positive or negative effect on the utility associated with the choice.

In the case of the trip distribution models, the utility associated with a particular zone is represented as a combination of the amount of retailing in the zone, the distance to the zone, and certain nonquantifiable characteristics. The nonquantifiable characteristics may include such attributes as safety, cleanliness, variety, or price. The effect of these nonquantifiable characteristics is captured in a constant term in the utility function for groups of zones. The utility associated with a zone could thus be written as follows:

$$U_{ij} = b_0 + b_1 \log(EMP_j) + b_2 \log(DIST_{ij}) + e_{ij}$$

where

U_{ij} = the utility that individual i associates with destination,

EMP_j = the retail employment in zone j,

$DIST_{ij}$ = the distance between individual i and zone j,

e_{ij} = an error term, and

b_0, b_1, b_2 = model estimated coefficients.

Model Specification

Trip Generation

There are three types of characteristics that could influence an employee's decision to make one of the four types of work-based trips under consideration:

1. Characteristics of the retail opportunities available to the employee,
2. Characteristics of the building in which the employee works, and
3. Characteristics of the employee.

The importance of the first type of characteristic is rather obvious. If there are no places where an employee can purchase a lunch within a reasonable travel time, the employee is not likely to decide to leave his or her building for lunch. Likewise, the greater the opportunities available for lunch or the closer the opportunities, the more likely the employee is to decide to leave the building for lunch. A similar argument could be made for the relationship between the availability of non-food retail opportunities and work-based shopping trips. The key to selecting appropriate variables to capture the essence of this availability is finding a measure that includes both the size of each opportunity and the location of each opportunity with respect to the employees's workplace.

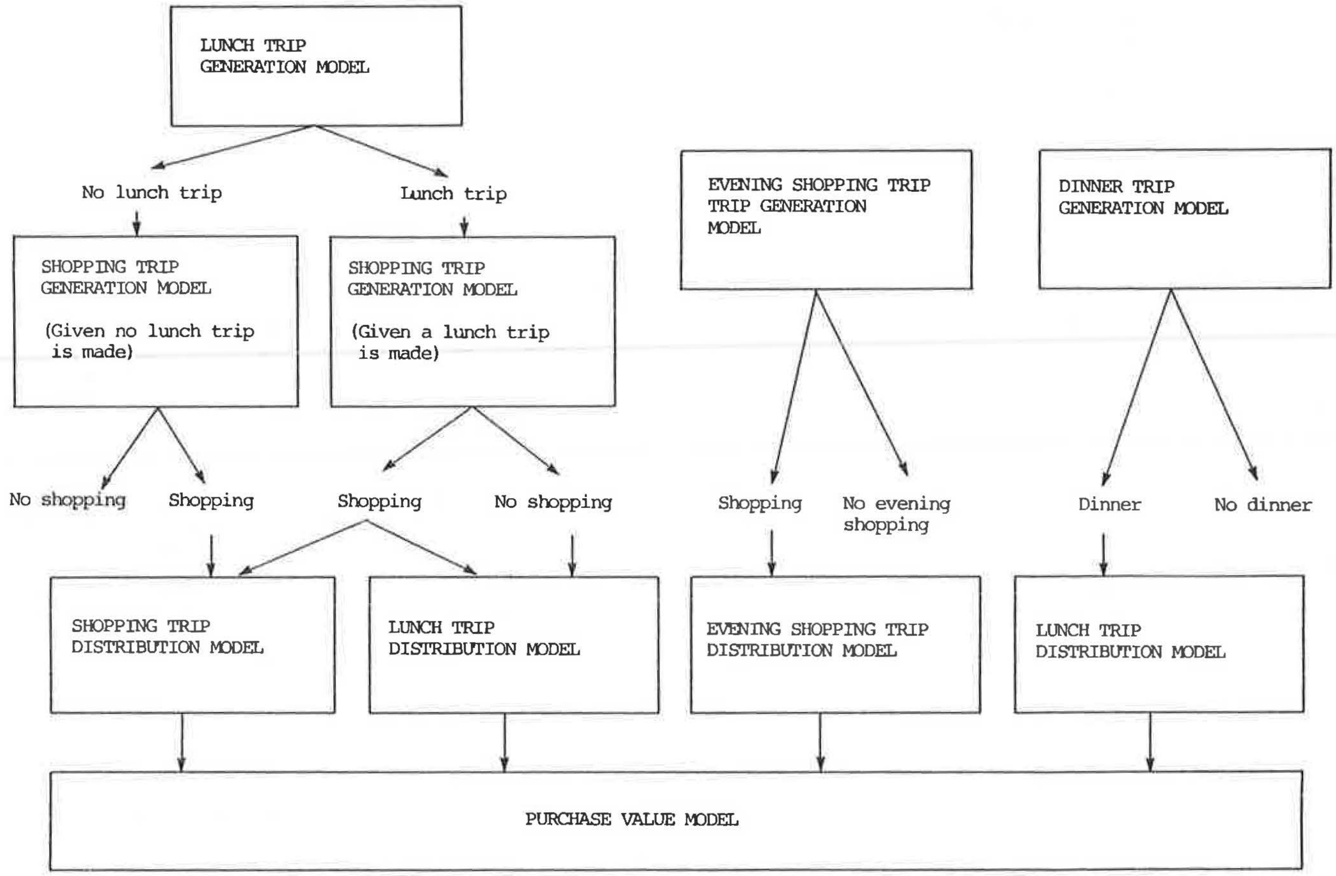

FIGURE 1 Structure of model system.

Two alternative functional forms were tested by calculating the measures

$$A_j = \sum_{\text{all } i} s_i/d_{ij} \text{ and } A_j = \sum_{\text{all } i} s_i/(d_{ij})^2$$

where s_i is the retail employment in block i and d_{ij} is the distance between employment location j and block i.

The measure using d_{ij} provided more explanatory power both in a direct comparison with trip rates and in actual multivariate modeling in which other variables were included.

Characteristics of the second type, those of the building in which the employee works, were not incorporated into the model because of the difficulty of collecting this type of data for forecasting. By not including these characteristics in the models, forecasts assume that future buildings are similar to those in the estimation data set.

One characteristic that was hypothesized to be an influencing factor and that proved to be so in preliminary tests was the availability of food services in an employee's building. The availability of food services in a building should satisfy the lunch needs of some employees without a trip out of the building. This should then reduce the employee's probability of making a trip out of the building for lunch and, because of the linkage between lunch and midday shopping trips, should also reduce the probability of a midday shopping trip. Some exploratory model estimation indicated that the effect did exist, generally reducing the number of lunch trips by about 10 percent and the number of shopping trips by about 7 percent.

Employee characteristics were the third type. The importance of these characteristics is most clearly demonstrated by the difference in shopping rates for men (26 per 100) and women (36 per 100). The difference in trip rates is reflected both in the stratification by sex and in a stratification by occupation primarily because of a high correlation between sex and occupation (84.4 percent of office clerical workers are women and 64.9 percent of executive or professional office workers are men).

Income was included as a variable in the trip generation models primarily on the basis of the hypothesis that a higher income indicates a greater purchasing power and, therefore, a greater financial ability to shop. Other justifications for its inclusion are also possible, however. It might be argued that the CBD provides better opportunities for the purchase of expensive or high quality goods than alternative shopping areas. Employees with higher incomes would then be more likely to shop downtown than would be explained solely on the basis of their purchasing power.

Reasons for including occupation in the trip generation models are not as obvious, particularly when one has controlled for differences in sex and income. The main justification for its inclusion would be that certain occupation types are more restrictive than others in the amount of time allowed for midday shopping or lunch trips. It might be argued that clerical positions tend to be less flexible in work hours, which restricts the employee's ability to shop during working hours. It might be expected that a greater proportion of work-based shopping trips may be made by clerical employees after rather than during working hours.

Information on the age of an employee proved to be of little value in either a theoretical or empirical way in explaining differences in lunch or shopping trip rates. There was some indication that the lunch trip frequency was highest among the youngest (under 25) and oldest (65 or over) employees but age was not included in the models.

The results of the model estimation for trip generation are given in Table 1. Included below each coefficient estimate is the t-statistic for the coefficient. The t-statistic provides an indication of the significance of the variable in the model. A value of 1.7 or more generally indicates that the estimated coefficient provides a significant improvement in the explanatory power of the model (reflecting a 90 percent level of confidence that the coefficient is significantly different from zero).

The two accessibility variables EACC and NACC were significant and of the appropriate sign for the midday models. It should be noted, however, that the accessibility variables provide little improvement to the evening models. Early estimation of the dinner model that included the variable EACC produced a negative coefficient that is counterintuitive. Subsequently, estimations were therefore made without an accessibility variable.

Each of the socioeconomic variables added explanatory power in at least one of the models but the effect of each variable differs dramatically from model to model. Income (HINC) and occupation (OCC), for example, are far more significant in the shopping models than in the lunch model. The variable SEX, which has a value of 1 if the employee is female, is positive and highly significant in each model, indicating that female employees shop and make lunch trips more frequently than male employees, all else being equal.

Trip Distribution

The trip distribution models contain only three types of variables.

1. The retail employment in a zone (EMP),
2. The distance from the employee's workplace to the zone (DIST), and
3. A constant term for each major area to reflect nonquantified elements of attractiveness.

Both the employment and distance variables are included in the model as the natural log of the variable: log(EMP) and log(DIST). This specification was chosen primarily because it provided a better fit to the data than other alternatives. The lunch and midday shopping trip distribution models include two employment terms: one representing food-oriented employment (FDR) and one representing nonfood employment (NFR). The models include both terms because of the linkage between lunch and shopping trips and because inclusion of both terms improved the explanatory power of the model.

The evening shopping trip model yielded the best result when a single employment term for all retail employment (TLR) was included rather than either a nonfood employment term alone or both the food and nonfood employment terms included separately. Evening dinner trip distribution could not be modeled directly because of an insufficient number of observations. To compensate, the dinner trip distribution has been represented by a distribution model estimated on the basis of trips for lunch only. In the model, only a food-oriented employment variable (FDR) was included. Because of differences in the types of food-oriented establishments in the various zones, a somewhat different distribution of lunch and dinner trips might be expected. Unfortunately, sufficient data were not available to produce a better distribution.

Eleven area-specific constant terms were estimated: three representing the main department stores and eight representing the main districts in downtown Boston. One additional area-specific constant, DTC(2), was included to represent attraction to the Downtown Crossing, the heart of the shopping district, for employees more than 20 min away. Because the Boston Employee Survey underrepresented employees in the areas more than 20 min from the Downtown Crossing, this variable is designed to reduce any bias in the model by controlling for it directly.

The results of the model estimation for trip distribution are given in Table 2. The t-statistics indicate that size and distance are important variables in the models but a significant amount of the variation is also explained by the area-specific constants.

Sensitivity Analysis

The sensitivity of expenditures for lunch and shopping trip purposes to changes in characteristics of the retail opportunities available and to changes in the composition of the employment can be illustrated by applying the model system for a hypothetical building in the downtown area. The building in the example has an employment of 1,000, all of whom are nongovernmental office employees. The sensitivity of shopping activity is illustrated by examining the effects of seven sample changes.

1. Addition of 50,000 ft^2 of new food-oriented retail floor space at a distance of 1,000 ft from the building.

TABLE 1 Estimated Trip Generation Model Coefficients

Trip Type	Constant Term	EACC	NACC	SEX	HINC	OCC
Lunch	−0.57	0.17×10^{0}	NA	0.58×10^{-1}	0.48×10^{-1}	-0.52×10^{-1}
Coefficient (t-statistic)	2.7	5.5		8.3	0.7	0.7
Midday shopping						
With lunch	−0.70	NA	0.33×10^{-1}	0.61	0.92×10^{-1}	0.14
Coefficient (t-statistic)	3.8		1.7	7.1	1.1	1.6
Without lunch	−1.62	NA	0.45×10^{-1}	0.48	0.23	0.29
Coefficient (t-statistic)	6.4		1.7	3.9	2.0	2.3
Dinner	−3.04	—[a]	NA	0.13	0.19	−0.45
Coefficient (t-statistic)	2.1			0.8	1.2	2.6
Evening shopping	−2.50	NA	0.11×10^{-1}	0.86	−0.46	−0.17
Coefficient (t-statistic)	10.4		0.4	7.2	4.2	1.6

Note: Variable definitions: EAC = Σ(food-oriented employment)$_i/d_{ij}$; NACC = Σ(nonfood employment)$_i/d_{ij}$; SEX = 1 if employee is female, 0 otherwise; HINC = 1 if household income is $30,000 or more, 0 otherwise; OCC = 1 if employee's occupation is clerical, 0 otherwise. NA = not applicable.

[a] Efforts to estimate a coefficient for this variable did not produce satisfactory results.

TABLE 2 Estimated Trip Distribution Model Coefficients

Trip Type	Store 1	Store 2	Store 3	Back Bay	Prudential Center	Quincy Market	Tremont Street	Downtown Crossing	Govern-ment Center	Park Square	DTC (2)	Log (FDR)	Log (NFR)	Log (TLR)	Log (DST)
Lunch	1.06	1.74	0.73	−0.20	0.68	2.41	1.40	0.32	0.98	−3.32	−1.12	0.09	0.21	NA	−1.22
	7.0	12.2	5.2	8.8	3.1	19.9	11.1	4.3	7.8	3.3	3.1	5.5	7.7		23.6
Midday shopping	1.40	1.88	1.00	2.77	1.00	2.16	1.54	0.69	0.98	−2.55	−1.08	0.06	0.21	NA	−1.31
	8.8	12.4	6.8	1.0	3.7	13.7	9.6	7.7	5.6	2.5	2.8	3.0	6.8		20.0
Evening dinner	0.95	1.78	0.36	0.43	1.19	2.64	1.42	0.17	0.91	−2.82	−0.99	0.19	NA	NA	−1.16
	3.4	8.1	1.3	1.4	4.3	16.5	8.1	1.7	5.4	2.8	1.7	8.0			16.4
Evening shopping	1.35	1.70	1.56	1.30	1.21	2.35	1.15	−0.07	1.52	0.38	NA	NA	NA	0.49	−0.55
	3.7	5.3	3.9	0.3	3.1	7.8	2.3	0.3	3.8	0.6				5.2	4.2

Note: NA = not applicable.

2. Addition of 50,000 ft² of new food-oriented retail floor space at a distance of 500 ft.
3. Addition of 100,000 ft² of nonfood retail floor space at a distance of 1,000 ft.
4. Addition of 100,000 ft² of nonfood retail floor space at a distance of 500 ft.
5. A 10 percent increase in the proportion of female employees in the building.
6. A 10 percent increase in the proportion of clerical employment in the building.
7. A 10 percent increase in the proportion of employees in the building with household incomes of $30,000 or more (1980 dollars).

The base distribution of employees by person type is assumed to be the same as the overall average for the Boston CBD office employment.

	%
Female	57.3
Clerical	43.1
Upper income	40.4

The results of the analysis are given in Table 3. Two important points emerge from the analysis. First, lunch trips are more sensitive to changes in accessibility to food-oriented floor space than shopping trips are to nonfood floor space. Second, among the characteristics of the employees, the sales volumes are most sensitive to the proportion of female employees. This result is significant in light of nationwide employment statistics that indicate that by 1990 the proportion of females among CBD employees may increase by 5 percentage points. According to the WRAM forecasts this change would produce an increase in downtown sales in Boston of 2 to 3 percent or about $10 million to $15 million per year (in 1982 dollars).

TABLE 3 Sensitivity Analysis: Change in Retail Sales

	Changes in Annual Expenditure (1982 dollars)	
Policy or Change	Lunch	Daytime Shopping
Add 50,000 ft² of food retail at 500 ft	164,000	20,000
Add 50,000 ft² of food retail at 1,000 ft	82,000	10,000
Add 50,000 ft² of nonfood retail at 500 ft	0	36,000
Add 50,000 ft² of nonfood retail at 1,000 ft	0	18,000
Increase in the proportion of female employees of 10 percent	2,000	36,000
Increase in the proportion of clerical employees of 10 percent	−2,000	10,000
Increase in the proportion of high income employees of 10 percent	2,000	8,000

Note: Changes are for a hypothetical office building with an employment of 1,000.

In the analysis for the Boston Redevelopment Authority, the WRAM was used to provide sales forecasts for 1985 and for a number of 1990 development scenarios for downtown Boston. The 1985 forecasts indicated that the added employment from development in progress would add $131 million (in 1982 dollars) over the 1982 level of sales--a 24 percent increase. Roughly 30 percent of that increase will be in food sales and 70 percent in nonfood sales.

In the examination of future development scenarios, eight possible combinations of office and retail development were examined in the CBD. The alternatives represented different locations for development and different levels of development (low, medium, and high) for both the retail and office components. The analysis indicated that the volume of sales generated (from employees) per square foot of new retail added varied significantly from a low of $188 per square foot for the "high office-high retail" alternative to a high of $815 per square foot for the "high office-low retail" option. The analysis clearly demonstrated the importance of the employee market to the success of new retail floor space added.

PROFILE OF EMPLOYEE RETAIL ACTIVITY

Average Annual Trip Rates

The Boston Employee Survey and the WRAM system output have revealed a suprisingly high frequency of trip making. The analysis indicated that on an average day, 43 percent of CBD employees make a trip out of the building for lunch. Shopping trips are made by 31 percent, and in all 53 percent leave the building for either lunch or shopping or both. Furthermore, an additional 6 percent leave the building for purposes other than lunch or shopping. Rates are provided for a number of stratifications of the survey sample as illustrated by the data in Table 4.

Purchase Type and Expenditures

There are considerable differences in expenditures between groups when the survey sample is stratified according to the employee characteristics included in the model. Table 4 gives the average expenditure per trip (including some trips for which no purchase is made) for different subsamples segmented according to occupation, sex, income, and employment location.

An analysis using the WRAM system suggests that in 1982, employees in downtown Boston contributed $546 million in retail sales. As illustrated by the data in Table 5, the average annual expenditure per employee was $1,540. Of this amount, roughly 27 percent was for food or drink and 73 percent was for nonfood goods. The difference that retail accessi-

TABLE 4 Trip Frequency and Expenditure Profile (Office and Government Employees)

	Trips per 100 Employees[a]		Average Expenditure[b]	
Survey Sample	Shop	Lunch	Shop	Lunch
Total sample	31.3	43.1	16.40	4.90
Sex				
Male	25.6	42.7	19.40	5.10
Female	35.7	43.9	16.20	4.40
Occupation				
Clerical	34.5	43.3	14.00	4.00
Executive/Professional	29.3	43.1	19.20	5.60
Sales and other	25.7	42.7	25.30	5.60
Income				
Less than $30,000	31.9	42.8	15.90	4.30
$30,000 or more	30.7	43.4	20.20	5.60
Employment location				
Financial district	32.0	44.5	17.50	4.60
Back Bay/Prudential	26.9	34.7	13.00	5.40

[a]Trip rates may reflect mulitiple trips by an individual in a single day.
[b]The average expenditure includes trips for which no purchase is made. Such trips are entered as a value of $0.00. Expenditures are in 1982 dollars and assume an average annual inflation of 7 percent between 1979 and 1982 and an average annual increase in real income (after inflation) of 3 percent.

bility and employee characteristics can produce is illustrated in Table 5 by the expenditure profile for employees of the financial district, the employment area with the greatest access to stores and restaurants. The total average of $1,770 is almost 15 percent greater than the average for downtown Boston.

With respect to occupation, clerical workers consistently have lower average purchase value than other employees. This might well be explained on the basis of income, however, because clerical workers have a significantly lower average income than other occupations. Women also have a lower average purchase value than men, which might also be a reflection of differences in income. After accounting for differences in trip rates, however, women office employees in the sample had an average annual expenditure roughly 10 percent higher than men.

As has been implied in the previous paragraphs, the largest difference in expenditure arises when the sample is divided according to income. Although there is a slightly higher overall trip rate among those with incomes under $30,000, the differences in purchase value (which are significant) result in a much higher annual expenditure from those with incomes of $30,000 or more. The result is roughly a 25 percent higher contribution from the higher income group.

Purchase Type

The data in Table 6 illustrate the distribution of purchases and the distribution of sales for a detailed enumeration of goods. Several interesting facts are apparent from the table. First, although food constitutes 56 percent of all purchases, it represents only 26 percent of total sales volume. In contrast, comparison goods (which excludes food, drugs, and toiletries) constitute 37 percent of all purchases but 72 percent of all sales volume. What makes this particularly interesting is that the major growth in sales in the Boston CBD over the past 20 years has been in the areas of food and convenience goods.

SUMMARY CAPABILITIES AND LIMITATIONS

The WRAM system provides a powerful tool for analyzing the retail impacts of many types of CBD development policies. There are, however, particular strengths and weaknesses that should be discussed and caveats given with the model's use. The model system is designed for analysis of three main types of changes:

1. Changes in the amount or location of office floor space;
2. Changes in the amount, location, or type (food or nonfood) of retail floor space; and
3. Changes in the characteristics of downtown employment (sex, occupation, income).

The model system is not designed to test physical changes in the shopping environment (such as automobile-free zones, or sidewalk bricking) or management policies (such as increased maintenance, added security, or increased marketing). The modeling system is also not designed to differentiate between types of floor space on the basis of qualitative differences. Floor space devoted to the sale of high quality merchandise is represented in the same manner as floor space devoted to the sale of discount merchandise except to the extent that difference can be represented by different employees-to-floor space ratios.

Within the limits of analyses for which the models are intended, the WRAM system has the following distinct attributes:

1. It provides the only mechanism for incorporating the effects of both size and distance from employment when evaluating the trip-generating effect of retail floor space. In addition, all retail opportunities are considered simultaneously, not each opportunity in isolation.

TABLE 5 Profile of Average Annual Employee Expenditures (1982 dollars)

Purchase Type	Financial District Employees ($)	All Boston Proper Employees ($)
Lunch	420	360
Dinner	60	60
Total food	480	420
Daytime	975	840
Evening	315	280
Total nonfood	1,290	1,120
Total	1,770	1,540

Note: Assumes 250 working days per year, an average annual inflation of 7 percent between 1979 and 1982 and an average annual increase in real income (after inflation) of 3 percent.

TABLE 6 Distribution of Employee Expenditures by Type

Purchase Type	Percentage of all Purchases[a] (%)	Average Value[b] of Purchase ($)	Percentage of Dollars Spent (%)
Meal (sit down)	26.6	5.84	15.9
Meal (take out)	18.9	3.53	6.9
Food (other than meal)	10.5	2.98	3.2
Clothing	14.0	23.63	33.9
Books/magazines	8.0	5.79	4.8
Jewelry	1.6	41.28	6.8
Shoes	1.7	26.37	4.6
Housewares	3.3	21.67	7.3
Furniture	0.2	49.24	1.0
Drugs or toiletries	7.3	2.66	2.0
Other (comparison)	7.9	16.77	13.6
Total	100.0		100.0

[a]Based on responses to both first trip and second trip purchases.
[b]Based on value of purchases on first trip only.

2. It allows for analysis of projects that are located outside of the original Boston Employee Survey area. The relationships developed on the basis of the survey responses can be extrapolated to test the impact of projects in outlying areas.

3. It requires little new data for the evaluation of a proposed project, and the model inputs are easily prepared.

4. The results are summarized at a level of detail that is useful for general policy analysis.

The advantages make the WRAM system an appropriate planning tool in a variety of settings.

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Implementation of Downtown Automobile-Use Management Projects

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ABSTRACT

Most capital improvement studies deal with feasibility analysis or evaluation of successfully completed projects. Relatively little is known about the many cases in which projects have been attempted but have not been successfully completed. Reported in this paper are the findings of a study that investigated the implementation process of downtown automobile-use management projects. This implementation process was compared with the process encountered in alternative central business district (CBD) revitalization efforts. Information was solicited through mail surveys of city planners in 67 cities about approximately 200 CBD revitalization projects, including 38 automobile-restricted zones that have been considered, initiated, or completed during the past 8 years. Implementation problems were perceived to be related to certain project attributes and the stage that the project had reached. The latter poses interesting questions about the identification and measurement of implementation problems in future research. The study reconfirmed an emerging role for city planners that emphasizes managing, negotiating, and coordinating projects that require public-private partnerships.

Cities are expanding their role of strictly providing services or regulating business. They have shifted away from the expensive urban renewal practices of the 1960s, which involved clearance or capital improvement projects without a firm commitment from the private sector. Their new orientation is toward policies that include ways to influence their economies through the creation of jobs, the coordination of private sector roles, and the facilitation of private development (1).

Central business district (CBD) revitalization has been the dominant strategy for urban economic development. Transportation improvements and automobile-use management projects have been used as means of improving the economic vitality of urban centers. Automobile-use management is the new term used to describe broader transportation policies that manage vehicle use in a large geographic area. Automobile restriction is such a form of management that goes beyond the scope of traditional linear pedestrian malls and includes supplementary transit services (2). In addition to economic goals, automobile-restricted zones (ARZs) seek to accomplish several other objectives such as improving traffic conditions, encouraging public transit and non-automobile modes of travel, creating a more relaxed and pleasant atmosphere for pedestrians, improving environmental quality, and increasing safety (3,4).

Despite the success of a few malls in the early 1960s, attempts at implementation of automobile-restricted projects have been limited, very modest in scale, and generally confined to a single street and no more than a couple of blocks long (4). According to Knack (5), there are 150 malls constructed in U.S. cities. Although most of them have not failed outright, few have lived up to expectations. During the 1970s the average number of ARZ projects per year doubled, and several major cities such as Baltimore, Boston, Chicago, and Philadelphia implemented large automobile-restricted zone projects.

Evaluation of UMTA's experience with the ARZ demonstration program (6,7), has led to the belief that the technical skills necessary to plan an effective ARZ project are insufficient to successfully undertake and complete the project. The political and managerial problems associated with the coordination of both public and private interests during the process of adopting an agreeable ARZ plan have emerged as formidable. Apparently, unexpected obstacles along the project's "institutional trial" are frequent and, even when circumvented, cause delays that are costly in terms of dollars, momentum, and support (2).

DEFINITION OF IMPLEMENTATION

Plan implementation has been a relatively recent field of investigation. According to Alterman (7) and Alexander (8), there are two basic approaches to defining implementation. The traditional view of putting programs into action (9) has been criticized as not very helpful in understanding the process. The second approach views implementation as a dynamic circular process. According to Barrett and Fudge (10), policy and implementation cannot be divorced from each other, but must be analyzed as one continuous, adaptive policy-action relationship. They suggest a perspective similar to Susskind's (11), that of viewing implementation as a negotiating process.

There is little distinction in the theoretical literature between implementation of policies, programs, and capital projects (12). Most of the case studies in the literature address the implementation of social policy such as education and welfare programs. The discussions of implementing capital improvement projects are limited to only a few cases (13). Such major projects usually take a long time to develop and during this time circumstances change, which implies a need for continuous project redefinition. The definition of implementation success also appears to be unclear. There appears to be confusion in distinguishing between achievement of project goals versus the means by which the goals are achieved (14).

The literature does not provide a ready-to-use, unified conceptual framework of the implementation process; however, it does suggest a set of general categories of variables that influence the outcome of the process. These include characteristics of the community environment, project characteristics, attributes of organization and interorganization relations, and the role that individuals play in influencing events (14-16).

STUDY DESIGN

Most ARZ policy planning studies deal with feasibility analysis or impact evaluation of successfully implemented cases (6,17,18) and pay little attention to the implementation process. There is another body of literature on ARZs that is characterized by its preoccupation with attention to describing physical design features (3,19). Very little is known about the many cities that have attempted to institute ARZs but have not been successful in bringing them to fruition. The findings of a study funded by UMTA to investigate the implementation process for ARZ projects in communities are reported in this paper.

The main goal of the study was to learn more about the implementation process of the ARZ demonstration program. To accomplish this goal it was decided that other CBD revitalization projects should be used as a basis for comparison. It was also decided that not only should successful completed projects be studied but other projects should be studied as well, in different stages of implementation.

The study also sought answers to questions such as: What are the critical socio-political and environmental factors responsible for the success or failure of ARZ and urban development projects in general? What is the role of personal and organizational motives, the timing of decisions, the external factors, preconditions in the environment, and community needs in fostering acceptance and endorsement of automobile-restriction projects?

The dependent variable that was to be explained was called "implementation problems." In building a conceptual understanding of implementation problems, project type was assumed to be a key variable. The project's organizational characteristics were suggested in the organizational behavior literature as explanatory variables as well. Successful implementation is generally viewed as dependent on the structure of organizations responsible for implementing the project, the strength of the mandate for the project, the specificity with which the goals are stated, and the personalities of the individuals involved. Finally, the city characteristics were considered to be the third predictor. The first three variables discussed were project level, whereas the latter is a city level variable. In the second phase of the study, the impact of a variable that related to various events influencing the successful completion of the ARZ projects was analyzed.

The study followed a multi-method approach to information collection that consisted of a combination of survey research, case studies, and the use of secondary sources in three sequentially dependent phases. In the absence of a clear definition of implementation success and with the limited examples afforded in the literature, this study had to adopt a descriptive and exploratory approach and had to rely to a great extent on unstructured, open-ended questionnaires in the design of the surveys.

In the first phase, information was solicited from city planning department directors through a mail survey about CBD projects in major U.S. cities during the past 7 to 8 years. One hundred twelve cities within 99 standard metropolitan statistical areas (SMSAs) were sampled. The sample, though not a random one, is representative of the U.S. population of SMSAs in terms of size and location. Respondents were asked to describe three projects from each city. A total of 67 cities responded (60 percent response rate) to the survey and 176 projects were described. Ten projects were dropped because they were planning studies rather than capital projects leaving 166 projects in the study sample.

In the second phase, the study focused on ARZ projects. It investigated whether specific problems or events that occurred during the implementation process of an ARZ project might have influenced its success. Two rounds of questionnaires were sent to the 51 cities that, according to information from the first phase, had proposed or constructed downtown ARZs during the past 7 to 8 years. One hundred sixteen individuals, who had been involved in the implementation of the ARZ projects, were contacted in those cities. The return rate was 38 percent for individuals and 58 percent for cities. Because of the low rate of return, only the response from one individual (the city planning director, when possible) from each city was used in the analysis.

In the last phase of the project, a more in-depth case study type of analysis was conducted for the six cities selected by UMTA as ARZ demonstration sites. The information focused on the roles played by organizations and individuals that influenced project development. Results from that phase are described elsewhere (20).

DESCRIPTION OF RESULTS

The values and the classification procedures used in defining the variables are described first and relations between implementation problems and the three predictor variables are subsequently discussed.

City Characteristics

Of the 67 cities responding, 14 are in the northeast, 13 are north central, 25 are in the south, and 15 are in the west. The locational distribution of responding cities does not differ significantly from the distribution of contacted cities. Socioeconomic census data for 1960-1980 were collected for 17 original variables and were summarized into 9 indices. These indices were used to group cities into three clusters using a principal components analysis. The three clusters were named (a) centralized and decaying, (b) decentralized and growing, and (c) small. Of the 67 cities, 29 were classified as centralized and decaying, 16 were classified as decentralized and growing, and the remaining 22 were classified as small.

Types of Projects

A perusal of the 166 CBD revitalization projects in 67 cities led to the identification of 22 different project elements. More than one-fourth of the projects in the sample included an office element, about one-fourth included a retail element, and more than one-eighth included both elements. Approximately 20 percent of the projects included at least one of the following elements: hotel, parking garage, and pedestrian amenities. It is noteworthy that 22 projects had a historic preservation component.

The physical elements and information on funding sources were considered in order to classify projects into eight general project types. the highest frequency of projects is associated with the mixed projects type, which include more than one element from private and public developments. Figure 1 shows the distribution of projects by the eight types.

For the purposes of analyzing the data, the eight categories of project types were further reduced to three categories. The four public improvement types, including street improvements, pedestrian amenities, open space, and ARZ projects were combined accounting for one-half of the projects reported. Such projects play an important role in the overall strategies for downtown development by facilitating private investment. ARZs accounted for 10 percent of all reported projects. Slightly more than one-fifth of the projects included only private development elements, whereas the remaining mixed projects (28 percent) contained both private and public development elements. In general, development projects were planned, funded, and implemented by the private sector, whereas the mixed projects were the result of public-private collaborations, and the public

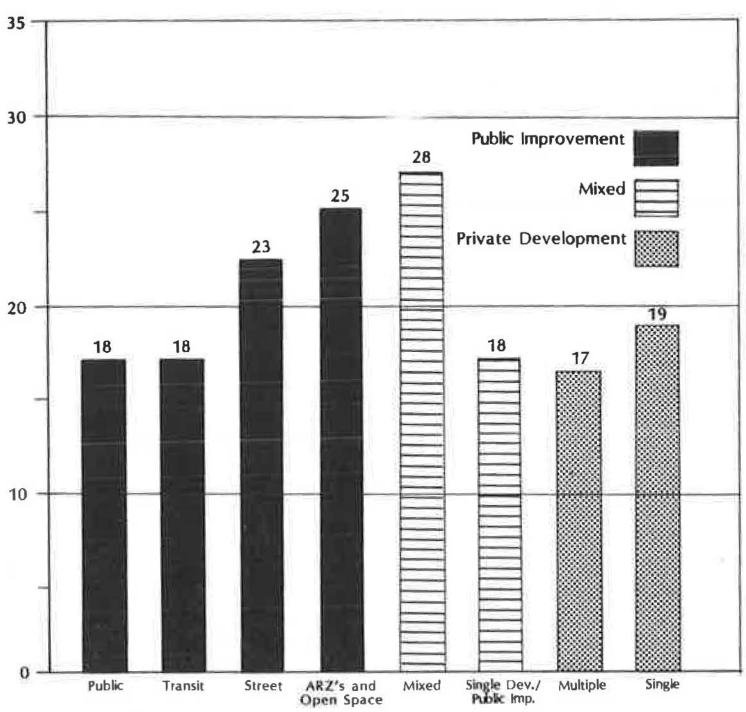

FIGURE 1 Frequency distribution of projects by type.

development projects were either planned, funded, and implemented primarily by the public sector.

Cost, duration, and organization were examined as CBD project characteristics. The average project cost was $42.5 million, ranging from $50,000 to $1.5 billion, with public improvements being the least expensive type of project, averaging about $4.9 million. The average duration of a project before completion was 5.4 years. This length of time was found to be independent of project cost and type. Forty-five percent of the reported projects were completed at the time of the survey. Similar rates were reported in the other phases of the study.

In the second phase, the average cost of ARZ projects was found to be $9.1 million. There were no significant differences in the average cost of completed versus non-completed ARZ projects. In completed ARZ projects for which there were cost overruns (36 percent of completed projects), the overruns were between about 17 and 29 percent of the cost of the project. Although overruns did not occur in the majority of the completed projects, in more than one-third of the projects these overruns had a significant impact on the cost of the project. Sixty-nine percent of the ARZ-completed projects took longer than anticipated; the average time overrun was estimated to be 1.75 times longer than planned. About one-half of the reported projects included a transit component.

Cities in different census groups did not systematically report different project types. An interesting relationship was observed between the project type and the project status variable; mixed projects were less likely to have been completed.

The organizational characteristics of CBD projects were approximated by three variables: responsibility for funding, planning, and implementation. The main funding source was a combination of federal and local public funds, which accounted for 22 percent of the reported projects. Projects funded primarily by the private sector comprised 6 percent of the total. There was some federal contribution in 65 percent of all projects. It is interesting to note that there were no reported cases for which the federal government paid more than one-half of the project cost while the private sector paid for the remaining cost. The project type variable and the organization variable were found to be strongly related. In ARZ-type projects, federal participation (an average of 50 percent) appeared to have little impact on whether the project was completed. Although not statistically significant, completed projects that had local participation in funding were almost twice as frequent as projects with local participation that were not completed.

City departments were most frequently responsible both for planning and for implementing projects. Seventeen percent of the CBD projects were planned by city departments and more than 25 percent were implemented by them. Forty-two percent of the cases reported that the same agencies planned and implemented the project. Sixteen percent of the projects were planned by the public and private sector and more than 12 percent were implemented by the same type of cooperative effort. Finally, 9 percent were privately planned and 11 percent were privately implemented.

Implementation Problems

Fifteen elements of implementation problems were identified in the first phase of the study. More than 70 percent of the CBD projects described in the sample included an implementation problem. The most frequently mentioned element was raising funds, cited in almost one-fifth of the projects. Around 10 percent of the reported implementation problems included at least one of the following elements: (a) acquiring land, (b) agreeing on the plan, (c) coordinating participants, and (d) anticipating economic changes. Frequently occurring combinations of elements were identified to yield seven implementation problems, which were named according to the most frequently occurring element. In addition to the five elements named earlier, categories also centered around the following elements: solving construction problems, minimizing impact of construction, and instigating support. Figure 2 shows the distribution of the implementation problems.

These seven categories of implementation problems were reduced to three on the basis of their structural similarities. Raising funds and acquiring land were combined to form a category believed to represent acquisition problems. Agreeing on the plan and solving construction problems were combined into a category of problems related to the plan, and the remaining three problems--anticipating economic changes, coordinating participants, and instigating support--were combined into a category representing support problems. There were more support problems than either acquisition or plan problems. The interpretation of the term support here is general and refers to political, managerial, and technical support functions.

ANALYSIS OF RESULTS

In this section relationships among the variables that may influence implementation problems of CBD revitalization projects in general are described first, followed by the results from the analysis in the second phase of the study, which deals with ARZ projects in particular. The influence of specific events in the implementation success of ARZ projects is analyzed last.

Implementation Problems of CBD Projects

A significant relationship was identified between CBD project types and implementation problems. Public improvement projects are less likely to report problems than other type projects. The problems on these projects are generally associated with the plan. Mixed development programs are more likely to report support and acquisition problems. When the relationship was conditioned on the city type, it was found that the relationship was no longer statistically significant. That is, data do not indicate that cities in different census groups experience different types of implementation problems.

When the variable of completion status was added to the relationship of project type and implementation problems, significant three-way interaction effects were found with project type, implementation problem, and completion status. In general, this result suggests that the perception of implementation problems depends on the stage that the project is in. That is to say, some phenomena may appear as problems at or near the time they occur; however, with the passage of time, they are not remembered as problems. This is reflected in the data by the higher probability of "no problem" for completed projects than for incomplete CBD projects.

Comparing the problems reported for completed and incomplete CBD projects, the incomplete projects are about twice as likely to be viewed as having support problems as are completed ones. This may mean that support problems appear as being major when they are occurring, but on their presumed resolution, they

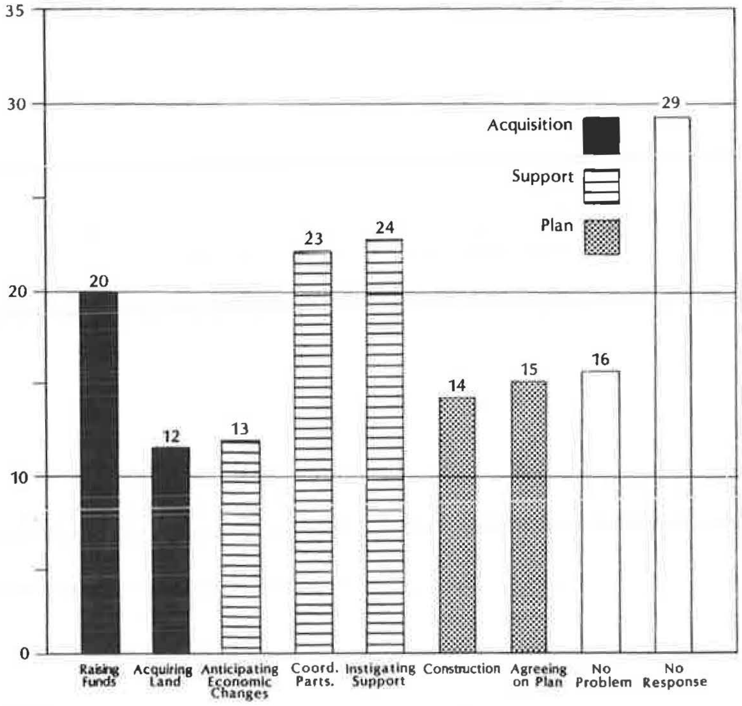

FIGURE 2 Frequencies of implementation problems.

are not recalled as having been major problems. It may also be that support problems, when they have occurred, are always recalled as major problems but when they are not resolved, the project is dropped. Only one dropped project was reported and it was not included in the sample. It is possible that some of the incomplete projects will never be completed.

Completed projects are about twice as likely to be viewed as having had plan problems as are incomplete ones. To some extent, this latter result is an artifact of the definition of plan problems, which include construction problems. Most of the incomplete projects have not yet entered the construction phase. Thus, it is impossible for them to have associated construction problems.

Differences between the project types without regard to completion status are few. Public improvement projects are less likely to have acquisition problems and are more likely to have plan problems than are either development or mixed projects. However, there are several differences within and between the project type and implementation problems for both completed and incomplete projects as shown in Figure 3.

The frequency distribution of implementation problems for complete and incomplete public improvement or mixed projects are not different from each other. However, completed development projects are reported to have had no problems, whereas incomplete projects are reported to have support problems.

Organizational variables were not found to be as highly related to implementation problems as might be suspected from reviewing the literature. Projects implemented by public agencies, however, were more likely to experience problems with the agreeing-on-the-plan problem or solving-construction problem, than projects implemented through a joint public-private effort. There was a tendency for projects planned and implemented by the same agency to be less likely to report a problem and less likely to have a problem with support.

The duration of a project was not related to implementation problems in a statistically signifi-

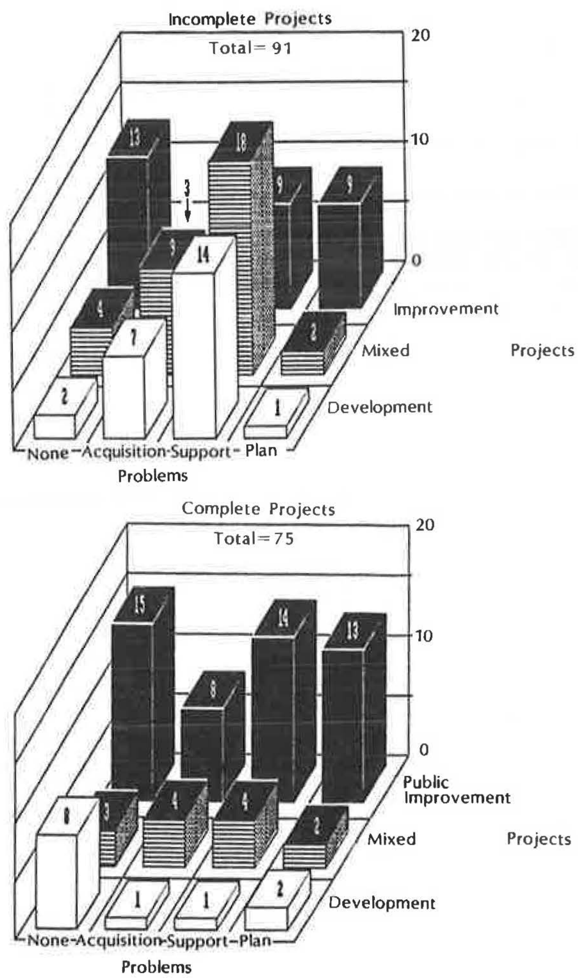

FIGURE 3 Joint frequencies of project type, implementation problems and completion status.

cant way, although such a relationship existed with cost. Smaller projects had a tendency to experience more agreement on plan problems than did larger projects. Smaller projects were also more likely to be public improvement projects. Finally, about one-half of the respondents rated the projects as successful, only 5 percent admitted failure, while about one-third responded that it was too early to evaluate the project.

Implementation Problems of ARZ Projects

Thus far, ARZ projects have been examined as another type of public improvement project. In this section the influence of 33 types of implementation problems on the success of ARZ projects will be analyzed. The second phase of the study found that 4 out of 33 problems yielded a response that indicated the problem was moderate or more severe in more than 50 percent of the sampled cities for responses other than the not applicable or not a problem variety. Raising funds was the only problem to occur in both cases for completed and incomplete projects. However, there were very definite differences between implementation problems occurring at different stages of projects. For completed projects, additional problems included underestimating costs, changing local government, and the project's impact on CBD activity. For incomplete projects, problems involved the organizational aspects of starting the project, the length of time to secure funds, and construction difficulties.

After combining the problems into the seven types similar (but not identical) to the ones defined in the previous section for CBD problems, no significant relationship was found between ARZ problem type and project completion status. It was found that for most problem types the majority of the responses were either not a problem or not applicable. More than 30 percent of the responses indicated that there were moderate or more severe problems with raising funds, solving construction problems, and acquiring land.

For completed projects, all but one problem type (agree on plan elements) elicited more than 25 percent responses. For incomplete projects, only two problem types (anticipating economic changes and coordinating participants) yielded less than 25 percent of the responses. The analysis revealed that small cities were more likely to have problems such as agreeing on plan elements, coordinating participants, and instigating support, if the project had been completed, but centralized and decaying cities had such problems if their project had not been completed.

Another variable analyzed for its relationship to the impact of problems on the success of the project was the existence of a transit component. It was found that completed projects without a transit component were more likely to have encountered problems.

Influence of Events in the Implementation of ARZ Projects

An important finding in the first round of questioning was that the step-wise process of planning an ARZ project was very much the same across most cities. This finding led to the conclusion that it was certain events that occurred during the process that were attributed to the successful implementation of projects and not the planning process itself.

In the second round of questioning, respondents were asked to assess the impact of 17 events on the successful completion of ARZ projects. Input to the development of a list of events was provided from the first two questionnaires. Most cities responded that 14 of 17 events, if they occurred, had a positive effect on the success of the project. Three events did not have a positive or negative effect on success. These were related to changes in government policies, officials, and exogenous events. An interesting result involving the event of having a mayor or a local business association involved in the project is that when this occurred, it had a 20 to 25 percent more positive impact on the success of the completed project than on incomplete projects. This result is similar to that of local participation in the funding of an ARZ project.

After combining the 17 events into 4 general categories, it was found that involvement of individuals, groups, or agencies, and changes occurring during the project yielded a more positive impact for completed ARZs but a more negative impact for ARZs not completed. Organizational or interorganizational events were considered highly positive by most cities regardless of the completion status of the project. A reversal occurs with public relations and exogenous events. For incomplete ARZs, the responses are often more positive than for completed ARZs. In the case of completed ARZ projects in small cities, the influence of individuals and organizations and the commitment of funds had a significantly stronger than expected positive influence on success than for other city types.

In analyzing the effects of the existence of a transit component in an ARZ, findings indicate that involvement of individuals and groups has a positive impact on the success of a project if that completed project does not have a transit component. Thus, it follows that projects that have transit components are less likely to find that events of this type have a positive influence on the project's success. This does not imply, however, that the absence of a transit component would have a negative influence.

DISCUSSION AND CONCLUSIONS

This study has contributed to the development of a classification of implementation problems of CBD revitalization projects and the measurement of the intensity of such problems for ARZ projects specifically. It has also demonstrated how such problems are related to various project attributes and city characteristics. This study has brought to light the need for greater understanding of the implementation process. It has established the importance of improving and expanding research in this area and has provided some information that planners may find useful in coping with a changing environment.

Other study contributions included information about the types of CBD revitalization projects that have occurred during the past 7 or 8 years, the description of ARZ projects, and the comparison of ARZ projects with other CBD revitalization projects. It was found that, since 1975, ARZ projects have received serious consideration as a strategy for downtown revitalization. Three-fourths of the responding cities in the first survey had considered ARZ projects and 27 percent had implemented one. In comparison, 13 percent of all U.S. cities with a population of more than 50,000 had implemented malls before 1977 (19). Public projects that include street improvements, pedestrian amenities, open space, and ARZs accounted for one-half of all reported projects in the first survey. ARZs accounted for 10 percent of all reported projects. An emphasis on reported improvements of urban amenities was noticed, including rehabilitation of historic structures, provision of cultural facilities, and increased attention to pedestrian needs. One-fifth of all the reported projects included private developments such as offices, retail, hotel, and mixed-use types of developments. The rest were projects resulting from joint public and private collaboration. The average public project costs less than the private developments. There was no evidence of geographic concentration by type of project.

Implementation Problems

Raising funds was the most frequently mentioned problem for CBD revitalization projects. On the other hand, it was interesting to note the number of creative approaches that have been established for financing development. Some of these approaches were tax increment financing, or the application of Community Development Block Grant (CDBG) and Urban Development Action Grant (UDAG) funds as guarantees for loans issued by commercial banks and as leverage for private capital. Implementation problems were found to be related to the type of project. Public improvement projects are less likely to have reported problems than the other two project types. Those problems that are reported are generally associated with agreeing on a plan.

One of the more interesting findings was that the completion status of the project had an effect on the type of problem that respondents perceived. Incomplete projects tended to have support problems, whereas completed projects reported disagreement on plans. One possible interpretation of this result is that planners tend to be more successful in gaining agreement on plans and solving construction problems ("plans" type of problems) on projects that reached the completion stage. These are the types of problems that are considered within the realm of traditional planning. On the other hand, planners tend to be less successful in instigating support, coordinating participants, and anticipating economic changes ("support" type of problems), if projects remained incomplete. The latter type of problems are considered within the scope of the emerging direction of planning.

It was reported that the frequency distribution of implementation problems for private development projects are different with respect to project completion status. Completed private development projects are reported to have had no problems, whereas incomplete ones are reported to have support problems. This finding, consistent in other phases of the study, suggests that the perception of implementation problems depends on the stage that the project is in and poses some interesting questions regarding the definition, identification, and management of implementation problems to be addressed in future research efforts. Here, it may be that development projects that suffer from support problems wind up being dropped. Another explanation is possible. Respondents, who are all members of public planning agencies, probably do not have adequate insight into development projects and there may have been a tendency for them to assume that there were no problems associated with the completed development projects. At the same time, there may have been a tendency for them to report ongoing development projects if they were hotly contested.

In the second survey, respondents were asked to evaluate ARZ implementations. The majority of the cities indicated "no" problems and only problems related to securing funds and lack of support from the private sector were of any significance. The involvement of the mayor or a local business association in the project had a much more positive impact on the success of completed projects than on projects not completed.

The type of city was found to have an important impact. In small cities the involvement of individuals and groups or exogenous events made a difference in the success of the project. Because of the small subsample sizes within each census group, this relationship should be further tested. It is advisable that subsequent research on implementation problems be either limited to a single census group or conducted on a large enough scale.

Finally, in completed projects without a transit component it was more likely that events such as involvement of individuals and groups had a more positive influence on the project success than projects with a transit component. One possible interpretation of this finding may be that ARZ projects with transit components are more difficult to finance and the involvement of individuals and organizations becomes more critical if they are to succeed.

Study Limitations

This study has been exploratory in many ways. It involved extensive surveys and the development of instruments in a field that has limited examples to offer as guidelines. Investigators had to rely to a great extent on intuition and unstructured, open-ended questionnaires in the design of surveys. Although precautions were taken to avoid the typical shortcomings inherent in survey research and case studies, it is important to acknowledge some of the limitations here and to suggest that the study results be interpreted with caution. The response rate in the first survey was considered very good. Subsequent surveys, although yielding similar responses at the city level, had lower rates of return at the individual level, making averaging of multiple views per city and multivariate analysis difficult. Results between the different data collection efforts are not directly comparable because different procedures were used in the data collection. The findings from the surveys can be generalized to opinions of city planners in other SMSAs.

In the question requesting that three CBD revitalization projects be described in each city, respondents were not given specific instructions on what types of projects to describe. However, there is no reason to believe that the list of projects obtained in this way is not representative for the purposes of this project. Because of the format of open-ended questionnaire and the subjective nature of the responses, statements of problems are expressions of perceptions colored by personal and organizational expectations, situational circumstances, and status of project completion.

There was an uneven quality of responses in terms of conceptualizing problems, articulating experiences, and the ability to draw lessons. The respondents' understanding of planning and implementation issues was variable. A review and comparison of multiple responses from the same cities indicated a 25 percent rate of agreement among two respondents regarding the importance of events or severity of problems in the same city and project. This leaves the study open to criticism as to whether some of the results may be artifacts resulting from the type of survey, the sampling procedure, and the respondents' biases. City planning directors or planning staff in charge of CBD planning were considered by the authors to be the most appropriate and informed individuals to provide the needed information. Planners by training and job definition should be able to bridge the gap between the decision makers/administrators and engineers and contractors.

Role of Planners in the Implementation Process

This study reconfirms an emerging role for planners that requires skills beyond those of preparing plans and emphasizes management of support-type problems and plan implementation. Capital improvement projects are not simply decided, drawn up, and implemented, but are continually adapted through a negotiating process. It is difficult to distinguish when project planning ends and action begins or when the project has changed so drastically that it must be considered a new project. The implementation process as a policy-action relationship as defined by Barrett and Fudge (10) proved to be a much more meaningful concept.

The skills of negotiation and coordination become essential when dealing with the private sector. Urban projects increasingly require a higher degree of public and private cooperation, and a redefinition of the role of the public sector is in order. In the past planners rarely played a continuing role throughout implementation. It is during that phase that dissatisfied segments of the community often create obstacles to a project's completion. This is a crucial phase and the planner can play an important role as a mediator in building and maintaining a durable consensus and in resolving disagreements that threaten to impede implementation (8,11).

According to Barrett and Fudge (10), there has been a tendency in the implementation literature to de-politicize the policy-action relationship. The results of the case studies in the last phase of this work confirmed the importance of political and institutional factors in explaining implementation success and problems (20). The influence of local actors, roles, skills, interests and motivation, and determination is paramount in getting things done. As Barrett and Fudge point out, informal organizations may play a more crucial role than traditional structures.

Policy subject matter has been suggested in the literature (10,14) to have an influence on the outcome of the policy-action relationship. This study provides further evidence in support of this view. Automobile-use management and automobile restriction in particular has been an innovative policy that entails trade-offs among categories of users and even discriminates in terms of inconvenience in favor of pedestrians and transit. Altshuler (21) states that "change strategies will vary in political acceptability in accordance with the degree to which they inconvenience powerful institutions and large or well-organized blocks of voters."

The downtown business community is usually a well-organized body that has traditionally regarded automobile restriction as a threat to its livelihood, even though a close look at such experiences has shown that the majority of businesses would not necessarily have been adversely affected and indeed would have benefited from the measure (18,22). Merchants and other members of the business community have been socialized to accept professional and organizational values and behavior, even if such values and behavior do not pertain to particular circumstances. The same accusation can be leveled at professional planners for whom separation of pedestrians from vehicle movements is traditionally associated with good design principles. The last and most important group in the implementation process is the politician whose leadership and commitment is the key if things are to start happening. In most of the cases the study findings indicated that if there is strong local support for a project it has a greater chance of being completed. In cases where there was a lack of evident support from the business community, the political leadership delayed taking the necessary action.

Although it was found that federal participation appeared to have little impact on project success, results from previous research indicate that UMTA's Service and Methods Demonstration program has made a significant contribution to the promotion of experimentation and scientific evaluation of innovative programs and deserves credit, but it only represents a beginning (2,23). It is essential that such efforts involving initial support, systematic monitoring and evaluation, and dissemination of results of experimental projects continue if our understanding is to be improved and generalizable conclusions are to be drawn.

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Internal Circulation Within Major Activity Centers: Issues and Problems

DARWIN G. STUART

ABSTRACT

Several different issue or problem categories are outlined in this paper followed by a review of three examples of internal circulation planning for major activity centers. The issue and problem categories include size and geographic dimensions, internal travel volumes, congestion levels, and special-purpose travel features. The examples include Post Oak Center in Houston, Woodlands Metro Center north of Houston, and Las Colinas in Irving, Texas. Potential negative impacts associated with internal circulation needs are described in association with (a) discontinuous or poorly designed facilities for pedestrian flow, and (b) excessive levels of internal automobile traffic. Remedies or solutions for these problems, as advanced in the three case studies, are evaluated; these remedies cover pedestrian improvements, automobile access and parking improvements, surface transit, and automated guideway transit.

IDENTIFICATION OF ISSUES AND PROBLEMS

Four major issues involving internal circulation within major activity centers can readily be identified. These issues reflect the basic land use configuration and geographic dimensions of activity centers themselves, as well as their functional role within an urban area. [Central business districts (CBDs) have not been included, in order to allow more attention to be devoted to the emerging major diversified center (MDC), as well as other types of major activity centers (MAC) in outlying and suburban areas.] The general sequence of issue and problem categories in priority order includes size and geographic dimensions, internal travel volumes, congestion levels, and special-purpose travel features.

Size, Land Use Mix, and Geographic Dimensions

Major activity centers have been defined as concentrations of office, retail, hotel, entertainment, and related land uses that generate daytime populations of 25,000 persons or more (1,2). Major diversified centers, such as a large-scale type of major activity center, may be expected to have daytime populations of 100,000 or more. The sheer size of major activity centers is certainly a primary determinant of internal circulation needs, together with the mix of land uses. For example, office and retail mixes (which generate travel between one another), density (employees per acre), and shape (particularly strong linear patterns of development) all are significant in influencing internal circulation patterns. Where circulation demands are high, other related problems may occur.

Internal Travel Volumes

Overall size, extent of sprawl (lower densities), and linearity (more than 1 mi long) are all physical characteristics of major activity centers that affect internal travel volumes. These internal travel volumes, and the modes chosen for them, reflect in turn both the land use-mix and the typical lengths of desired trips. Volumes of travel generated by workers, shoppers, visitors, tourists, and others can begin to tax the capacity of available facilities or vehicles, including both pedestrian and vehicular travelways. Nodal concentrations of land developments can create associated internal travel concentrations.

Congestion and Peaking

Depending on land use mix, major activity centers may experience morning and evening peaks (office employment-oriented), midday peaks (retail and service-oriented), or both. For very large centers, these peaking patterns may lead to automobile congestion, pedestrian congestion, or both. Where both office and retail and service concentrations are large, congestion may in effect stretch throughout the day for as long as 12 hr. The severity of congestion at particular street or walkway intersections depends, of course, on the specifics of travelway network geometry. Congestion-related travel delays and traveler aggravation are perhaps the most serious internal circulation problems facing major activity centers, especially the emerging MDC.

Special-Purpose Centers

A number of special-purpose centers, particularly recreational ones, may not meet the 25,000 daily population threshold, but may still have unique internal circulation needs. For example, the Mud Island automated transit linkage in Memphis and the Harbour Island automated transit linkage in Tampa both provide river crossings that involve vital, direct linkages between specialized land uses (recreational and new community) and the adjacent CBD. Bus shuttle systems in Vail and Aspen, Colorado, provide similar recreation-oriented services.

Trip Purpose, Frequency, and Length

In general, secondary issues associated with internal travel volumes and congestion may be associated with more detailed travel characteristics. For example, increasing average trip length may be an issue for strongly linear activity center configurations, and it is likely to be a factor dictating automobile versus pedestrian mode choice. Density of activity center development may well influence trip frequency (especially for shopping trips, including multiple-stop trips). Multiple-purpose pedestrian excursions are facilitated by the variety and mix of land uses in a major activity center. Issues associated with these travel characteristics are tied to the spatial distribution of travel opportunities and capacity constraints.

DESCRIPTION OF EXAMPLES

Three examples in Texas illustrate the kinds of issues and problems that can emerge within MDCs and, to a lesser extent, within smaller major activity centers. One of these examples, the Post Oak Center in Houston, has been under development for a number of years and experimented with a minibus distributor system a few years ago. Though that system was abandoned because of the slow travel times due to surface street congestion, the bus alternative may well merit attention in other activity centers. The second example, the Woodlands Metro Center, is part of a major new town north of Houston. Here, a linear trolley shuttle is currently being considered to link several nodes within the major activity center of the project. In the third case study, the Las Colinas development project in Irving (Dallas region), plans for an automated guideway transit (AGT) distributor system have recently been formulated, tied as well as to a planned regional rail transit line.

Post Oak, Houston

The Post Oak area, under development for the past 20 years by a number of different large landholders, currently maintains a daytime population of about 100,000 (3). Office employment is about 45,000 and retail square footage about 2,500,000. Traffic congestion already stretches throughout much of the day and is a major problem for the center. Projected development to the year 2000 would accommodate a daytime population of 150,000, with appropriate percentage increases in office, retail, and hotel facilities. Such growth indicates that congestion problems will persist, in spite of some increase in street capacities. Figure 1 shows the estimated 1980 employment and daily shopper and visitor population for subareas within the center. The total land area of the activity enter is estimated at 1,300 acres; the longest north-south dimensions is 2.25 mi.

Las Colinas, Dallas

Las Colinas is a major office-commercial development, under single ownership, currently experiencing major development activity. Most of the 1,000-acre project is planned for completion by the year 2000; ultimate development is anticipated to contain about 25,000,000 ft^2 of office and retail space, almost 4,000 hotel rooms, and more than 4,500 multi-family dwelling units. The daytime population at that point is estimated to be approximately 150,000. A meandering lake forms a spine within the project, with high-density office uses scattered along its shore, flanked by hotel, commercial, and residential structure (see Figure 2). The development is to be served by two regional rapid transit stations. Internal circulation needs, due in part to the linear pattern of the nearly 2-mi long center, have suggested that some form of grade-separated distributor system be considered. Such a system is now in the initial planning stages (5).

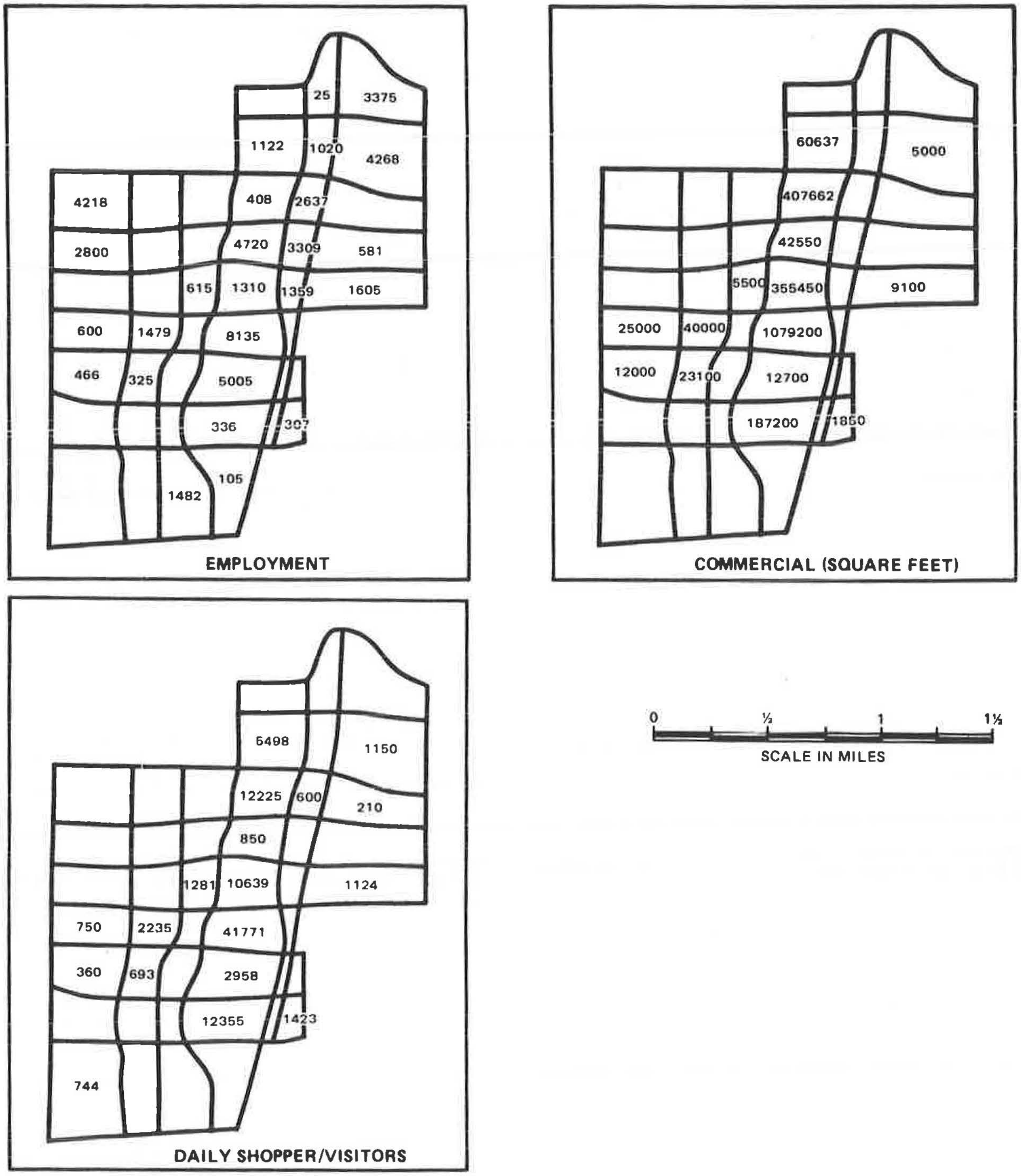

FIGURE 1 Estimated 1980 employment, commercial space, and shopper and visitor distribution: Post Oak Center.

Woodlands Metro Center, Houston

The Woodlands Metro Center, intended as the office and commercial core of the major Woodlands new town some 30 mi north of Houston, is at an earlier stage of development than the other two examples. Nevertheless, its ultimate concept is also of major scale. Total projected employment for this center is more than 50,000, involving 13,400,000 ft^2 of office development, 1,700,000 ft^2 of retail and commercial development, 1,300 hotel rooms, and 1,600 high-rise and mid-rise multi-family dwelling units. This center comprises a total land area of about 1,300 acres and has an ultimate daytime population of about 90,000. A number of alternative transit options were assessed for a linear distributor that would link several development nodes within the central core, parallel to a canal that would also be a part of the project (5).

SEVERITY OF NEGATIVE IMPACTS

A more specific set of negative impacts, or undesired consequences of internal circulation needs within major activity centers, can readily be associated

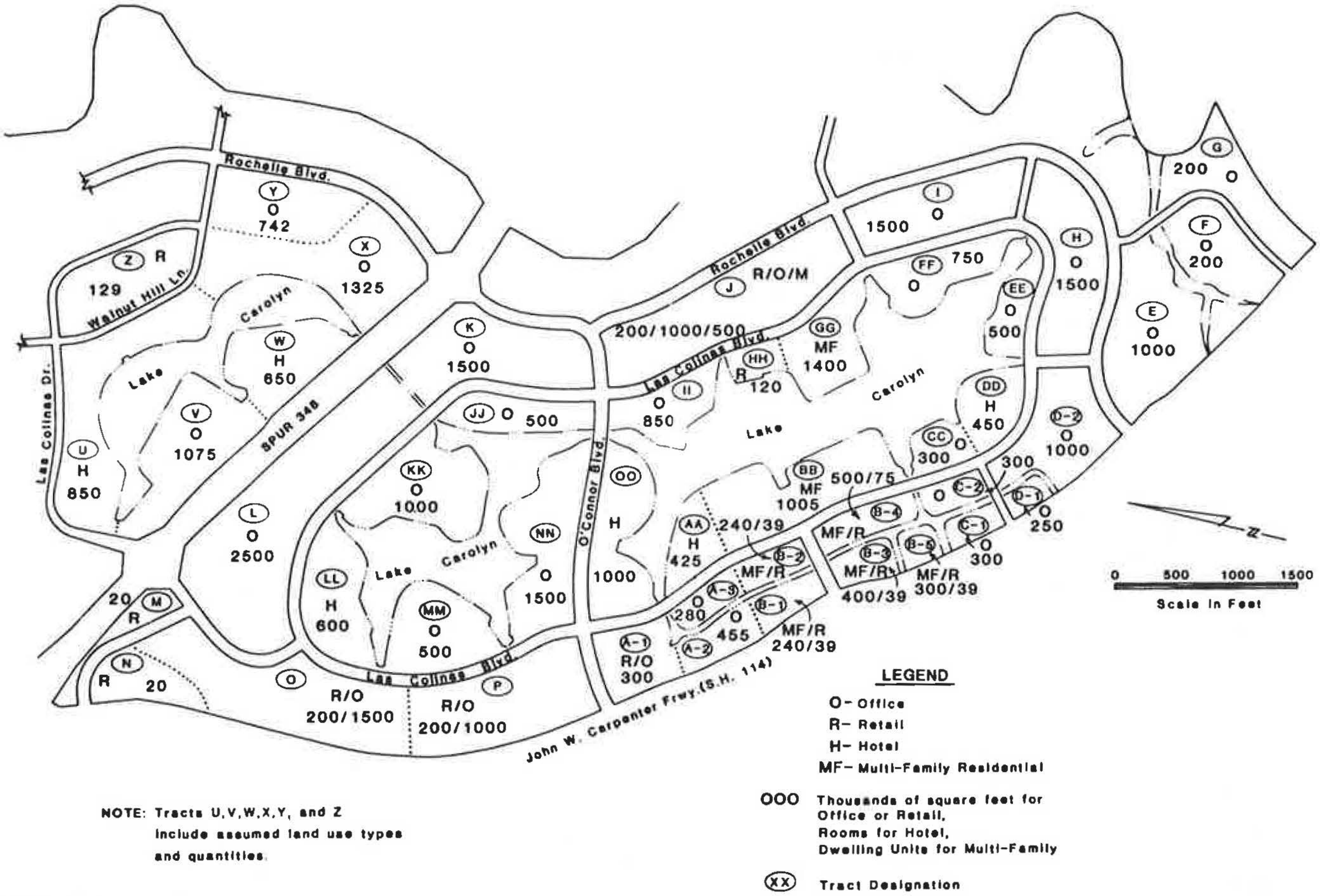

FIGURE 2 Las Colinas development plan.

with the broader issues or problems listed previously. In general, these areas of negative impact are associated with either (a) discontinuous or poorly designed facilities for pedestrian flow, or (b) excessive levels of internal automobile traffic.

PEDESTRIAN FLOW

Pedestrian-Vehicular Conflicts

For major activity centers that involve multiple land developers and an underlying grid-like street network, opportunities for pedestrian-vehicular conflict are numerous. Post Oak represents a classic example of these potentials. Grade separations for major flows of pedestrian and vehicular traffic represent clear, but costly, alternatives. The vehicle-free pedestrian mall associated with both regional shopping centers and revitalized central business districts represents another kind of solution. Pedestrian-vehicular accidents offer a direct measure of such conflicts.

Lack of Pedestrian Amenities

Multi-developer or multiple-node activity centers may vary in the extent to which pedestrian connections are fully designed to be integrated with adjacent land uses. Unevenness in the provision of amenities (landscaping, walking surfaces, street furniture, etc.) can represent a kind of negative impact (or at least the incomplete achievement of overall urban design goals). Long walks through hot asphalt parking lots or along sidewalks adjacent to busy arterial streets can represent these kinds of undesired pedestrian environments.

Clear Identity as a Center

Recognition and image as a specific, identifiable, and unique urban place is one of the important goals of MDCs and other major diversified centers. However, as such centers become large and as multiple developers are involved, the maintenance of an overall theme becomes more difficult. This is an elusive kind of negative impact, and again represents an achievement of less than what might be desired. In other words, disjointed and unclear pedestrian-transit-automobile connections to the fringes of major centers tend to diminish the participation of those fringe areas in the overall retail sales volume, achievable office rental rates, and marketability of the center itself.

AUTOMOBILE TRAFFIC FLOW

Traffic Congestion

Morning and evening peak-hour traffic congestion of employees at major activity centers reflect access problems (rather than internal circulation problems). Congestion that extends throughout the day reflects both (a) internal circulation by employees who use their automobile for short internal trips, and (b) access and egress and internal circulation during the day by shoppers or visitors. The threat of all-day congestion represents perhaps the most serious negative impact of "growing large," though the severity again varies by street configuration and size of center, as well as mix of traffic along any given arterial (including through travel).

Air Quality Impacts

The level of air pollutant emissions is related to the extent of traffic congestion and internal automobile traffic flow. Development of carbon monoxide "hot spots" is not uncommon for major intersections near MDCs, and as a general rule the level of air pollutant emissions associated with high volumes of automobile traffic flow is undesirable for immediately adjacent land uses (and pedestrians).

Energy Consumption

In a similar vein, the energy consumption associated with high volumes of short-trip vehicular flow within a major activity center can be of concern. Though energy conservation is currently less of a transportation issue today than it was several years ago (6), any improvement in internal circulation options that reduces vehicular flow, and thereby also reduces energy consumption, is additionally desirable.

REMEDIES AND SOLUTIONS ATTEMPTED

Attempts to resolve internal circulation problems within major activity centers, particularly as those centers grow, have been straightforward. They either involve the expansion, extension, or improvement of an existing mode, or the introduction of a new mode. In the first instance, existing pedestrian facilities and services could be improved, as could the configuration and capacity of existing roadways and parking areas. In the second instance, a variety of surface street transit modes could be introduced for internal circulation purposes. Conventional buses, trolley buses, or light rail streetcars could all be considered. Grade-separated automated guideway transit systems, though more costly, represent another alternative.

Pedestrian Improvements

Nearly all major activity centers have one major shopping and commercial core with enclosed, weather-protected pedestrian malls connecting a variety of department stores and related shops. In Post Oak, for example, the Galleria development plays this role whereas in the Woodlands Metro Center an enclosed regional mall is under design. Because such cores are typically self-contained and surrounded by parking, it is difficult to effectively extend their enclosed pedestrian environments across adjacent streets and parking areas. Grade-separated extensions are costly, yet they may be desirable to improve linkages with other areas of a center. A variety of surface treatments, edgings, street furniture, lighting, and other "theme" features could be used to strengthen overall pedestrian walkway systems, involving both open and weather-protected elements.

Automobile Access and Parking Improvements

The most common approach to solving automobile congestion is to seek ways to provide additional street capacity, via appropriate traffic engineering measures or reorganization of traffic flow patterns in accommodating new street segments. Double-decking or other structure treatment for parking facilities is also common. Because convenient automobile access is generally the key to discretionary shopper and visitor travel to such centers, major attention legitimately should be devoted to improving vehicular circulation. In many cases, however, options for expanded capacity reach space or cost limits or both, and it may become prudent to consider investment in and encouragement of the use of alternate transit modes.

Surface Transit

A number of conventional bus and specialized trolleybus and streetcar services have been inaugurated in several major centers, with mixed success. One of the keys to success has been the extent to which such services provide easily recognized and available linkages (e.g., in a strongly linear corridor) and the extent to which they are not themselves impeded by at-grade street traffic congestion. Unique vehicle design treatments (e.g., trolleybus vehicles outfitted as old-time rail trolley cars) have also been effective. Bus or trolley vehicles that hold from 15 to 55 passengers may be appropriate.

Automated Guideway Transit

Through automated guideway transit circulation systems have been well proven in a growing number of airport and theme recreation park settings, they have yet to be implemented in non-downtown, mixed-use major activity centers. The downtown people-movers currently being implemented in Miami and Detroit should be examined carefully for their transferability to other MAC/MDC settings when they become operational (6). Grade-separated AGT alternatives have been evaluated for the Post Oak area (2) and are currently under consideration for the Las Colinas development (4). They have been examined, with varying degrees of seriousness, for other special-purpose linkages and are being implemented in some instances (Mud Island in Memphis and Harbour Island in Tampa, are examples but not ones in which the AGT distributor forms an integral element of major mixed-use developments lying along its length). Vehicle size may also vary for such systems, but typically 20 to 100 passengers is considered.

EVALUATION OF RELATIVE SUCCESS OF ATTEMPTED REMEDIES

Using the three case studies outlined earlier, the evaluation of supplementary transit distributors within major activity centers is emphasized. Such internal circulation and distribution services have either been attempted or preliminarily investigated for feasibility. Although improvement in pedestrian and vehicular facilities (particularly grade separations) can certainly help resolve some of the negative impacts associated with pedestrian environments (described earlier), these remedies tend to be quite site-specific in nature. They also have less dramatic potential for resolving the more serious problems associated with traffic congestion within activity centers. In addition to the three types of vehicle miles of travel (VMT) reduction-related impacts listed previously, three other criteria for comparing supplemental transit options (surface versus grade-separated) include the range of longer trip opportunities offered, mode choice percentages, and cost

TABLE 1 Preliminary Evaluation of Internal Transit Distributor Options: Three Examples

Evaluation Criteria	Transit Distributor Option: Post Oak, Surface Bus or Rail	Post Oak, AGT	Woodlands Metro Center, Surface Bus or Rail	Woodlands Metro Center, AGT	Las Colinas, AGT
Gross leasable area (million square feet)					
Office	12.4		13.4		{ 24.9
Commercial/retail	2.5		1.7		
Daily population (000)	100,000		90,000		140,000-150,000
Average speed (mph)	10-15	20-25	20	20	15-20
Daily ridership	22,000-44,000	40,000-90,000	24,000-30,000	24,000-30,000	150,000
Mode split percentage	4-8	8-17	8	8	20
Annualized cost per passenger (1983 dollars)	0.09-0.26	0.20-0.59	0.06-0.26	0.45-0.87	NA
VMT reduction, %	-1	-1-2	NA	NA	-5
Air pollutant emissions reduction, %					
CO	+4	-1			-8
NO_x	-10	-5-10			-4
NC	-	-			-8
Energy consumption change, %	+4	+14	NA	NA	-5

Note: NA = not applicable.

per passenger. Table 1 gives a summary of the preliminary evaluation.

Range of Trip Opportunities

This impact reflects the number of discretionary trip opportunities (shopping, lunch, personal services, etc.) that may be available to activity center populations within a given travel time, for example, 15 min one-way by walking. The implicit assumption here is that, if a person could reach a desired destination by walking or by transit within 10 to 15 min, this would usually be preferable to making the same trip between parking lots via an automobile.

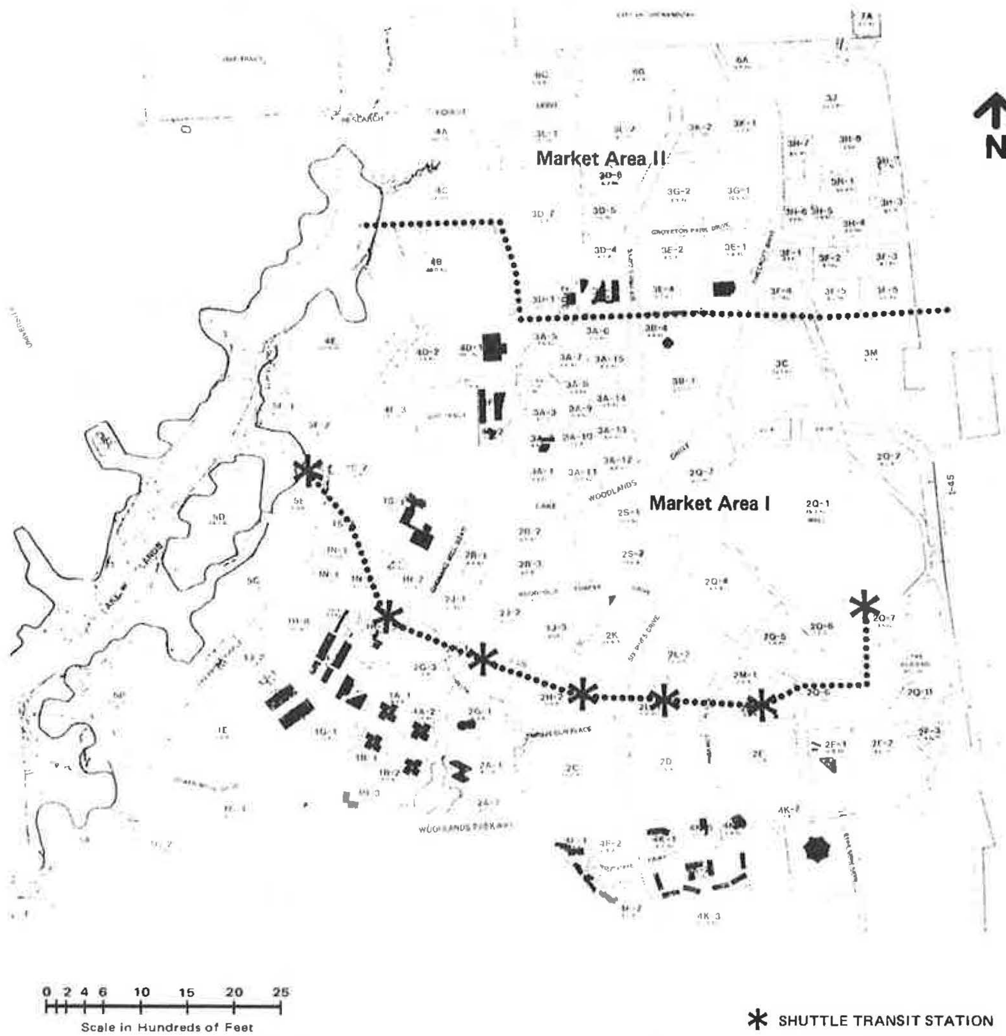

FIGURE 3 Proposed shuttle transit alignment: Woodlands Metro Center.

Increasing the range of trip opportunities would tend to draw a spread-out activity center closer together, and it could conceivably increase the total number of internal trips, and thereby the total number of shoppers or visitors and retail sales and economic vitality of the center.

A crude measure of this potential for internal transit distributor systems is the average speed that can be achieved. As might be expected, grade-separated systems can generally achieve a faster average speed than surface systems. In a study of distributor options for the Post Oak area, average speeds for AGT options were 20 to 25 mph, whereas average speed for surface options was 10 to 15 mph). In the Woodlands Metro Center example, the available right-of-way was grade-separated for all options (see Figures 3 and 4), and speeds were assumed equivalent at 20 mph for both AGT and conventional bus, streetcar, and trolley modes. Because of its large size and linear character, the Las Colinas Center (Figure 5) could particularly benefit from an AGT speed of 20 to 25 mph.

Mode Split

Because of equivalent speeds, station spacing, and frequencies of service (headways of about 5 min) assumed in the Woodlands example, ridership estimates for the various modal options were also the same--about 3 percent or 24,000 to 30,000 daily trips. In the more comprehensive Post Oak example, ridership for AGT options ranged from 8 to 17 percent (40,000 to 90,000 daily trips), whereas for surface street options (with slightly lesser service frequency of every 5 to 8 min, versus service every 2 to 4 min for AGT), these ridership estimates declined to 4 to 8 percent (25,000 to 45,000 daily trips). It should be remembered that these mode split percentages apply against a total base of

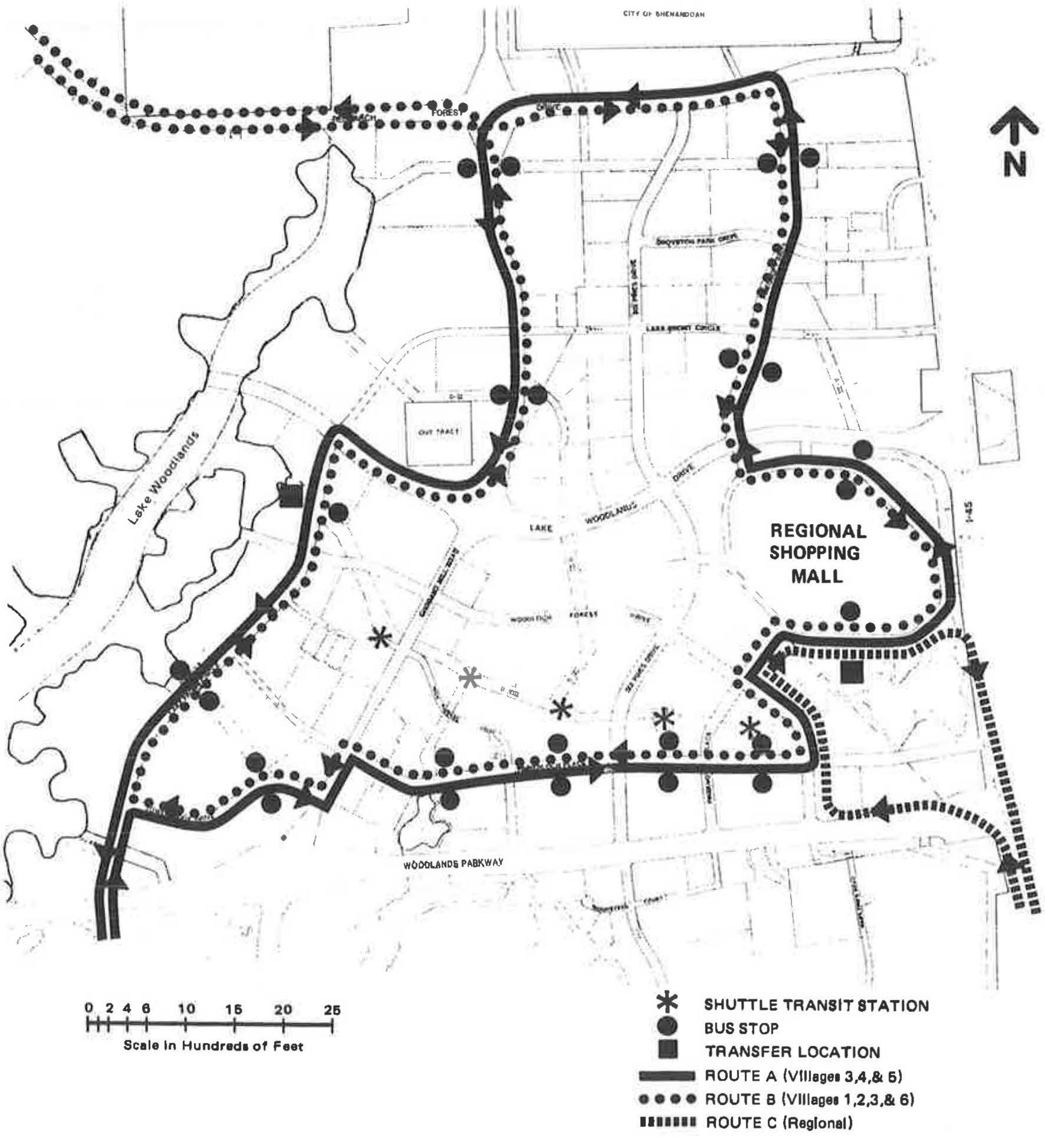

FIGURE 4 Interface between shuttle transit and local and regional bus system: Woodlands Metro Center.

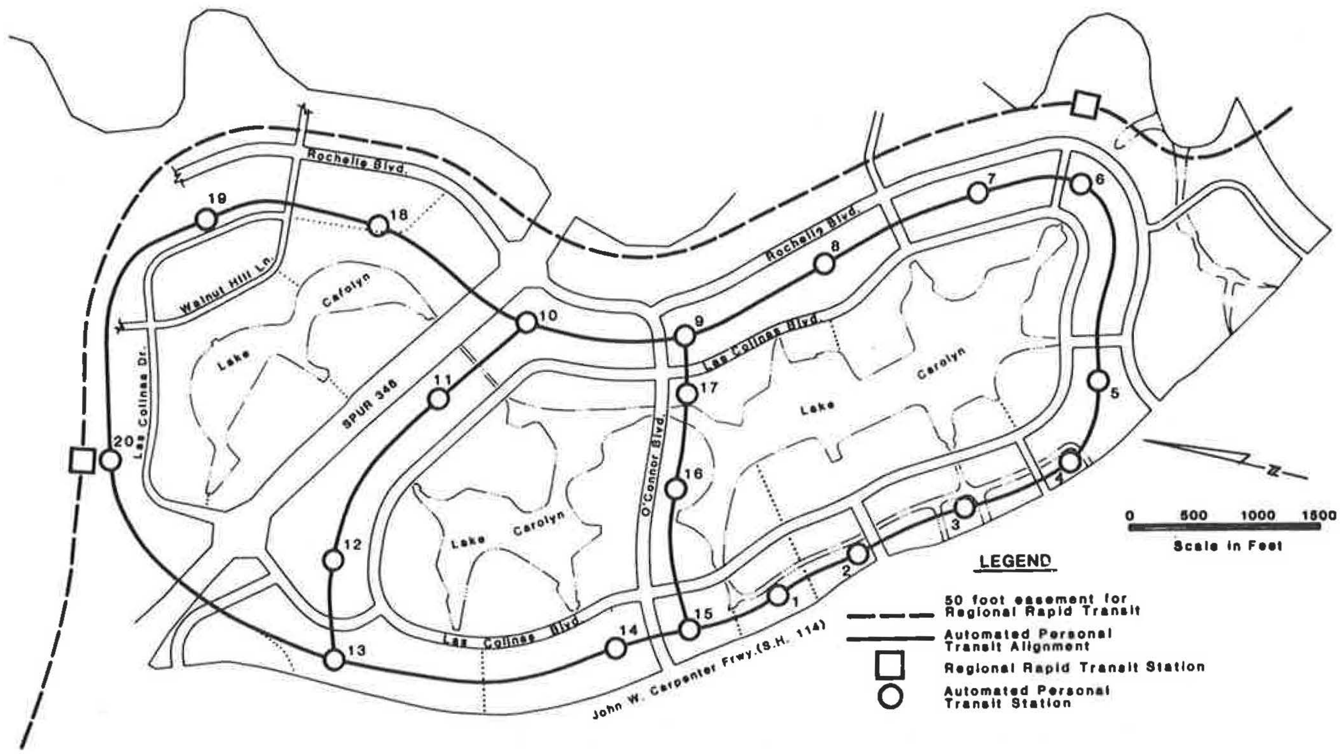

FIGURE 5 Proposed internal circulation system: Las Colinas.

internal trips, which are more than 70 percent pedestrian. In the Las Colinas example only AGT was investigated, and a mode split of about 20 to 25 percent (150,000 daily trips) was estimated.

Cost Per Passenger

These ridership estimates reflect fairly intensive use of the supplementary transit options analyzed. Annualized costs per passenger for Post Oak and the Woodlands Metro Center, covering both capital and operating costs, suggest that the surface street modes could achieve operating costs of under 25 cents per passenger (1983 dollars), perhaps as low as 6 cents per passenger. The bulk of these costs would cover operations and maintenance. For the grade-separated modes, however, capital cost amortization significantly raises required costs to as high as 90 cents per passenger, with considerable variability between the Post Oak and Woodlands example (see Table 1). If, to encourage usage, modest fares on the order of 10 or 20 cents are desired, some form of subsidy for capital investment should be considered.

Although the results shown here for grade-separated modes are not based on real-world experience (only on preliminary feasibility studies), it is important to examine the mixed experience with surface bus distributor modes in activity centers across the country. A shuttle bus distributor along the north-south axis of Post Oak was implemented several years go, but terminated because of low ridership levels. These low ridership levels reflected in turn the slow speeds achieved in mixed traffic congestion and led to an unacceptable operating cost per passenger. Similar low ridership experience was encountered in an internal shuttle bus operation associated with the sprawling Tyson's Corner, Virginia MDC in 1982-1983. An initial total of 10 different routes across the center was reduced to two routes; both routes were terminated after about a year of operation, in spite of free fares. On the other hand, a linear shuttle bus service along Central Avenue in Phoenix is currently experiencing economically viable ridership levels, and bus shuttles in such recreation and mixed-use centers as Aspen and Vail, Colorado, are also regarded as successful.

Congestion Reduction

It is important to realize that the supplementary transit ridership levels described previously largely represent diversions of former pedestrian travelers. The impact on internal automobile vehicular travel is estimated to be quite modest. As indicated in Table 1, this reduction ranges from only 1 to 5 percent for all three case studies. This certainly represents a desired impact but not a dramatic one. Significant ridership levels for an internal transit distributor mode might therefore best be regarded as an additional environmental plus, improving discretionary travel opportunities within the center. However, internal shuttles do not really solve the major congestion problems of activity centers, although they contribute to such solutions.

Air Quality and Energy Consumption

Associated with these modest impacts on VMT reduction are equally modest impacts on the reduction of air pollutant emissions and energy consumption. As indicated in Table 1, the estimated air pollutant emission reductions for each illustrative case study range from 1 to 8 percent for AGT modes, but CO emissions may actually increase slightly for diesel-powered surface bus modes. When the energy to operate a transit distributor mode is considered, there may be no net energy savings, and possibly an increased energy requirement of 10 percent or more for AGT modes.

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An Application of the Lens Model in Measuring Retail Attractiveness and the Effects of Alternative Public and Private Policies on a Retail Area

KARLA H. KARASH

ABSTRACT

The objective of this research was to use the lens model as a technique to measure the effect of an automobile-restricted zone and other private and public policies in the downtown Boston retail area on shopping trips to the area. The lens model accounts for perceptions and preference in the individual choice process. Findings were that individual's preferences for hypothetical futures for the Downtown Crossing could be linked to actual choice of shopping area only by explicitly accounting for measurement errors and feedback effects of preferences on perceptions. Removal of the automobile-restricted zone was predicted to decrease shopping trips to the shopping area by about 8 percent. Better maintenance and security were predicted to increase trips by about 5 percent. New retail development was predicted to increase trips by 10 to 11 percent; and vastly improved parking was predicted to increase trips by 6 percent.

In 1978 the city of Boston made a major effort to improve its major downtown retail area by implementing an automobile-restricted pedestrian mall known as the Downtown Crossing. More than $5 million were spent on capital improvements from combined city and federal funds. Traffic was removed from streets in the heart of the retail district and rerouted to other corridors. Streets were bricked over and new lighting and benches were provided.

Although consultant reports after the first 2 years of the pedestrian zone showed that sales in current dollars were up by about 12 percent and thus keeping pace with inflation (1), a feeling of gloom overshadowed the area in the summer of 1981. The city of Boston was suffering from a tax limitation law that severely limited the budgets of city departments. The result for the retail area meant that maintenance was inadequate, the area was quite dirty, and there were concerns about safety because of limited police protection. Spokespersons for the two major department stores in the area asked the city to consider ending its experiment and put the automobiles back on the street. They argued that automobile traffic would make the area feel safer, particularly at night.

At this same time the Boston Redevelopment

Authority (BRA) began an UMTA-sponsored study to determine how to better manage and develop the automobile-restricted area. Because it is largely respected as a retail analysis tool by retailers, a detailed shopping gravity model was built by the BRA to address the development questions. However, the gravity model would not address some of the basic policy issues such as the effect of eliminating the automobile-restricted zone, the effect of better maintenance and security, the effect of improved parking, or even the effect of different types of department stores on people's choice of shopping area. In order to address these issues a new analysis methodology was required. The BRA, although skeptical of state-of-the-art techniques, was willing to provide a small subsidy for Massachusetts Institute of Technology (MIT) research that held some promise for addressing the key policy issues.

THE LENS MODEL

The MIT approach was the lens model. The lens model is a representation of the human decision-making process. It was named by Egon Brunswik (2), a psychologist who described perceptions as lenses through which a human being interprets reality. The lens model has been further developed by researchers such as Hammond (3), Anderson (4), Fishbein (5), Hauser and Urban (6), and Holbrook (7), among others.

The lens model theory is that physical features or characteristics of an object or concept, for example a shopping area, are perceived through the senses of individual human beings. The image of an object or concept retained in the memory is based more on a limited number of qualitative impressions of the physical features rather than on numerous separate physical details. These qualitative impressions or perceptions form the basis of an individual's evaluation or preference. An individual's choice between alternative objects or concepts is related to preference but will be affected by environmental constraints. In the case of a shopping area, such constraints include travel time or distance.

The research steps required to implement the lens model were to (a) determine the important attributes of shopping areas, (b) determine the scenarios to test, (c) conduct a survey to gather the required data, (d) specify model form, and (e) estimate the model. The steps are described in the following sections.

DEFINITION AND MEASUREMENT OF LENS MODEL VARIABLES

Hypothetical Scenarios

MIT researchers worked closely with the BRA to determine the scenarios and the physical features that should be tested for the Downtown Crossing. It was important to measure the effect of the automobile-restricted zone itself on retail shopping trips to determine if this change had helped or hurt the area. The procedure for evaluating the effect of the automobile-restricted zone was to propose scenarios that would include allowing automobiles back on the pedestrian street. The change in shopping trips was expected to be of similar magnitude but opposite sign of the change in shopping trips caused by the implementation of the automobile-restricted zone.

The five other features of interest were those that would strengthen the area. These were better maintenance, better security, improved parking, and the addition of high-fashion or national chain department stores.

The chosen experimental design organized the 6 features into 11 different scenarios or hypothetical futures that included combinations of features of interest. No more than three features were included in any one scenario in order to minimize the burden of survey respondents.

Perceptions

The next step in implementing the lens model was to determine how people perceive a shopping area and how to measure their perceptions. There have been many studies of shopping center image that attempt to define the perceptual constructs. The approach taken for this research was to select a set of constructs that were commonly found in the literature and that would be useful for the analysis at hand. Five major constructs for shopping area attractiveness or image were selected as perceptual variables to be measured for this research. These constructs were identified in many studies of retail image including those by Stephenson (8), Koppelman and Hauser (9), and Gautschi (10). The five constructs of retail attractiveness were (a) quality, (b) variety, (c) value, (d) parking convenience, and (e) attractiveness of the walk environment.

The measurement instrument for the perceptions was a categorical rating scale. Following is an example of a portion of a categorical rating scale as it was used in a mail questionnaire for the study:

Rating for Downtown Crossing
(circle your answer)

	Unusually High						Very Low
Quality	+++	++	+	0	-	--	---

Categorical rating scales were used for measuring perceptions because they are simple to use and because the results compare very favorably to more accurate but complex methods such as paired comparisons, which will be discussed in the following section.

Preference

The preference variable in the lens model tells how much one alternative is liked compared with another alternative. The measurement instrument used for preference in this research was constant sum-paired comparisons.

With constant sum-paired comparisons, the respondent must divide, for example, 100 points between a set of two alternatives to show how much one alternative is preferred over another. Respondents can indicate the intensity of their preference as well as the order in their distribution of points. Constant sum-paired comparisons have been found to be more powerful discriminators than either rank order or category scale data (11).

Because only one preference measure per alternative was required for this research (in comparison with five perceptual measures), the more powerful technique of paired comparisons was chosen to measure preference over the category scaling technique.

DATA COLLECTION AND EVALUATION

Survey Approach

The survey approach used was a randomly selected telephone survey followed by a mail survey. Dillman's

(12) recommendations for approach, style, and followup were closely adhered to for both the telephone and mail survey used in this research.

Households were randomly selected from the telephone book from communities in the Boston area in proportion to the number of households in each community. Persons responding to the telephone survey were asked if they had shopped in the Downtown Crossing in the last year. Those who had done so and who could name one other shopping area where they had shopped were asked if they would be willing to fill out a mail survey. Those who agreed to complete a mail survey were sent one. Followup telephone calls were made to encourage response.

Evaluation of the Survey Data

Before the data collected in the telephone and mail surveys were used for model estimation purposes, they were evaluated in terms of overall quality and representation of the population of shoppers of interest. Of all telephone calls attempted, 64 percent of the persons called agreed to take the mail survey, and there were 1,894 telephone interviews. Of 1,174 telephone survey respondents who agreed to take the mail survey, 44 percent actually responded, providing 518 completed questionnaires.

Respondents who worked in downtown Boston had a higher mail response rate than others, and these respondents tended to use the Downtown Crossing more frequently. Thus, there was a need to separate workers and nonworkers in the modeling analysis work to correct for the different response rates.

The data from the survey were found to be of reasonably high quality. Where there was more than one measure of perceptual, preference, and choice variables, these different measures were significantly correlated. Respondents did discriminate well between preference and choice, and they did discriminate between a number of the perceptual variables. Respondents had difficulty discriminating between the perceptual variables of quality, variety, and value. Thus, these variables were averaged as a single store-related variable for analysis purposes.

MODEL ESTIMATION

Figure 1 shows the submodels to be estimated. Information was available from the surveys to estimate both a preference model (linking perceptions with preference) and a choice model (linking preference and travel impedance with choice) for the real shopping alternatives of the Downtown Crossing and the most used alternative shopping area. Information was also available to estimate a perceptual model (linking features with perceptions) and a preference model for hypothetical futures for the Downtown Crossing.

In order to link the changes in features for the Downtown Crossing with changes in patronage for the area, it was necessary to link the two partial lens systems. This was to be done by comparing the preference model for real alternatives with the one for hypothetical futures. If these two models were similar in a statistical sense, changes in perceptions predicted from the perceptual model for hypothetical futures could be used with the lens system for real alternatives to predict changes in patronage due to the changes in features of the Downtown Crossing.

Logistic Preference Model

The next task was to find an appropriate form for the relationship between preferences and perceptions.

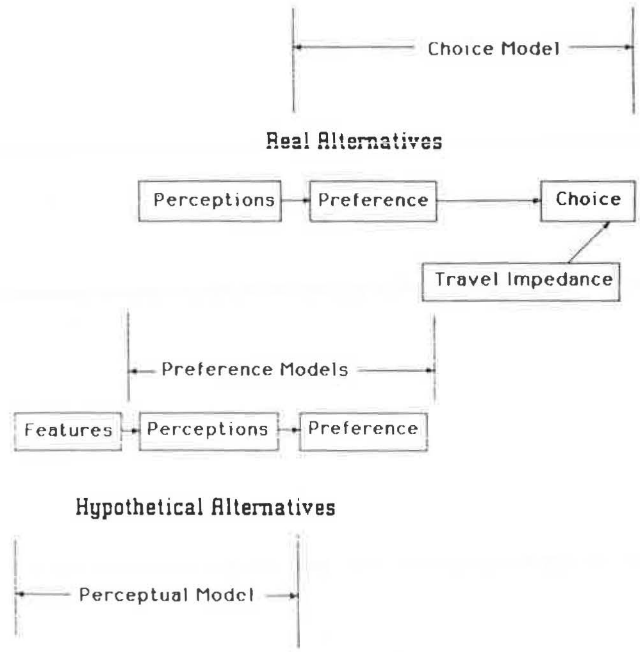


FIGURE 1 Relationship of the submodels to the lens model system.

Constant sum-paired comparisons are often assumed to have ratio scale properties. That is, respondents are assumed to divide points among alternatives so that the ratio of points indicates how much one alternative is preferred over the other. Transitivity tests performed on the survey data showed that there was indeed justification for the ratio scale assumption. On the other hand, the perceptual rating questions were designed to encourage interval scale responses. If preferences are ratio scaled and perceptions interval scaled, a functional form is required for the preference model that will map the interval scale perceptions to the ratio scale preferences. A form that will accomplish this for ratio scale constant sum-paired comparison preference data is a logistic function as shown:

$$PREFj1/100 = 1/\{1 + \exp[-B'(PERCj1-PERCj2)]\} \times e \quad (1)$$

where

PREFj1 = observed number of points given to alternative j1 out of a 100 point paired comparison between j1 and j2,
exp = exponential,
PERCj1-PERCj2 = vector of observed perceptual rating differences for alternatives j1 and j2, and
e = error term assumed to have a mean of 1 and a log normal distribution.

Regression estimation of the logistic form can be done by taking the ratio of the preferences for two alternatives in a paired comparison, and then taking logs. Table 1 gives the results of ordinary least-squares regressions for the logistic preference models for the Downtown Crossing and the most-used other shopping area (the real alternatives), and separately for the different Downtown Crossing futures (the hypothetical alternatives). As can be observed, the order of the coefficients is the same. The magnitudes are very different from one another, however.

TABLE 1 Estimation of Logistic Preference Models

	Downtown Crossing Versus The Alternative Mall		Hypothetical Futures	
Variable	Value	t-Statistic	Value	t-Statistic
Constant	.22	1.84[a]	-.03	-.92
STOREDIF	.44	8.45[b]	.21	4.70[b]
PARKDIF	.05	1.69[a]	.11	7.45[b]
WALKDIF	.11	3.97[b]	.20	11.64[b]
OBSERVATIONS	211		741	
R-SQUARED	.44		.30	
F(3.00, 737)	54.38		103.51	

Note: Estimated Model:
log(PREFj1/PREFj2) = B0 + B1 x STOREDIF + B2 x PARKDIF + B3 x WALKDIF

PARKDIF and WALKDIF are the difference in categorical ratings for parking convenience, and the attractiveness of the walk environment, respectively. STOREDIF is the average difference between the three store-related variables of quality, variety, and value. PREFj1/PREFj2 is the ratio of preference points for alternatives j1 and j2 given in a paired comparison.

[a]Significant at the 5 percent level, 1 tailed test.
[b]Significant at better than the 2.5 percent level, 1 tailed test.

Use of Instrumental Variables

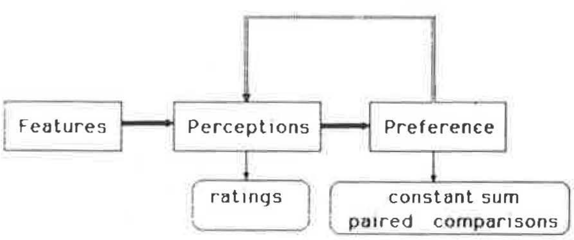
There are two factors that could cause problems with the regressions. First, measurement error in the independent variables will result in biased and inconsistent coefficients (13). In general, the greater the measurement error, the smaller the coefficient.

Probably a more serious problem with the data is the existence of halo effects that can affect the measurement of perceptions. Halo effects occur when respondents give perceptual ratings that reflect their preferences. Such effects are commonly found in data such as that collected for this research (14).

One theory about the feedback of perceptions to preference for the hypothetical alternatives is shown in Figure 2. Rectangles are used to indicate true values, and ovals are used to indicate measurements. The assumption in Figure 2 is that preference does affect the perceptions of attributes for a hypothetical alternative. A set of equations can be specified for the relationships shown in Figure 2.

The true value of the log of the preference ratio is assumed to be equal to a linear function of the true differences in perceptions plus a disturbance term due to omitted variables. Equation 2 shows this structural relationship. Equation 3 shows that the log of the measured preference ratio is equal to the log of the true preference ratio plus measurement error. Preference does not affect the measured perceptual differences directly; thus they are equal to the true differences plus measurement error. Equations 4-6 show these relationships. Measurement error is assumed to be uncorrelated with the true variables.

The true perceptual differences are assumed equal



Note: Rectangles indicate true values, and ovals indicate their measurement.

FIGURE 2 Representation of the relationship between features, perceptions, preference, and their measures.

to a linear-in-parameters function of the differences in relevant features, the log of the preference ratio, and a disturbance term due to omitted variables. The measured perceptual differences are therefore assumed to be equal to a linear-in-parameters function of the differences in relevant features, the log of the preference ratio, and an error term that includes measurement error as well as omitted variables. The equations for the measured perceptual variables are shown in Equations 7-9:

$$*\text{LPREFDIF} = B0 + B1 \times (*\text{STOREDIF}) + B2 \times (*\text{PARKDIF}) + B3 \times (*\text{WALKDIF}) + e0 \quad (2)$$

$$\text{LPREFDIF} = *\text{LPREFDIF} + u0 \quad (3)$$

$$\text{STOREDIF} = *\text{STOREDIF} + u1 \quad (4)$$

$$\text{PARKDIF} = *\text{PARKDIF} + u2 \quad (5)$$

$$\text{WALKDIF} = *\text{WALKDIF} + u3 \quad (6)$$

$$\text{STOREDIF} = C0 + C1 \times \text{NATDIF} + C2 \times \text{FASHDIF} + F1 \times (*\text{LPREFDIF}) + (e1 + u1) \quad (7)$$

$$\text{PARKDIF} = A0 + A1 \times \text{GARAGEDIF} + F2 \times (*\text{LPREFDIF}) + (e2 + u2) \quad (8)$$

$$\text{WALKDIF} = D0 + D1 \times \text{CLEANDIF} + D2 \times \text{SECURDIF} + D3 \times \text{AUTODIF} + F3 \times (*\text{LPREFDIF}) + (e3 + u3) \quad (9)$$

where

*LPREFDIF = the difference of the logs of the true preferences;
*STOREDIF = the true difference in store perceptions for the two alternatives;
*PARKDIF = the true difference in parking convenience perception;
*WALKDIF = the true difference in walk environment perception;
NATDIF = an indicator variable that is 1 if the first alternative alone has a national chain department store, -1 if the second alternative alone has a national chain department store, and 0 if both alternatives either have a national chain store or if both do not;
FASHDIF = an indicator variable for the high fashion department store;
GARAGEDIF = an indicator variable for the parking garage;
CLEANDIF = an indicator variable for improved maintenance;
SECURDIF = an indicator variable for improved security;
AUTOSDIF = an indicator variable for allowing automobiles back on Washington Street;
LPREFDIF = the difference in the logs of the measured preferences from the constant sum-paired comparisons;
STOREDIF = the average measured difference in perceptual ratings for store variables of quality, variety, and value;
PARKDIF = the measured difference in perceptual ratings for parking convenience;
WALKDIF = the measured difference in perceptual ratings for the attractiveness of the walk environment;
ei = errors due to omitted variables in the equations;
ui = errors due to measurement error; and
Bi, Ci, Di, and Fi = coefficients.

This set of equations can be estimated with the use of instrumental variables. An instrument for preference can be obtained by a dummy variable regression of the measured preference on the features as follows:

$$\text{LPREFDIF} = E0 + E1 \times \text{NATDIF} + E2 \times \text{FASHDIF} + E3 \times \text{GARAGEDIF} + E4 \times \text{CLEANDIF} + E5 \times \text{SECURDIF} + E6 \times \text{AUTODIF} + \text{error} \quad (10)$$

An estimate (LESTPREF) for the preference difference can then be obtained from the right side of the estimated regression equation.

Because *LPREFDIF, or the true preference difference, is not observed but is measured with error, a least-squares regression can lead to biased and inconsistent parameter estimates (13). The problem is that when LPREFDIF is substituted in Equations 7-9, the preference measurement error, u0, becomes part of the error term. LPREFDIF is correlated with u0, so the least-squares assumption that the error is uncorrelated with the independent variables fails. However, LESTPREF, which is independent of the measurement error, can be used as an instrumental variable in Equations 7-9. Least squares will then provide consistent estimates for the parameters.

With consistent estimates for Ci, Ai, and Di, instrumental variables can be derived for the true perceptual differences, *STOREDIF, *PARKDIF, and *WALKDIF. Call these instruments ESTSTOR, ESTPARK, and ESTWALK, respectively. Then ESTSTOR, ESTPARK, and ESTWALK may be substituted into Equation 2 and used to obtain least-squares estimates of the coefficients (Bi).

The data in Table 2 show the results of the regressions for Equations 7-10. All coefficients in these regressions other than the constant term are highly significant. As expected, the variable LESTPREF was found to contribute significantly to the perceptual model regressions for Equations 7-9 verifying the existence of halo effects.

TABLE 2 Dummy Variable Regressions for Equations 7-10

	Equation			
Variable	10	7	8	9
Dependent variable	LPREFDIF	STOREDIF	PARKDIF	WALKDIF
Independent variables	Value	Value	Value	Value
Constant	-.02	.01	-.02	.00
CLEANDIF	.52			.94
SECURDIF	.49			.62
AUTOSDIF	-.60			-1.64
GARAGEDIF	.59		3.08	
NATDIF	.38	.49		
FASHDIF	.35	.59		
LESTPREF		.34	.54	.93
CLEANSEC				-.55
OBSERVATIONS	1,215	1,053	1,013	1,086
R-SQUARED	.22	.19	.52	.38
F STATISTIC	58.19	80.89	548.40	135.06

The final step in this analysis is to use the estimates of the perceptual differences (ESTSTOR, ESTPARK, ESTWALK) derived from the regressions as instrumental variables to estimate Equation 2. Table 3 gives the regression estimation results for the preference model for the hypothetical alternatives and also compares these results with those for real alternatives previously shown in Table 1.

The estimated coefficients for hypothetical futures are reasonably close to the coefficients estimated for real alternatives. The store coefficients are about the same magnitude, and the order is correct. The estimated coefficients for the store perception variable and the parking perception variable are not significantly different for the hypothetical alternatives and for the real alternatives. The walk coefficients are still significantly different.

Comparing the coefficients in Table 3 for hypothetical futures with Table 1, it can be observed that the major difference from incorporating estimated variables rather than measured variables for perceptions is to increase the coefficient of the store-related perceptions. This implies that the store perceptions may be measured with more error relative to the parking and walk environment perceptions in the hypothetical case. A logical explanation for this is that most of the alternative futures affected the perceptual variables other than the store-related variables. Inspection of the ratings for each perceptual variable in the mail survey showed that variance among respondents increased when they rated perceptual attributes that were not expected to change. Thus, it is likely that there was more error in the ratings of the store-related perceptions than in the parking or walk environment perceptions.

In comparing the coefficients for the real and hypothetical alternatives, an assumption is made that the perceptions for the real alternatives are not affected by the preferences as in the case for the hypothetical alternatives. Because the real alternatives are shopping areas currently used by the respondents, it appears reasonable that perceptions of their attributes would be less susceptible to halo effects than perceptions of hypothetical shopping areas. It must also be assumed that there is little measurement error in the perceptions for the real alternatives. Because there is little reason to believe that the store-related perceptual variables for real alternatives were more subject to measurement error than the parking- and walk-related variables, and because the parking- and walk-related variables appear not to suffer from measurement error, at least in the hypothetical case, this appears to be a reasonable assumption.

Choice Model

The lens model represents choice as an action that is dependent on preference and on environmental constraints. In the case of shopping area choice, the environmental constraint is the travel impedance to the shopping areas.

A logit random utility model has often been used to predict choice of shopping area, given data on individual choices (15). A very simple logit model was used for the choice model for this research. Independent variables used as part of the choice utility function were the log of the preference points, an indicator variable for workers, and travel time in minutes. Further details on the choice model are provided by Karash (16).

FORECASTING WITH THE MODELING SYSTEM

In order to use the models to forecast changes in trips to the Downtown Crossing, some important assumptions must be made about the difference in human perceptions and preferences, given real alternatives that were discovered for the hypothetical alternatives. Given plenty of time to observe changes in the Downtown Crossing, it is assumed that perceptions of the area can be assessed independent of preference so that there will be no halo effect. This is a conservative assumption in that the impacts of changes will be less if there is no halo effect.

TABLE 3 Preference Model Using Estimated Perceptions as Independent Variables for the Hypothetical Futures for the Downtown Crossing Compared with the Preference Model for Real Alternatives

Hypothetical Futures			Real Alternatives		
Variable	Value	t-Statistic	Variable	Value	t-Statistic
Constant	-.01	-.51	Constant	.22	1.84[a]
ESTSTORE	.42	4.80[b]	STOREDIF	.44	8.45[b]
ESTPARK	.10	6.16[b]	PARKDIF	.05	1.69[a]
ESTWALK	.24	10.47[b]	WALKDIF	.11	3.97[b]
OBSERVATIONS	1,215		OBSERVATIONS	211	
R-SQUARED	.20		R-SQUARED	.44	
F(3.00, 1,211)	100.71		F(3.00, 737)	54.38	

Note: Estimated model for hypothetical futures:
LPREFDIF = -.01 + .42 x ESTSTORE + .10 x ESTPARK + .24 x ESTWALK

Estimated model for real alternatives:
LPREFDIF = .22 + .44 x STOREDIF + .05 x PARKDIF + .11 x WALKDIF

[a]Significant at the 5 percent level, 1 tailed test.
[b]Significant at the 2.5 percent level, 1 tailed test.

Equations 7-9 can then be used to estimate average changes in perceptions due to hypothetical futures.

Given the predicted changes in the perceptual ratings for the changes in the Downtown Crossing, the next step is to predict the average change in preferences. To do so the assumption is made that the appropriate preference model to use is the one estimated for the real alternative shopping areas as given in Table 1.

The new market share for trips to the Downtown Crossing out of the trips to either the Downtown Crossing or the alternative mall due to preference changes can be calculated by using the logit choice model knowing only the existing market share and the change in the log of the preference ratio. The data in Table 4 show the new market shares and the percent change in market shares computed for the last trip for workers and for others. To determine the overall effect on the Downtown Crossing, the shares of last trips for workers and others must be weighted to account for different current use of the Downtown Crossing. The overall effect is also shown in Table 4.

The predicted change in market share of shopping trips is around 10 percent for adding department stores. A garage that would make parking readily available and cheap would be expected to increase trips by about 6 percent. Superior maintenance or highly visible security would increase trips around 3 or 4 percent, whereas the combination would increase trips by about 5 percent. Allowing automobiles back on Washington Street would reduce trips by about 8 percent.

These predictions were accepted as reasonable by the Boston Redevelopment Authority staff and the retail experts who were hired to predict retail sales for the Downtown Crossing, given similar development scenarios to those tested in this research. The gravity model could not be an independent check on the results given in Table 4, however, since early results from this research heavily influenced the calibration process for the gravity model.

The MIT research thus helped to quantify the retail experts' intuition. For example, the finding that better maintenance and security could increase traffic by 5 percent was consistent with recent experience in shopping centers that had been revitalized by new management (17).

The major result of interest, however, is the impact of allowing automobiles back on Washington Street. The prediction that workers' trips increased by 6 percent and others increased by 10 percent is compatible with the pedestrian counts taken in 1978 before the mall was implemented and in 1980 after implementation (18). Thus these results clearly indicate that the pedestrian mall was a positive development for the area, holding all else constant.

DISCUSSION AND CONCLUSIONS

This research accomplished its objectives, which were to measure the effect of an automobile-restricted zone in downtown Boston on retail trips to the area and to use a theory of consumer decision making known as the lens model to determine the effect of a number of hypothetical changes in the downtown Boston retail area. In order to link hypothetical changes with actual choice using the lens model it was necessary to show that shoppers' preferences for the hypothetical futures for the Downtown Crossing were formed on a similar basis as their preferences between real alternatives. Preference models for real and hypothetical alternatives were found to be reasonably similar, but only if problems of measurement error and halo or feedback effects were explicitly accounted for in the analysis for the hypothetical alternatives.

This research work has influenced policy in the Downtown Crossing. The predicted increases in trips due to improved maintenance and security helped to provide economic justification for the establishment of a tax district that would raise fees to provide better area management. Legislation for such a tax

TABLE 4 Percent Change in Market Shares

	Downtown Workers	Other Shoppers	Weighted Total
Addition of a high-fashion department store	8	14	11
Addition of a national chain department store	6	12	10
Addition of a large parking garage	4	8	6
Improved maintenance	3	5	4
Improved security	2	4	3
Improved maintenance and security	3	6	5
Automobiles allowed on Washington Street	-6	-10	-8

district was developed at the request of area merchants, although no district has been created to date.

Finally, the findings of the positive impact of the automobile-restricted zone have certainly quieted criticism of that program. The prediction of the loss in patronage due to removal of the automobile-restricted zone has eliminated consideration of that option by merchants upset about other problems that have beset the Downtown Crossing.

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